TDE0109-0

RIKEN KEIKI

GAS DETECTION HAND BOOK

RIKEN KEIKI Co.,Ltd.

2-7-6 Azusawa, Itabashi-ku, Tokyo, 174-8744, Japan
Phone : +81-3-3966-1113
Fax : +81-3-3558-9110
E-mail : intdept@rikenkeiki.co.jp
Web site : http://www.rikenkeiki.co.jp/

Contents

1

Introduction

The Riken Keiki Gas Detection Handbook is a reference guide for customers considering using fixed or portable gas detectors. It provides both basic and comprehensive information about gas detection.

Riken Keiki's gas detectors and environmental monitoring devices protect people from invisible hazards by swiftly detecting combustible and toxic gases that can cause disasters. Above all, our mission is to create an environment that allows people to work with peace of mind—something essential for industrial growth and development.

2

What is gas?

2-1. Air composition

Air consists of approximately 78 % nitrogen, 21 % oxygen, and 1 % other gases (e.g., argon and carbon dioxide). Nitrogen, the largest component of air, forms the basis of proteins made of amino acids and contained in numerous living organisms. Nitrogen is essential for almost all life on the planet. However, nitrogen is not absorbed directly into the body from the air. The nitrogen we breathe in is simply expelled when we breathe out. Essential to life and absorbed directly into our bodies, oxygen accounts for 21 % of air. Carbon dioxide, which is vital for plant photosynthesis, accounts for less than 1 %. Animals absorb oxygen and expel carbon dioxide and plants absorb carbon dioxide and expel oxygen, maintaining a constant balance of the overall air composition and life processes on the planet.

Major atmospheric constituents

Constituent	Chemical formula	Percentage by volume [%]	Percentage by mass [%]
Nitrogen	N_2	78.084	75.524
Oxygen	O_2	20.9476	23.139
Argon	Ar	0.934	1.288
Carbon dioxide	CO_2	0.0314	0.0477
Neon	Ne	0.001818	0.00127
Helium	He	0.000524	0.000072
Krypton	Kr	0.000114	0.00033
Xenon	Xe	0.0000087	0.000039
Hydrogen	H_2	0.00005	0.000003
Methane	CH_4	0.0002	0.0001
Dinitrogen monoxide	N_2O	0.00005	0.00008

From JIS W 0201-1990 (ISO 2533-1975)

2-2. Gas hazards

Broadly speaking, gas hazards fall into the following three categories:

① Combustible gases

Gases that have an explosive range (combustible range) when mixed with air.

The GHS* refers to substances in a gaseous state at standard atmospheric pressure (101.3 kPa) and 20 °C.

* GHS: Globally Harmonized System of Classification and Labelling of Chemicals

② Toxic gases

Gases that impair human biological function

Toxic gases are regulated based on threshold values set to safeguard against harmful health effects for workers exposed to such substances at the work site eight hours a day, 40 hours a week.

② Oxygen deficiency

The human body is able to function normally at atmospheric oxygen concentrations around 21 %.

If oxygen is consumed and its concentrations are reduced (by metal oxidation or by microorganisms) or if oxygen is displaced by other gases (e.g., N_2 and Ar), effects on the human body become apparent when concentrations fall below around 18 %. Death becomes a risk between 6 % and 8 %.

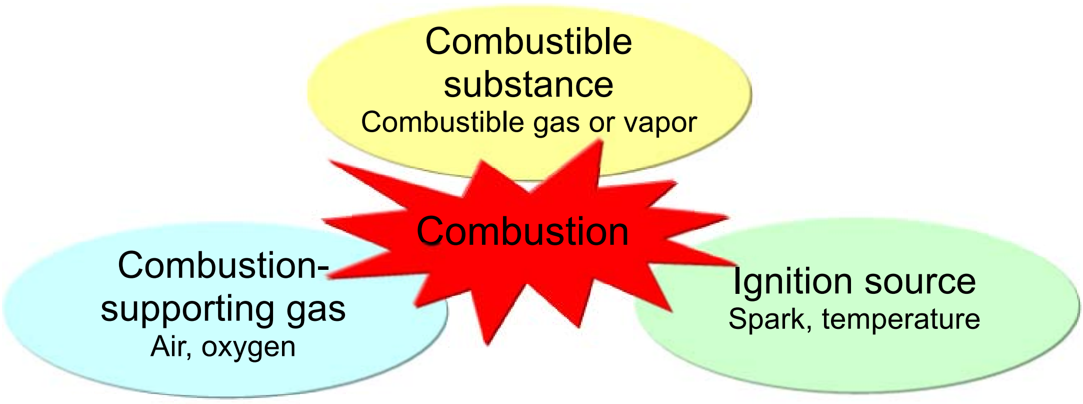
3

Combustible Gas Hazards

3-1. Three elements necessary for combustion

Combustion generally refers to an oxidation reaction (in which substances are combined with oxygen) involving heat and light.

The combustion of a substance requires three elements: ① a combustible substance; ② a combustion-supporting gas; and ③ an ignition source. Combustion is not possible if any one of these is missing. To prevent gas combustion, it is vital to regulate and maintain gas concentrations below the concentration at which it can combust (assuming the presence of a combustion-supporting gas and an ignition source).

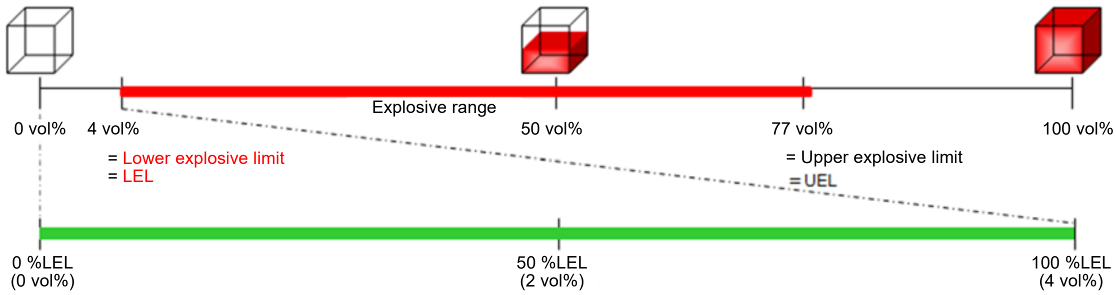


Three elements necessary for combustion

3-2. Explosive Limit

If a combustible gas or vapor from a combustible liquid mixes with air or oxygen, it will explode in the presence of an ignition source when the concentration is within a specific range. This concentration range is called the explosive range. The lower concentration limit is called the lower explosive limit (LEL). The upper concentration limit is called the upper explosive limit (UEL).

Example: Hydrogen



The lower explosive limit is a value determined experimentally, but the results obtained can vary depending on test conditions and methods. Caution is therefore necessary; the values quoted may vary depending on the reference source.

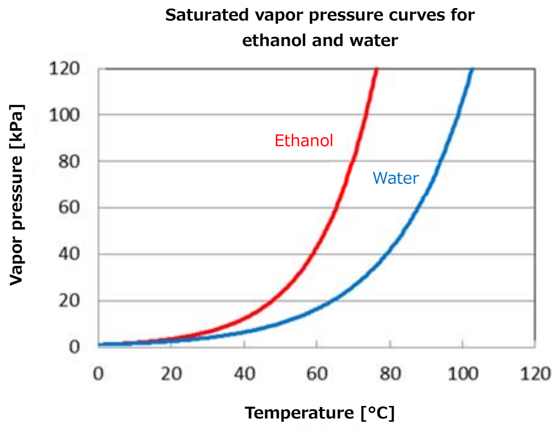
Gas detectors generally monitor gas concentrations based on the lower explosive limit. This is because even if a gas is present at concentrations exceeding the upper explosive limit, if a gas leakage occurs into the atmosphere, the gas will be immediately diluted and diffuse, bringing concentrations to within the explosive range. The unit %LEL is frequently used to express a concentration with respect to the lower explosive limit (100 %LEL).

3-3. Combustible vapor

While both are substances in the gaseous state, gas and vapor generally refer to different things. Vapor refers to a substance that exists in the liquid (or solid) state at normal temperature but vaporizes into the gas phase from the liquid phase under certain conditions. The following physical properties, based on temperature changes, determine whether a combustible vapor can become a hazard.

1. **Saturated vapor pressure**
   This refers to the pressure at which a substance at a specific temperature vaporizes from liquid to gas. The vapor pressure typically increases as temperature rises. The temperature at which the pressure equals atmospheric pressure (101.3 kPa ≈ 760 mmHg) is called the boiling point. The concentration (concentration by volume) of gas that vaporizes at a particular temperature can be determined by calculating the percentage of the vapor pressure with respect to atmospheric pressure.

The figure on the right shows saturated vapor pressure curves for ethanol and water. Since the boiling point of water is 100 °C, we see that the vapor pressure curve indicates 100 °C at 101.3 kPa. In other words, the saturated water vapor concentration at this point is 100 vol%. Ethanol, on the other hand, is a liquid more volatile than water (i.e., having a higher vapor pressure), as is readily understood by anyone who has been swabbed with sterilizing ethanol before receiving an injection at the hospital.



In practice, the boiling point of ethanol is 78 °C. This data, too, shows that ethanol is more volatile than water.

We can calculate the gas concentration of ethanol at a particular temperature based on the vapor pressure at that temperature. For example, we can read off from the saturated vapor pressure curve that the vapor pressure at 20 °C is approximately 5.8 kPa. We can insert this into the following equation to calculate the gas concentration:

Gas concentration (volume % concentration)	=	[Vapor pressure at a particular temperature] ÷ (Atmospheric pressure) × 100
	=	5.8 (kPa) ÷ 101.3 (kPa) × 100
	=	5.7 vol%

This calculation is worth remembering. Even if no vapor pressure curve like the one above is available, the SDS (safety data sheet) provided by the chemical manufacturer typically includes vapor pressure data points for normal temperatures (20 °C to 30 °C). These can be used to calculate gas concentrations.

2. Flash point

The flash point refers to the lowest temperature at which a concentration that allows ignition is reached when the substance is vaporized and mixed with air. This can also be interpreted as the temperature at which the combustible vapor reaches the LEL concentration. If the flash point of a liquid that produces combustible vapor is lower than the ambient temperature at which the liquid is used, caution is necessary when assessing the risk of ignition, due to the high risk of combustion and explosion accidents.

3. Ignition point

This refers to the lowest temperature at which a combustible substance in the air spontaneously ignites due to an increase in the temperature of the substance itself, as opposed to ignition due to localized contact with a hot object (e.g., electrical spark, flame, red-hot metal wire) generally called an ignition source. Manufacturers of explosion-proof electrical equipment must design and manufacture the equipment to ensure that the surface temperature of the equipment likely to come into contact with combustible gas or vapor will not exceed the ignition temperature of the corresponding gas or vapor.

3-4. Physical properties of combustible gases

The following table shows the three different lower explosive limits of combustible gases: ① ISO 10156, ② IEC 60079-20-1, and ③ the Riken Keiki standard value.

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
1	50-00-0	Formaldehyde HCHO	-	7.0	7.0
2	51-80-9	N,N,N',N'-Tetramethyl methanediamine (CH3)2NCH2N(CH3)2	-	1.61	
3	57-14-7	1,1-Dimethylhydrazine (CH3)2NNH2	-	2.4	
4	60-29-7	1,1´-Oxybisethane (CH3CH2)2O	1.7	1.7	1.7
5	62-53-3	Benzenamine C6H5NH2	-	1.2	1.3
6	64-17-5	Ethanol CH3CH2OH	3.1	3.1	3.3
7	64-18-6	Formic Acid HCOOH	-	18.0	18.0
8	64-19-7	Acetic acid CH3COOH	-	4.0	4.0
9	64-67-5	Sulfuric acid diethyl ester (CH3CH2)2SO4	-	-	
10	67-56-1	Methanol CH3OH	6.0	6.0	5.5
11	67-63-0	2-Propanol (CH3)2CHOH	-	2.0	2.0
12	67-64-1	2-Propanone (CH3)2CO	2.5	2.5	2.15
13	68-12-1	N,N-Dimethyl formamide HCON(CH3)2	-	1.8	
14	71-23-8	1-Propanol CH3CH2CH2OH	-	2.1	2.1
15	71-36-3	1-Butanol CH3(CH2)2CH2OH	-	1.4	1.4
16	71-41-0	1-Pentanol CH3(CH2)3CH2OH		1.06	1.2
17	71-43-2	Benzene C6H6	1.2	1.2	1.2
18	74-82-8	Methane CH4	4.4	4.4	5.0
19	74-84-0	Ethane CH3CH3	2.4	2.4	3.0
20	74-85-1	Ethene (CH2=CH2	2.4	2.3	2.7
21	74-86-2	Ethine CH≡CH	2.3	2.3	1.5
22	74-87-3	Methyl chloride CH3Cl	7.6	7.6	8.1
23	74-89-5	Methylamine CH3NH2	4.9	4.2	4.9
24	74-90-8	Hydrocyanic acid HCN	5.4	5.4	5.6

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
25	74-93-1	Methanethiol CH3SH	4.1	4.1	3.9
26	74-96-4	Bromoethane CH3CH2Br	-	6.7	
27	74-98-6	Propane CH3CH2CH3	1.7	1.7	2.0
28	74-99-7	Propyne CH3C≡CH	1.8	1.7	
29	75-00-3	Chloroethane CH3CH2Cl	3.6	3.6	3.6
30	75-01-4	Chloroethene CH2=CHCl	3.8	3.6	3.8
31	75-04-7	Ethylamine C2H5NH2	3.5	3.5	3.5
32	75-05-8	Acetonitrile CH3CN	-	3.0	3.0
33	75-07-0	Ethanal CH3CHO	4.0	4.0	4.0
34	75-08-1	Ethanethiol CH3CH2SH	-	2.8	2.8
35	75-15-0	Carbon Disulfide CS2	0.6	0.6	1.3
36	75-19-4	Cyclopropane CH2CH2CH2	2.4	2.4	
37	75-21-8	Oxirane CH2CH2O	2.6	2.6	3.0
38	75-28-5	2-Methylpropane (CH3)2CHCH3	1.5	1.3	1.8
39	75-29-6	2-Chloropropane (CH3)2CHCl	-	2.8	2.8
40	75-31-0	2-Propaneamine (CH3)2CHNH2	-	2.3	
41	75-34-3	1,1-Dichloroethane CH3CHCl2	-	5.6	
42	75-35-4	1,1-Dichloroethene (= Vinylidene Chloride) CH2=CCl2	-	6.5	5.6
43	75-36-5	Acetyl chloride CH3COCl	-	5.0	
44	75-38-7	1,1-Difluoroethene CH2=CF2	4.7	3.9	2.3
45	75-50-3	Trimethylamine (CH3)3N	2.0	2.0	2.0
46	75-52-5	Nitromethane CH3NO2	-	7.3	
47	75-56-9	2-Methyloxirane CH3CHCH2O	1.9	1.9	2.8
48	75-83-2	2,2-Dimethylbutane (= Neohexan) (CH3)3CCH2CH3	1.2	1.0	
49	75-85-4	2-Methylbutan-2-ol CH3CH2C(OH)(CH3)2	-	1.4	
50	75-86-5	2-Hydroxy-2-methyl-propionitrile CH3 C(OH)CNCH3	-	2.2	2.2
51	75-89-8	2,2,2-Trifluoroethanol CF3CH2OH	-	8.4	5.5

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
52	76-37-9	2,2,3,3-Tetrafluoropropan-1-ol HCF2CF2CH2OH	-	-	4.8
53	77-73-6	3a,4,7,7a-Tetrahydro-4,7-methano-1H-indene (= Dicyclopentadiene) (= Cyclopentadiene dimer) C10H12	-	0.8	1.0
54	77-78-1	Sulfuric acid dimethyl ester (= Dimethyl sulfate) (CH3O)2SO2	-	-	
55	78-10-4	Tetraethoxy Silane (= Silicic acid tetraethyl ester) (= Tetraethyl silicate) (= Silicon tetraethoxide) (C2H5)4Si	-	0.45	1.4
56	78-78-4	2-Methylbutane (= Ethyl dimethyl methane) (= Isopentane) (CH3)2CHCH2CH3	1.3	1.3	1.3
57	78-80-8	2-Methyl-1-buten-3-yne HC≡CC(CH3)CH2	-	1.4	
58	78-81-9	2-Methylpropan-1-amine (= iso-Butylamine) (CH3)2CHCH2NH2	-	1.47	
59	78-83-1	2-Methyl-1-propanol (= iso-Butanol) (= iso-Propylcarbinol) (= iso-Butyl alcohol) (CH3)2CHCH2OH	-	1.4	1.7
60	78-84-2	2-Methyl-1-propanal (= iso-Butanal) (= iso-Butyraldehyde) (CH3)2CHCHO	-	1.6	1.6
61	78-86-4	2-Chlorobutane (= sec-Butyl chloride) CH3CHClCH2CH3	-	2.0	
62	78-87-5	1,2-Dichloropropane (= Propylene dichloride) CH3CHClCH2Cl	-	3.4	3.4
63	78-92-2	2-Butanol (= sec-Butyl alcohol) (= Butylene hydrate) (= 2-Hydroxybutane) (= Methyl ethyl carbinol) CH3 CHOHCH2 CH3	-	1.7	1.7
64	78-93-3	2-Butanone (= Ethyl methyl ketone) (= Methyl acetone) (= Methyl ethyl ketone) CH3CH2COCH3	1.5	1.5	1.8
65	79-09-4	Propionic acid (= Carboxyethane) (= Ethanecarboxylic acid) (= Methyl acetic acid) CH3CH2COOH	-	2.1	
66	79-10-7	2-Propenoic acid (= Acroleic acid) (= Ethylenecarboxylic acid)	-	2.4	3.0

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
		(= Glacial acrylic acid) (= Acrylic acid) CH2=CHCOOH			
67	79-20-9	Acetic acid methyl ester (= Methyl acetate) (= Ethanoic acid methyl ester) (= Methyl ethanoate) CH3COOCH3	3.1	3.1	3.1
68	79-22-1	Carbonochloridic acid methyl ester (= Methyl chloroformate) (= Methoxycarbonyl chloride) CH3OOCCl	-	7.5	7.5
69	79-24-3	Nitroethane CH3CH2NO2	-	3.4	
70	79-29-8	2,3-Dimethylbutane (= Diisopropyl) (CH3)2CH(CH3)CH2CH3	-	1.0	
71	79-31-2	2-Methylpropanoc acid (= iso-Butyric acid) (= Dimethylacetic acid) (CH3)2CHCOOH	-	2.0	
72	79-38-9	Chlorotrifluoroethene (= Chlorotrifluoroethylene) CF2=CFCl	4.6	4.6	8.4
73	80-62-6	2-Methyl-2-propenoic acid methyl ester (= Methyl methacrylate) (= Methacrylate monomer) (= Methyl ester of methacrylic acid) (= Methyl-2-methyl-2-propenoate) CH3=CCH3COOCH3	-	1.7	1.7
74	91-20-3	Naphthalene (= Tar camphor) (= White tar) C10H8	-	0.6 at 150°C	
75	95-47-6	1,2-Dimethyl benzene (= o-Xylene) (= o-Xyol) C6H4(CH3)2	-	1.0	1.0
76	95-92-1	Ethanedioic acid diethyl ester (= Diethyl Oxalate) (= Oxalic acid diethyl ester) (COOCH2CH3)2	-	-	
77	96-22-0	Pentan-3-one (= Diethyl ketone) (= Metacetone) (= Propione) (CH3CH2)2CO	-	1.6	1.6
78	96-33-3	Propenoic acid methyl ester (= Acrylic acid methyl ester) (= Methoxycarbonyl ethylene) (= Methyl propenoate) (= Methyl Acrylate) CH2=CHCOOCH3	-	1.95	2.4
79	96-37-7	Methylcyclopentane CH3CH(CH2)3CH2 .	-	1.0	
80	97-62-1	2-Methylpropanoic acid ethyl ester (= Ethyl isobutyrate)	-	1.6	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
		(= Ethyl 2-methylpropanoate) (CH3)2CHCOOC2H5			
81	97-63-2	2-Methyl-prop-2-enoic acid ethyl ester (= Methacrylic acid ethyl ester) (= Ethyl methacrylate) CH2=CCH3COOCH2CH3	-	1.5	
82	97-85-8	2-Methylpropanoic acid 2-methylpropyl ester (= iso-Butyl isobutyrate) (CH3)2CHCOOCH2CH(CH3)2	-	0.8	
83	97-88-1	2-Methyl-2-propenoic acid butyl ester (= Butyl methacrylate) (= Butyl-2-methylprop-2-enoate) CH2=C(CH3)COO(CH2)3CH3	-	1.0	2.0
84	97-95-0	2-Ethyl-1-butanol (= Isohexyl alcohol) CH3CH(CH2CH3)CH2CH2OH	-	1.2	
85	97-99-4	Tetrahydro-2-furan methanol) (= Tetrahydrofurfuryl alcohol) (= Tetrahydrofuran-2-yl-methanol) (= Tetrahydro-2-furan carbinol) (= 2-Hydroxymethyl oxolane) OCH2CH2CH2CHCH2OH	-	1.5	
86	98-00-0	2-Furylmethanol (= Furfuryl Alcohol) (= 2-Hydroxymethylfuran) OC(CH2OH)CHCHCH	-	1.8	1.8
87	98-01-1	2-Furancarbox aldehyde (= Fural) (= Furfural) (= 2-Furaldehyde) OCH=CHCH=CHCHO	-	2.1	
88	98-82-8	(1-Methylethyl) benzene (= Cumene) (= Isopropyl benzene) (= 2-Phenyl propane) C6H5CH (CH3)2	-	0.8	0.9
89	98-83-9	α-Methyl styrene (= Isopropenyl benzene) (= 1-Methyl-1-phenylethylene) (= 2-Phenyl propylene) C6H5C(CH3)=CH2	-	0.8	0.9
90	98-95-3	Nitrobenzene (= Nitrobenzol) (= Oil of mirbane) C6H5NO2	-	1.4	1.8
91	99-87-6	1-Methyl-4-(1-methylethyl)benzene (= p-Cymene) (= *p*-isopropyltoluene) CH3C6H4CH (CH3)2	-	0.7	
92	100-37-8	2-Diethylaminoethanol (= Diethylaminoethanol) (= 2-Diethylaminoethyl alcohol) (= N,N-Diethylethanol amine) (= Diethyl-(2-hydroxyethyl)amine) (= 2-Hydroxytriethylamine) (C2H5)2NCH2CH2OH	-	-	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
93	100-40-3	4-Ethenylcyclohexene (= Vinyl cyclohexene) (CH2=CH)CH(CH2)4CH2	-	0.8	
94	100-41-4	Ethylbenzene (= α-Methyltoluene) (= Phenylethane) C6H5CH2CH3	-	0.8	1.0
95	100-42-5	Ethenylbenzene (= Styrene) (= Vinylbenzene) (= Phenylethylene) (= Styrol) C6H5CH=CH2	-	1.0	1.1
96	100-43-6	4-Vinylpyridine (= 4-Ethenylpyridine) (= γ-Vinylpyridine) NCHCHC(CH2=CH)CHCH	-	1.1	1.0
97	100-44-7	(Chloromethyl)benzene (= Benzyl chloride) (= α-Chlorotoluene) (= Tolyl chloride) C6H5CH2Cl	-	1.1	
98	100-52-7	Benzaldehyde C6H5CHO	-	1.4	
99	100-69-6	2-Vinylpyridine (= 2-Ethenylpyridine) (= α-Vinylpyridine) NC(CH2=CH)CHCHCHCH	-	1.2	
100	103-09-3	Acetic acid-2-ethylhexyl ester (= 2-Ethylhexyl acetate) CH3COOCH2CH(C2H5)C4H9	-	0.8	
101	103-11-7	Prop-2-enoic acid 2-ethylhexyl ester (= 2-Ethylhexyl 2-propenoate) (= 2-Ethylhexyl acrylate) CH2=CHCOO(CH2)4CH3	-	0.7	0.6
102	104-76-7	2-Ethyl-1-hexanol CH3 (CH2)3CH(CH2CH3)CH2OH	-	0.9	
103	105-45-3	3-Oxo-butanoic acid methyl ester (= Acetoacetic acid methyl ester) (= 1-Methoxybutane-1,3-dione) (= Methyl acetoacetate) CH3COOCH2COCH3	-	1.3	
104	105-46-4	Acetic acid 1-methylpropyl ester (= sec-Butyl acetate) (= sec-Butyl ester of acetic acid) (= 1-Methylpropyl acetate) CH3COOCH(CH3)CH2CH3	-	1.3	
105	105-48-6	Chloroacetic acid-1-methylethyl ester (= iso-Propyl chloroacetate) (= Propan-2-yl 2-chloroacetate) ClCH2COOCH(CH3)2	-	1.6	
106	105-54-4	Butanoic acid ethyl ester (= Ethyl butanoate) (= Ethyl butyrate) (= Butyric acid ethyl ester) CH3CH2CH2COO CH2CH3	-	1.4	
107	105-58-8	Carbonic acid diethyl ester (= Diethyl carbonate) (CH3CH2O)2CO	-	1.4	1.4

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
108	106-35-4	3-Heptanone (= Ethyl butyl ketone) CH3CH2CO[CH2]3CH3	-	1.1	
109	106-42-3	1,4-Dimethyl benzene (= p-Xylene) (= p-Xyol) C6H4(CH3)2	-	0.9	1.0
110	106-46-7	1,4-Dichlorobenzene (= Dichlorocide) C6H4Cl2	-	2.2	2.2
111	106-58-1	1,4-Dimethylpiperazine NH(CH3)CH2CH2NH(CH3)CH2CH2	-	1.0	
112	106-89-8	(Chloromethyl) oxirane (= Epichlorohydrin) (= 1-Chloro-2,3-epoxypropane) (= 2-Chloropropylene oxide) OCH2 CHCH2Cl	-	2.3	2.3
113	106-92-3	[(2-Propenyloxy) methyl] oxirane (= Allyl 2,3- epoxypropylether) (= 1-(Allyloxy)-2,3-epoxypropan) (= Glycidyl allyl ether) (= Allyl glycidyl ether) CH2=CH-CH2-O-CHCH2CH2O	-	-	
114	106-96-7	3-Bromo-1-propine (= Bromo propyne) CH3CH≡CBr	-	3.0	
115	106-97-8	n-Butane (= Butyl hydride) (= Diethyl) (= Methylethylmethane) CH3(CH2)2CH2	1.4	1.4	1.5
116	106-98-9	1-Butene (= n-Butylene) (= Ethylethylene) CH2=CHCH2CH3	1.5	1.6	1.6
117	106-99-0	1,3-Butadiene (= Biethylene) (= Bivinyl) (= Divinyl) (= Erythrene) (= Vinylethylene) CH2=CHCH=CH2	1.4	1.4	1.1
118	107-00-6	1-Butine (= Ethylacetylene) CH3CH2C≡CH	1.3	-	
119	107-02-8	2-Propenal (inhibited) (= Acraldehyde) (= Acrylaldehyde) (= Acrylic aldehyde) (= Allyl aldehyde) (= Propenal) (= Acrolein) CH2=CHCHO	-	2.8	2.8
120	107-05-1	3-Chloro-1-propene (= Allyl chloride) (= 1-Chloro-2-propene) (= 3-Chloropropylene) CH2=CHCH2Cl	-	2.9	2.9

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
121	107-06-2	1,2-Dichloroethane (= Ethylene chloride) (= Ethylene dichloride) CH2ClCH2Cl	-	6.2	6.2
122	107-07-3	Ethylene chlorohydrin (= 2-Chloroethanol) (= 2-Chloroethyl alcohol) CH2ClCH2OH	-	4.9	4.9
123	107-10-8	1-Propaneamine (= 1-Aminopropane) CH3(CH2)2NH2	-	2.0	2.0
124	107-13-1	2-Propenenitrile (= Acrylonitrile) (= Cyanoethylene) (= Propenenitrile) (= Acrylonitrile) (= Vinyl cyanide, VCN) CH2=CHCN	-	2.8	2.8
125	107-15-3	1,2-Ethanediamine (= Ethylenediamine) (= Dimethylenediamine) NH2CH2CH2NH2	-	2.5	2.7
126	107-18-6	2-Propen-1-ol (= Allylic alcohol) (= Propenol) (= Allyl alcohol) (= Vinyl carbinol) CH2=CHCH2OH	-	2.5	2.5
127	107-19-7	2-Propine-1-ol (= Prop-2-yn-1-ol) (= Propargyl alcohol) HC≡CCH2OH	-	2.4	
128	107-20-0	Chloroacetaldehyde (= 2-Chloroethanal) ClCH2CHO	-	5.7	
129	107-30-2	Chloromethoxymethane (= Chloromethyl methyl ether) (= Chlorodimethyl ether) (= Chloromethoxy methane) (= Dimethylchloroether) (= Methylchloromethyl ether) CH3OCH2Cl	-	-	
130	107-31-3	Formic acid methyl ester (= Methyl formate) (= Methyl methanoate) HCOOCH3	5.0	5.0	4.5
131	108-01-0	2-(Dimethylamino)ethanol (CH3)2NC2H4OH	-	-	1.5
132	108-03-2	1-Nitropropane CH3CH2CH2NO2	-	2.2	
133	108-05-4	Acetic acid ethenyl ester (= Vinyl acetate) (= 1-Acetoxyethylene) CH3COOCH=CH2	-	2.6	2.6
134	108-10-1	4-Methylpentan-2-one (= Hexone) (= Isopropylacetone)	-	1.2	1.2

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
		(= Methyl isobutyl ketone) (CH3)2CHCH2COCH3			
135	108-11-2	4-Methylpentan-2-ol (= Isobutylmethylcarbinol) (= Methyl amyl alcohol) (= Methyl isobutyl carbinol) (CH3)2CHCH2CHOHCH3	-	1.14	1.0
136	108-18-9	n-(1-Methylethyl)-2-propanamine (= Diisopropylamine) ((CH3)2CH)2NH	-	1.2	
137	108-20-3	2,2´-Oxybispropane (= Diisopropyl ether) (= 2-Isopropoxy propane) ((CH3)2CH)2O	-	1.0	1.4
138	108-21-4	Acetic acid-1-methylethyl ester (= iso-propyl acetate) (= iso-propyl ester of acetic acid) (= 1-Methylethyl ester of acetic acid) (= 2-Propyl acetate) CH3COOCH(CH3)2	-	1.7	1.8
139	108-24-7	Acetic anhydride (= Acetic acid anhydride) (= Acetic oxide) (= Acetyl oxide) (= Ethanoic anhydride) (CH3CO)2O	-	2.0	2.0
140	108-38-3	1,3-Dimethylbenzene (= m-Xylene) (= m-Xylol) C6H4(CH3)2	-	1.0	1.0
141	108-62-3	2,4,6,8-Tetramethyl-1,3,5,7- tetraoxocane (= Metaldehyde) (C2H4O)4	-	-	
142	108-67-8	1,3,5-Trimethylbenzene (= Mesitylene) CHC(CH3)CHC(CH3)CHC(CH3)	-	0.8	1.1
143	108-82-7	2,6-Dimethylheptan-4-ol (= Diisobutylcarbinol) ((CH3)2CHCH2)2CHOH	-	0.7	
144	108-87-2	Methylcyclohexane (= Hexahydrodoluene) CH3CH(CH2)4CH2	-	1.0	1.15
145	108-88-3	Methyl benzene (= Toluene) (= Methyl benzol) (= Phenyl methane) C6H5CH3	1.0	1.0	1.2
146	108-89-4	4-Methylpyridine (= γ-Picoline) NCHCHC(CH3)CHCH2 .	-	1.1	
147	108-90-7	Chlorobenzene (= Phenyl chloride) (= Monochlorobenzene) C6H5Cl	-	1.3	1.3
148	108-91-8	Cyclohexylamine (= Aminocyclohexane) (= Aminohexahydro-benzene)	-	1.1	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
		(= Hexahydroaniline) (= Hexahydro-benzenamine) CH2 (CH2)4CHNH2 .			
149	108-93-0	Cyclohexanol (= Cyclohexyl alcohol) (= Hexahydrophenol) (= Hexalin) CH2 (CH2)4CHOH	-	1.2	1.2
150	108-94-1	Cyclohexanone (= Anone) (= Cyclohexyl ketone) (= Pimelic ketone) CH2 (CH2)4CO	-	1.3	1.1
151	108-95-2	Phenol (= Carbolic acid) (= Hydroxybenzene) (= Monohydroxybenzene) (= Monophenol) (= Oxybenzene) C6H5OH	-	1.3	1.8
152	108-99-6	3-Methylpyridine (= β-Picoline) NCHC(CH3)CHCHCH	-	1.4	
153	109-06-8	2-Methylpyridine (= α-Picoline) NC(CH3)CHCHCHCH .	-	1.2	
154	109-55-7	N,N-Dimethylpropane-1,3-diamine (= 3-Dimethylamino-propylamine) (= 1-Amino-3-dimethyl-aminopropane) (CH3)2N(CH2)3NH2	-	1.2	
155	109-60-4	Acetic acid n-propyl ester (= n-Propyl acetate) (= 1-Acetoxypropane) (= n-propyl ester acetic acid) CH3COOCH2CH2CH3	-	1.7	1.7
156	109-65-9	1-Bromobutane (= n-Butyl bromide) CH3(CH2)2 CH2Br	-	2.5	
157	109-66-0	n-Pentane CH3(CH2)3CH3	1.1	1.1	1.5
158	109-69-3	1-Chlorobutane (= n-Butyl chloride) (= n-Propylcarbinyl chloride) CH3(CH2)2CH2Cl	-	1.8	
159	109-73-9	1-Aminobutane (= n-Butylamine) CH3(CH2)3NH2	-	1.7	1.7
160	109-79-5	1-Butanethiol (= Butanethiol) (= n-Butyl mercaptan) (= n-Butanethiol) (= 1-Mercaptobutane) CH3(CH2)3SH	-	1.4	
161	109-86-4	2-Methoxyethanol (= Ethylene glycol monomethyl ether) CH3OCH2CH2OH	-	1.8	2.5

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
162	109-87-5	Dimethoxymethane (= Methylal) (= Dimethyl acetal methanal) (= Dimethyl acetal formaldehyde) (= Dimethyl formal) (= 2,4-Dioxapentane) CH2(OCH3)2	-	2.2	2.2
163	109-89-7	n-Ethylethanamine (= Diethamine) (= Diethylamine) (C2H5)2NH	-	1.7	1.8
164	109-94-4	Formic acid ethyl ester (= Ethyl methanoate) (= Ethyl formate) HCOOCH2CH3	2.7	2.7	
165	109-95-5 or (8013-58-9) comment: both are valid	Nitrous acid ethyl ester (= Ethyl nitrite ; see 5.2.2) CH3CH2ONO	-	3.0	
166	109-99-9	Tetrahydrofuran (= 1,4-Epoxybutane) (= Oxolane) (= Oxacyclopentane) (= Tetramethylene oxide) CH2(CH2)2CH2O	-	1.5	2.0
167	110-00-9	Furan (= Divinylene oxide) (= Furfuran) (= Tetrole) (= Oxole) (= Oxacyclopentadiene) CH=CHCH=CHO	-	2.3	
168	110-01-0	Tetrahydrothiophene (= Tetramethylene sulphide) (= Thiolane) (= Thiophane) (= Thiocyclopentane) CH2(CH2)2CH2S	-	1.1	1.1
169	110-02-1	Thiophene (= Divinylene sulphide) (=Thiacyclopentadiene) (= Thiofuran) CH=CHCH=CHS	-	1.5	
170	110-05-4	bis(1,1-Dimethylethyl) peroxide (= tert-Dibutyl peroxide) (CH3)3COOC(CH3)3	-	0.74	
171	110-43-0	Heptan-2-one (= 1-Methylhexanal) (= 2-Oxoheptane) (= Amyl methyl ketone) (= Butylacetone) CH3CO(CH2)4CH3	-	1.1	
172	110-54-3 (n-Hexane)	Hexane (mixed isomers) (= Hexyl hydride) CH3(CH2)4CH3	1.0	1.0	1.2
173	110-62-3	1-Pentanal (= Amyl aldehyde)	-	1.4	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
		(= Butyl formal) (= Valeraldehyde) CH3 (CH2)3CHO			
174	110-71-4	1,2-Dimethoxyethane (= Monoglyme) (= Ethylene glycol dimethyl ether) (= Dimethylglycol) (= 2,5-Dioxahexane) CH3O(CH2)2OCH3	-	1.6	1.6
175	110-80-5	2-Ethoxyethanol (= Ethane-1,2-diol ethyl ether) (= Ethyl cellosolve) (=3-Oxapentan-1-ol) (= Ethylene glycol ethyl ether) (= Ethylene glycol monoethyl ether) CH3CH2OCH2CH2OH	-	1.7	1.8
176	110-82-7	Cyclohexane (= Hexahydrobenzene) (= Hexamethylene) (= Hexanaphthene) CH2(CH2)4CH2	1.0	1.0	1.3
177	110-83-8	Cyclohexene (= Benzene tetrahydride) (= Tetrahydrobenzene) CH2(CH2)3CH=CH	-	1.1	1.2
178	110-86-1	Pyridine (= Azine) (= Azabenzene) C5H5N	-	1.7	1.8
179	110-88-3	1,3,5-Trioxane (= Trioxymethylene) OCH2OCH2OCH2	-	3.2	
180	110-91-8	Morpholine (= Diethylene imidoxide) (= Diethylene oximide) (= Tetrahydro-1,4-oxazine) OCH2CH2NHCH2CH2	-	1.4	2.0
181	110-96-3	2-Methyl-n-(2-methylpropyl)-1- propanamine (= Diisobutylamine) ((CH3)2CHCH2)2NH	-	0.8	
182	111-15-9	Acetic acid 2-ethoxy-ethyl ester (= 2-Ethoxyethyl acetate) (= Ethylene glycol monoethyl etheracetate) (= Glycol monoethyl ether acetate) CH3COOCH2CH2OCH2CH3	-	1.2	1.7
183	111-27-3	1-Hexanol (= Amylcarbinol) (= Hexyl alcohol) (= 1-Hydroxyhexane) (= Pentylcarbinol) CH3(CH2)4CH3	-	1.1	1.3
184	111-43-3	1,1´-Oxybispropane (= Dipropylether) (= 1-propoxy-propane) CH3(CH2)2O	-	1.18	
185	111-49-9	Hexahydro-1H-acepine (= Azepane) CH2 (CH2)5NH	-	-	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
186	111-65-9	n-Octane CH3(CH2)6CH3	0.8	0.8	0.8
187	111-69-3	Hexanedinitrile (= 1,4-Dicyanobutane) (= Adiponitrile) (= Tetramethylene cyanide) NC(CH2)4CN	-	1.70	
188	111-70-6	Heptan-1-ol (= hexylcarbinol) (= heptyl alcohol) (= enanthic alcohol) (= 1-hydroxyheptane) CH3(CH2)5CH2OH	-	0.9	
189	111-76-2	2-Butoxyethanol (= Ethylene glycol monobutyl ether) (= Butyl cellosolve) (= Butylglykol) CH3(CH2)3OCH2OH	-	1.1	1.1
190	111-84-2	Nonane (= Nonyl hydride) CH3(CH2)7CH2	0.7	0.7	0.7
191	111-87-5	1-Octanol (= Caprylic alcohol) (= Heptyl carbinol) (= 1-Hydroxyoctane) (= n-Octyl alcohol) CH3(CH2)6CH2OH	-	0.9	
192	111-90-0	2- (2-Ethoxyethoxy) ethanol (= Diethylene glycol monoethyl ether) (= 3,6-Dioxaoctan-1-ol) CH3CH2OCH2CH2OCH2CH2OH	-	1.3	1.2
193	112-07-2	2-Butoxyethanol acetate (= Ethylene glycol monobutyl etheracetate) C4H9O(CH2)2OCOCH3	-	0.9	0.8
194	112-30-1	1-Decanol (= Decyl alcohol) CH3(CH2)9OH	-	0.7	
195	112-34-5	2-(2-Butoxyethoxy) ethanol (= Butyldiglykol) (= Diglycol monobutyl ether) CH3(CH2)3OCH2CH2OCH2CH2OH	-	0.85	
196	112-41-4	1-Dodecene CH3(CH2)9CH=CH2	-	0.6	
197	112-58-3	1,1´-Oxybishexane (= Dihexyl Ether) (CH3(CH2)5)2O	-	-	
198	115-07-1	Propene (= Methylethylene) (= Propylene) CH2=CHCH3	1.8	2.0	2.0
199	115-10-6	Oxybismethane (= Methyl ether) (= Dimethylether) (= Wood ether) (= Methoxymethane) (CH3)2O	2.7	2.7	3.0
200	115-11-7	2-Methylprop-1-ene (= 1,1-Dimethylethylene)	1.6	1.6	1.8

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
		(= Isobutylene) (= Isobutene) (= 2-Methylpropene) (CH3)2C=CH2			
201	116-14-3	Tetrafluoroethylene CF2=CF2	10.5	10	10
202	121-44-8	N,N-Diethylethanamine (= Triethylamine) (CH3CH2)3N	-	1.2	1.2
203	121-69-7	N,N-Dimethylbenzeneamine (= N,N-Dimethylaniline) C6H3(CH3)2NH2	-	1.2	1.2
204	123-05-7	2-Ethylhexanal (= 2-Ethylhexaldehyde) CH3CH(CH2CH3)(CH2)3CHO	-	0.9	
205	123-38-6	1-Propanal (= Propionic aldehyde) CH3CH2CHO	-	2.0	2.3
206	123-42-2	4-Hydroxy-4-methylpenta-2-one (= Diacetone alcohol) (= 2-Methyl-2-pentanol-4-one) CH3COCH2C(CH3)2OH	-	1.8	1.8
207	123-51-3	3-Methylbutan-1-ol (= Isoamyl alcohol) (CH3)2CH (CH2)2OH	-	1.3	
208	123-54-6	Pentane-2,4-dione (= Acetylacetone) CH3COCH2COCH3	-	1.7	
209	123-63-7	2,4,6-Trimethyl-1,3,5-trioxane (=p-Acetaldehyde) (= Paracetaldehyde) (= Paraldehyde) OCH(CH3)OCH(CH3)OCH(CH3)	-	1.3	
210	123-72-8	1-Butanal (= Butyraldehyde) (= Butyl aldehyde) CH3CH2CH2CHO	-	1.7	2.5
211	123-86-4	Acetic acid n-butyl ester (= n-Butyl acetate) (= n-Butyl ester of acetic acid) (= Butyl ethanoate) CH3COOCH2(CH2)2CH3	-	1.2	1.4
212	123-91-1	1,4-Dioxane (= Diethylene dioxide) (= Diethylene ether) OCH2CH2OCH2CH2 .	-	1.4	1.9
213	124-13-0	Octanal (= Octaldehyde) CH3(CH2)6CHO	-	-	
214	124-18-5 (n-Decane)	Decane (mixed isomers) C10H22	0.7	0.7	0.7
215	124-40-3	n-Methylmethanamine (= Dimethylamine) (CH3)2NH	2.8	2.8	2.8

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
216	126-99-8	2-Chloro-1,3-butadiene (= Chloroprene) CH2=CClCH=CH2	-	1.9	
217	138-86-3	1-Methyl-4-(1-methylethenyl) cyclohexene CH3CCHCH2CH(C(CH3)=CH2)CH2CH2	-	0.7	0.7
218	140-88-5	2-Propenoic acid ethyl ester (= Acrylic acid ethyl ester) (= Ethyl acrylate) (= Ethyl propenoate) CH2=CHCOOCH2CH3	-	1.4	1.4
219	141-32-2	2-Propenoic acid butyl ester (inhibited) (= n-Butyl acrylate) (= Butyl ester of acrylic acid) (= Butyl-2-propenoate) CH2=CHCOOC4H9	-	1.2	1.5
220	141-43-5	2-Aminoethanol (= Ethanolamine) (= beta-Aminoethyl alcohol) (= Ethylolamine) (= 2-Hydroxyethylamine) (= Monoethanolamine) NH2CH2CH2OH	-	-	5.5
221	141-78-6	Acetic acid ethyl ester (= Ethyl acetate) (= Ethyl ethanoate) CH3COOCH2CH3	2.0	2.0	2.1
222	141-79-7	4-Methylpent-3-en-2-one (= Mesityl oxide) (CH3)2CCHCOCH3	-	1.6	0.4
223	141-97-9	3-Oxobutanoic acid ethyl ester (= Acetoacetic acid ethyl ester) (= 1-Ethoxybutane-1,3-dione) (= Ethyl acetoacetate) CH3COCH2COOCH2CH3	-	1.0	
224	142-29-0	Cyclopentene CH=CHCH2CH2CH .	-	1.48	
225	142-82-5 (n-Heptane)	Heptane (mixed isomers) C7H16	0.8	0.85	1.1
226	142-84-7	n-Propyl-1-propanamine (= Dipropylamine) (CH3CH2CH2)2NH	-	1.2	1.8
227	142-96-1	1,1´-Oxybisbutane (= Dibutyl ether) (= 1-Butoxybutane) (CH3(CH2)3)2O	-	0.9	1.5
228	151-56-4	Ethylenimine (= Aminoethylene) (= Aziridine) CH3CH2N	-	3.3	
229	287-23-0	Cyclobutane (= Tertamethylene) CH2(CH2)2CH2	1.8	1.8	
230	287-92-3	Cyclopentane (= Pentamethylene) CH2(CH2)3CH2	-	1.4	1.4

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
231	291-64-5	Cycloheptane CH2(CH2)3CH2	-	1.1	
232	300-62-9	(+-)-α-Methylbenzeneethanamine (= Amphetamine) (=1-Phenylpropan-2-amine) C6H5CH2CH(NH2)CH3	-	-	
233	350-57-2	1,1,2,2-Tetrafluoroethoxybenzene C6H5OCF2CF2H	-	1.6	
234	359-11-5	Trifluoroethylene CF2=CFH	10.5	15.3	
235	420-46-2	1,1,1-Trifluoroethane (= Methylfluoroform) CF3CH3	7.0	6.8	9.8
236	461-53-0	Butanoyl fluoride (= Butyryl fluoride) CH3(CH2)2COF	-	2.6	
237	463-58-1	Carbonyl sulfide COS	6.5	6.5	12.0
238	493-02-7	trans-Decahydronaphthalene CH2(CH2)3CHCH(CH2)3CH2	-	0.7	
239	504-60-9	Penta-1,3-diene (= Piperylene) CH2=CH-CH=CH-CH3	-	1.2	
240	507-20-0	2-Chloro-2-methylpropane (CH3)3CCl	-	-	
241	513-35-9	2-Methylbut-2-ene (= Amylene) (= Trimethylethylene) (CH3)2C=CHCH3	-	1.3	1.5
242	513-36-0	1-Chloro-2-methylpropane (CH3)2CHCH2Cl	-	2.0	
243	526-73-8	1,2,3-Trimethylbenzene (= Hemimellitene) CHCHCH(CH3) C(CH3)C(CH3)	-	0.8	
244	534-22-5	2-Methylfuran OC(CH3) CHCHCH	-	1.4	
245	536-74-3	Phenylacetylene (= Ethynylbenzene) (= Phenyl ethyne) C6H5C≡CH	-	-	
246	540-54-5	1-Chloropropane CH3CH2CH2Cl	-	2.4	
247	540-59-0	1,2-Dichloroethene (= Acetylene dichloride) (= trans-Acetylene dichloride) (= sym-Dichloroethylene) ClCH=CHCl	-	9.7	
248	540-67-0	Ethyl methyl ether (= Methoxythane) CH3OCH2CH3	2.0	2.0	
249	540-84-1	2,2,4-Trimethylpentane (= iso-Butyltrimethyl methane) (= iso-Octane) (CH3)2CHCH2C(CH3)3	1.0	0.7	0.8
250	540-88-5	Acetic acid 1,1-dimethylethyl ester (= tert-Butyl acetate)	-	1.3	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
		(= tert-Butyl ester of acetic acid) CH3COOC(CH3)3			
251	542-92-7	1,3-Cyclopentadiene CH2CH=CHCH=CH	-	-	
252	544-01-4	1,1´-Oxybis(3-methylbutane) (= Diisopentylether) (= Di(3-methyl-1-butyl) ether) (= 3-Methyl-1-(3-methyl-butoxy)-butane) (CH3)2CH(CH2)2O(CH2)2CH (CH3)2	-	1.27	
253	554-14-3	2-Methylthiophene SC(CH3) CHCHCH	-	1.3	
254	557-99-3	Acetyl fluoride CH3COF	-	5.6	
255	563-47-3	3-Chloro-2-methyl-1-propene CH2=C(CH3)CH2Cl	-	2.1	
256	583-48-2	3,4-Dimethylhexane CH3CH2CH(CH3)CH(CH3)CH2CH3	-	0.8	
257	590-01-2	Propionic acid butyl ester (= Propanoic acid, butyl ester) (= Butyl propanoate) (= Butyl propionate) C2H5COOC4H9	-	1.0	
258	590-18-1	2-Butene (cis) CH3CH=CHCH3	1.5	1.6	
259	590-86-3	3-Methylbutanal (= iso-Pentanal) (= iso-Valeraldehyde) (= 3-Methylbutyraldehyde) (CH3)2CHCH2CHO	-	1.3	
260	591-78-6	2-Hexanone (= Hexan-2-one) (= Methyl butyl ketone) CH3CO(CH2)3CH3	-	1.2	
261	591-87-7	Acetic acid-2-propenyl ester (= Acetoxypropene) (= Acetic acid, allyl ester) (= Allyl acetate) CH2=CHCH2OOCCH3	-	1.7	
262	592-77-8	Hept-2-ene CH3(CH2)3CH=CHCH3	-	-	
263	598-61-8	Methylcyclobutane CH3CH(CH2)2CH2	-	-	
264	623-36-9	2-Methylpent-2-enal CH3CH2CHC(CH3)COH	-	1.46	
265	624-83-9	Methylisocyanate (= Methyl ester of isocyanic acid) CH3NCO	-	5.3	
266	625-55-8	Formic acid-1-methylethyl ester (= iso-Propyl formate) (= Formic acid isopropyl ester) (= 1-Methylethyl formate) HCOOCH(CH3)2	-	-	
267	626-38-0	Acetic acid 1-methylbutyl ester (= sec-Amyl acetate) (= 1-Methylbutyl acetate) (= 2-Pentanol acetate)	-	11.0	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
		(= 2-Pentyl ester of acetic acid) CH3COOCH(CH3)(CH2)2CH3			
268	628-63-7	Acetic acid penthyl ester (= n-Amyl acetate) (= Amyl acetic ester) (= 1-Pentanol acetate) (= Pentyl Acetate) (= Pentyl ester of acetic acid) (= Primary amyl acetate) CH3COO(CH2)4CH3	-	1.0	
269	629-14-1	1,2-Diethoxyethane (= 3,6-Dioxaoctane) CH3CH2O(CH2)2OCH2CH3	-	-	
270	630-08-0	Carbon monoxide (water saturated air at 18°C; see 5.2.3) CO	10.9	10.9	12.5
271	645-62-5	2-Ethyl-2-hexenal (= Ethylpropylacrolein) CH3CH(CH2CH3)=CH(CH2)2CH3	-	-	
272	646-06-0	1,3-Dioxolane (= glycolformal) (= formaldehyde ethylene acetal) (= ethylene glycol formal) OCH2CH2OCH2	-	2.3	
273	674-82-8	4-Methylene-2-oxetanone (= Acetyl ketene) (= But-3-en-3-olide) (= Diketene) CH2=CCH2C(O)O	-	-	
274	677-21-4	3,3,3-Trifluoroprop-1-ene CF3CH=CH2	-	4.7	4.0
275	693-65-2	1,1´-Oxybispentane (= Dipentylether) (CH3(CH2)4)2O	-	-	
276	760-23-6	3,4-Dichlorobut-1-ene CH2=CHCHClCH2Cl	-	1.3	
277	764-48-7	理研計器標準+A1:G304	-	-	
278	765-43-5	1-Cyclopropyl ethanone (= acetylcyclopropane) (= Cyclopropyl methyl ketone) CH2CH2CHCOCH3	-	1.7	
279	814-68-6	Acryloyl chloride (= Propenoyl chloride) (= Acrylic acid chloride) CH2CHCOCl	-	2.68	
280	872-05-9	1-Decene CH2(CH2)8CH3	-	0.55	
281	920-46-7	Methacryloyl chloride (= Methacrylic acid chloride) (= 2-Methyl-2-propenoyl chloride) CH2CCH3COCl	-	2.5	
282	926-57-8	1,3-Dichloro-2-butene CH3CCl=CHCH2Cl	-	-	
283	994-05-8	2-Methoxy-2-methyl-butane (= 1,1-Dimethylpropyl methyl ether) (= Methyl tert-pentyl ether) (CH3)2C(OCH3)CH2CH3	-	1.18	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
284	1120-56-5	Methylenecyclobutane C(=CH2)(CH2)2CH2	-	1.25	
285	1122-03-8	4,4,5-Trimethyl-1,3-dioxane OCH2OCH(CH3)C(CH3)2CH2	-	-	
286	1300-73-8	Xylidenes (Mixture of isomers) (= Xylidine) C6H3(CH3)2NH2	-	1.0	
287	1319-77-3 (o-Cresol)	Cresol (mixed isomers) CH3C6H4OH	-	1.1	1.1
288	1333-74-0	Hydrogen H2	4.0	4.0	4.0
289	1498-64-2	O-Ethyl phosphoro dichloridothioate C2H5OPSCl2	-	-	
290	1634-04-4	2-Methoxy-2-methylpropane (= tert-Butyl methylether) (= Methyl tert-butylether) CH3OC(CH3)3	-	1.5	1.6
291	1640-89-7	Ethylcyclopentane CH3CH2CH(CH2)3CH2	-	1.05	
292	1678-91-7	Ethylcyclohexane CH3CH2CH(CH2)4CH2	-	0.9	0.9
293	1712-64-7	Nitric acid-1-methylethyl ester (= iso-Propyl nitrate) (= Nitric acid isopropyl ester) (= Propane-2-nitrate) (CH3)2CHONO2	-	2.0	
294	1719-53-5	Dichlorodiethylsilane (= Diethyl-dichloro-silane) (C2H5)2SiCl2	-	3.4	
295	1738-25-6	3-(Dimethylamino) propiononitrile (CH3)2NHCH2CH2CN	-	1.57	
296	2032-35-1	2-Bromo-1,1-diethoxyethane (CH3CH2O)2CHCH2Br	-	-	
297	2426-08-6	(Butoxymethyl)oxirane (= n-Butyl glycidil ether) (= Butyl 2,3- Epoxypropylether) (= 1,2-Epoxy-3-butoxypropane) (CH2)3OCH2 CH3CH2(CH2)3O CH2 CHCH2O	-	-	
298	2673-15-6	2,2,3,3,4,4,5,5-Octafluoro-1,1- dimethylpentan-1-ol H(CF2CF2)2C(CH3)2OH	-	-	
299	2993-85-3	2,2,3,3,4,4,5,5,6,6,7,7-Dodecafluoroheptyl methacrylate CH2=C(CH3)COOCH2(CF2)6H	-	1.6	
300	3583-47-9	1,4-Dichloro-2,3 Epoxybutane (= 2,3-bis(chloromethyl) oxirane) CH2ClCH2CHCHOCH2Cl .	-	1.9	
301	4170-30-3	2-Butenal (= Crotonaldehyde) (= beta-Methyl acrolein) (= Propylene aldehyde) CH3CH=CHCHO	-	2.1	
302	4806-61-5	Ethylcyclobutane CH3CH2CH(CH2)2CH2	-	1.2	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
303	5870-82-6	1,1,3-Triethoxybutane (CH3CH2O)2CHCH2CH(CH3CH2O)CH3	-	0.78	
304	5891-21-4	5-Chloro-2-pentanone CH3CO(CH2)3Cl	-	2.0	
305	7383-71-3	2,2,3,3-Tetrafluoropropyl acrylate (= Acrylic acid 2,2,3,3-tetrafluoro-propyl ester) (= 2,2,3,3-Tetrafluoro propyl prop-2- enoate) CH2=CHCOOCH2CF2CF2H	-	2.4	
306	7397-62-8	Hydroxyacetic butylester (= Butyl glycolate) (= Butyl-2-hydroxyacetate) HOCH2COO(CH2)3CH3	-	-	
307	7664-41-7	Ammonia (= Anhydrous ammonia) NH3	15.4	15	15.0
308	7783-06-4	Hydrogen Sulfide (= Hydrosulfuric acid) (= Sewer gas) (= Sulfuretted hydrogen) H2S	-	4.0	4.0
309	8006-61-9	Gasoline (= Motor fuel) (= Natural gasoline) (= Petrol)	-	1.4	
310	8006-64-2	Turpentine oil	-	0.8	0.8
311	8008-20-6	Kerosene (= Diesel Oil No. 1) (= Fuel Oil No. 1)	-	0.7	0.7
312	17639-76-8	Methyl-2-methoxypropionate CH3CH(CH3O)COOCH3	-	1.2	
313	20260-76-8	2-Methyl-5-vinylpyridine NC(CH3)CHCHC(CH2=CH)CH	-	-	
314	25377-83-7	Octene (mixed isomers) C8H16	-	0.9	
315	25639-42-3	Methylcyclohexanol (mixed isomers) (= Hexahydromethyl phenol) (= Hexahydrocresol) C7H13OH	-	-	
316	26519-91-5	Methylcyclopentadiene-1,3 (CH3)C=CHCH=CHCH2	-	1.3	
317	29553-26-2	2,2,3,3-Tetrafluoro-1,1-dimethylpropan- 1-ol HCF2CF2C(CH3)2OH	-	-	
318	30525-89-4	Paraformaldehyde (= Polyoxymethylene) (= Polymerised formaldehyde) (= Formaldehyde polymer) poly(CH2O)	-	7.0	
319	34590-94-8	(2-Methoxymethylethoxy)propanol (= Dipropylene glycol monomethyl ether) H3COC3H6OC3H6OH	-	1.1	
320	35158-25-9	2-iso-Propyl-5-methylhex-2-enal -(= 2-Hexenal, 5-methyl-2-(1- methylethyl)) (CH3)2CH-C(CHO)CHCH2CH(CH3)2	-	-	
321	45102-52-1	2,2,3,3-Tetrafluoropropyl methacrylat (= 2,2,3,3-Tetrafluoro propyl 2- methylprop-2-	-	1.9	

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
		enoate) CH2=C(CH2)COOCH2CF2CF2H			
322	68476-34-6	Diesel Oil No. 2 (= Diesel fuel No. 2) (=Fuel Oil No. 2)	-	0.6	
323	No CAS	1-Chloro-2,2,2-trifluoroethyl methyl ether CF3CHClOCH3	-	8.0	
324	No CAS	Coke oven gas (see 5.2.1)	-	-	
325	No CAS	Fuel oil-6	-	-	
326	No CAS	4-Methylenetetra-hydropyran OCH2CH2C(=CH2) CH2CH2	-	1.5	
327	No CAS	2-Methylhexa-3,5-dien-2-ol CH2=CHC=CHC(OH)(CH3)2	-	-	
328	No CAS	Water gas Mixture of CO + H2	-	-	
329	7784-42-1	Arsine	3.9	-	5.1
330	74-83-9	Bromomethan	8.6	-	8.6
331	590-19-2	1,2-Butadiene	1.4	-	
332	624-64-6	trans-Butene	1.5	-	
333	75-68-3	Chlorodifluoroethane (R142b)	6.3	-	7.8
334	460-19-5	Cyanogen	3.9	-	
335	7782-39	Deuterium	6.7	-	5.0
336	19287-45-7	Diborane	0.9	-	0.8
337	4109-96-0	Dichlorosilane	2.5	-	4.1
338	75-37-6	Difluoroethane (R152a)	4.0	-	3.7
339	463-82-1	Dimethylpropane (neopentane)	1.3	-	
340	353-36-6	Fluoroethane	3.8	-	
341	7782-65-2	Germane	1.0	-	0.8
342	7783-03-5	Hydrogen selenide	4.0	-	
343	7783-06-4	Hydrogen sulfide	3.9	-	4.0
344	624-91-9	Methyl nitrite	5.3	-	
345	992-94-9	Methyl silane	1.3	-	
346	563-45-1	Methylbutene (3-methylbut-1-ene)	1.5	-	
347	7803-51-2	Phosphine	1.6	-	1.8
348	463-49-0	Propadiene	1.9	-	
349	7803-62-5	Silane	1.4	-	0.8

NO.	CAS-No.	Name formula	ISO 10156 4th ed.	IEC60079-20-1 LEL(vol%)	RIKEN Standard
350	993-07-7	Trimethylsilane	1.3	-	
351	593-60-2	Vinyl bromide	5.6	-	
352	75-02-5	Vinyl fluoride	2.9	-	
353	107-25-5	Vinyl methyl ether	2.2	-	
354	503-17-3	Dimethyl acetylene (2-butyne, crotonylene)	1.4	-	1.4
355	112-40-3	n-Dodecane	0.6	-	
356	78-00-2	Lead tetraethyl (tetraethyllead)	1.8	-	
357	75-09-2	Methylene chloride (Dichloromethane)	13.0	-	13.0
358	13465-78-6	Monochlorosilane	1.0	-	
359	13463-39-3	Nickel carbonyl (tetracarbonylnickel)	0.9	-	
360	110-74-7	Propyl formate	2.1	-	

4

Toxic Gas Hazards

4-1. Toxic gas hazards

The gases used or generated as process byproduct gases in a wide range of industries include toxic gases that can cause serious health damage or even death in humans, even at extremely low concentrations.

Certain gases like hydrogen sulfide (H_2S) and ammonia (NH_3) have a distinct odor that allows us humans to detect their presence. Even so, the human olfactory sense is unable to determine whether concentrations have reached potentially harmful threshold levels (in the case of H_2S TLV-TWA: 1 ppm, ACGIH 2018).

1 ppm corresponds to the concentration obtained, for example, by adding just a single drop (1 mL = 1 g or 1 cc) of toxic liquid into a large 1,000 L (1 t or 1 m^3) tank of water and mixing thoroughly. Suppose the single drop (1 ppm) is a drop of soy sauce. Not only would it be impossible to detect this visually after mixing, it would be impossible to detect by taste. While gases differ from liquids, many toxic gases are both colorless and odorless.

One such example of a toxic gas is carbon monoxide (CO), a potentially fatal gas that can be generated by the incomplete combustion of gas heaters in homes. It’s sometimes referred to as a silent killer, due to its capacity to poison or kill undetected.

4-2. Threshold limit values of toxic gases

Name formula (ACGIH)	CASNo.	Chemical formula	ACGIH 2018		
			TWA	STEL	C
Acetaldehyde	75-07-0	C2H4O			25ppm
Acetic acid	64-19-7	C2H4O2	10ppm	15ppm	
Acetic anhydride	108-24-7	C4H6O3	1ppm	3ppm	
Acetone	67-64-1	C3H6O	500ppm	750ppm	
Acetonitrile	75-05-8	C2H3N	20ppm		
Acetophenone	98-86-2	C8H8O	10ppm		
Acrolein	107-02-8	C3H4O			0.1ppm
Acrylic acid	79-10-7	C3H4O2	2ppm		
Acrylonitrile	107-13-1	C3H3N	2ppm		
Allyl alcohol	107-18-6	C3H6O	0.5ppm		
Allyl chloride	107-05-1	C3H5CL	1ppm	2ppm	
Allyl glycidyl ether(AGE)	106-92-3	C6H10O2	1ppm		
Ammonia	7664-41-7	NH3	25ppm	35ppm	
Aniline	62-53-3	C6H7N	2ppm		
Antimony hydride	7803-52-3	H3Sb	0.1ppm		
Arsine	7784-42-1	AsH3	0.005ppm		
Benzene	71-43-2	C6H6	0.5ppm	2.5ppm	
Benzyl chloride	100-44-7	C7H7CL	1ppm		
Boron tribromide	10294-33-4	BBr3			1ppm
Boron trifluoride	7637-07-2	BF3			1ppm
Bromine	7726-95-6	Br2	0.1ppm	0.2ppm	
Bromine pentafluoride	7789-30-2	BrF5	0.1ppm		
1-Bromopropane	106-94-5	C3H7Br	0.1ppm		
1,3-Butadiene	106-99-0	C4H6	2ppm		
Butane, all isomers	75-28-5	C4H10		1000ppm	
Butane, all isomers	106-97-8	C4H10		1000ppm	
n-Butanol	71-36-3	C4H10O	20ppm		
sec-Butanol	78-92-2	C4H10O	100ppm		
tert-Butanol	75-65-0	C4H10O	100ppm		
Butenes, all isomers Isobutene	106-98-9	C4H8	250ppm		
Butenes, all isomers Isobutene	115-11-7	C4H8	250ppm		
Butenes, all isomers Isobutene	107-01-7	C4H8	250ppm		
2-Butoxyethanol(EGBE)	111-76-2	C6H14O2	20ppm		
2-Butoxyethyl acetate(EGBEA)	112-07-2	C8H16O3	20ppm		
n-Butyl acetate	123-86-4	C6H12O2	150ppm	200ppm	
tert-Butyl acetate	540-88-5	C6H12O2	200ppm		
n-Butyl acrylate	141-32-2	C7H12O2	2ppm		
n-Butylamine	109-73-9	C4H11N			5ppm
Carbon dioxide	124-38-9	CO2	5000ppm	30,000ppm	
Carbon disulfide	75-15-0	CS2	1ppm		
Carbon monoxide	630-08-0	CO	25ppm		
Carbon tetrabromide	558-13-4	CBr4	0.1ppm	0.3ppm	

Name formula（ACGIH）	CASNo.	Chemical formula	ACGIH 2018		
			TWA	STEL	C
Carbon tetrachloride	56−23−5	CCL4	5ppm	10ppm	
Carbonyl fluoride	353−50−4	COF2	2ppm	5ppm	
Carbonyl sulfide	463−58−1	COS	5ppm		
Catechol	120−80−9	C6H6O2	5ppm		
Chlorine	7782−50−5	CL2	0.5ppm	1ppm	
Chlorine dioxide	10049−04−4	CLO2	0.1ppm	0.3ppm	
Chlorine trifluoride	7790−91−2	CLF3			0.1ppm
Chlorobenzene	108−90−7	C6H5CL	10ppm		
Chlorobromomethane	74−97−5	CH2CLBr	200ppm		
Chlorodifluoromethane	75−45−6	CHF2CL	1000ppm		
Chloroform	67−66−3	CHCL3	10ppm		
Chloropentafluoroethane	76−15−3	C2F5CL	1000ppm		
Chloropicrin	76−06−2	CNO2CL3	0.1ppm		
o−Chlorotoluene	95−49−8	C7H7CL	50ppm		
Cumene	98−82−8	C9H12	50ppm		
Cyclohexane	110−82−7	C6H12	100ppm		
Cyclohexanol	108−93−0	C6H12O	50ppm		
Cyclohexanone	108−94−1	C6H10O	20ppm	50ppm	
Cyclohexene	110−83−8	C6H10	300ppm		
Cyclopentadiene	542−92−7	C5H6	75ppm		
Cyclopentane	287−92−3	C5H10	600ppm		
Diacetone alcohol	123−42−2	C6H12O2	50ppm		
Diborane	19287−45−7	B2H6	0.1ppm		
o−Dichlorobenzene p−Dichlorobenzene	95−50−1(ortho) 106−46−7(para)	C6H4CL2	25ppm(ortho) 10ppm(para)	50ppm(ortho)	
Dichlorodifluoromethane	75−71−8	CF2CL2	1000ppm		
1,1−Dichloroethane	75−34−3	C2H4CL2	100ppm		
1,2−Dichloroethylene, all isomers	156−59−2	C2H2CL2	200ppm		
1,2−Dichloroethylene, all isomers	156−60−5	C2H2CL2	200ppm		
Dichlorofluoromethane	75−43−4	CHFCL2	10ppm		
Dichloromethane	75−09−2	CH2CL2	50ppm		
1,3−Dichloropropene	542−75−6	C3H4CL2	1ppm		
Dichlorotetrafluoroethane	76−14−2	C2F4CL2	1000ppm		
Dicyclopentadiene	77−73−6	C10H12	5ppm		
Diethylamine	109−89−7	C4H11N	5ppm	15ppm	
Diethylene glycol monobutyl ether	112−34−5	C8H18O3	10ppm		
Diethyl ketone	96−22−0	C5H10O	200ppm	300ppm	
Difluorodibromomethane	75−61−6	CF2Br2	100ppm		
Diisobutyl ketone	108−83−8	C9H18O	25ppm		
Diisopropylamine	108−18−9	C6H15N	5ppm		
N,N−Dimethyl acetamide	127−19−5	C4H9NO	10ppm		
Dimethylamine	124−40−3	C2H7N	5ppm	15ppm	
Dimethylaniline	121−69−7	C8H11N	5ppm	10ppm	
Dimethyl disulfide	624−92−0	C2H6S2	0.5ppm		
Dimethylformamide	68−12−2	C3H7NO	10ppm		
Dimethyl sulfate	77−78−1	C2H6O4S	0.1ppm		
Dimethyl sulfide	75−18−3	C2H6S	10ppm		

Name formula（ACGIH）	CASNo.	Chemical formula	ACGIH 2018		
			TWA	STEL	C
1,4-Dioxane	123-91-1	C4H8O2	20ppm		
1,3-Dioxolane	646-06-0	C3H6O2	20ppm		
Divinyl benzene	1321-74-0	C10H10	10ppm		
Enflurane	13838-16-9	C3H2ClF5O	75ppm		
Epichlorohydrin	106-89-8	C3H5OCL	0.5ppm		
Ethanol	64-17-5	C2H6O		1000ppm	
Ethanolamine	141-43-5	C2H7NO	3ppm	6ppm	
2-Ethoxyethanol(EGEE)	110-80-5	C4H10O2	5ppm		
2-Ethoxyethyl acetate(EGEEA)	111-15-9	C6H12O3	5ppm		
Ethyl acetate	141-78-6	C4H8O2	400ppm		
Ethyl acrylate	140-88-5	C5H8O2	5ppm	15ppm	
Ethylamine	75-04-7	C2H7N	5ppm	15ppm	
Ethyl benzene	100-41-4	C8H10	20ppm		
Ethyl bromide	74-96-4	C2H5Br	5ppm		
Ethyl tert-butyl ether	637-92-3	C6H14O	25ppm		
Ethyl chloride	75-00-3	C2H5CL	100ppm		
Ethylene	74-85-1	C2H4	200ppm		
Ethylene chlorohydrin	107-07-3	C2H5OCL			1ppm
Ethylenediamine	107-15-3	C2H8N2	10ppm		
Ethylene dichloride	107-06-2	C2H4CL2	10ppm		
Ethylene oxide	75-21-8	C2H4O	1ppm		
Ethyleneimine	151-56-4	C2H5N	0.05ppm	0.1ppm	
Ethyl ether	60-29-7	C4H10O	400ppm	500ppm	
Ethyl formate	109-94-4	C3H6O2		100ppm	
Ethylidene norbornene	16219-75-3	C9H12	2ppm	4ppm	
Ethyl mercaptan	75-08-1	C2H6S	0.5ppm		
Ethyl silicate	78-10-4	C8H20O4Si	10ppm		
Fluorine	7782-41-4	F2	1ppm	2ppm	
Formaldehyde	50-00-0	CH2O			0.3ppm
Formaldehyde	50-00-0	CH2O			0.3ppm
Formic acid	64-18-6	CH2O2	5ppm	10ppm	
Furfural	98-01-1	C5H4O2	2ppm		
Furfuryl alcohol	98-00-0	C5H6O2	10ppm	15ppm	
Gasoline	68606-10-0 86290-81-5		300ppm	500ppm	
Germanium tetrahydride	7782-65-2	GeH4	0.2ppm		
Halothane	151-67-7	C2HF3CLBr	50ppm		
Heptane, all isomers	142-82-5	C7H16	400ppm	500ppm	
Hexafluoroacetone	684-16-2 34202-69-2 (trihydrate)	C3OF6	0.1ppm		
Hexafluoropropylene	116-15-4	C3F6	0.1ppm		
n-Hexane	110-54-3	C6H14	50ppm		
Hexane isomers, other than n-Hexane	75-83-2	C6H14	500ppm	1000ppm	
1-Hexene	592-41-6	C6H12	50ppm		2ppm
Hydrazine	302-01-2	N2H4	0.01ppm		2ppm
Hydrogen bromide	10035-10-6	HBr			2ppm
Hydrogen chloride	7647-01-0	HCL			2ppm

Name formula(ACGIH)	CASNo.	Chemical formula	ACGIH 2018		
			TWA	STEL	C
Hydrogen cyanide	74-90-8	CHN			4.7ppm
Hydrogen fluoride, as F	7664-39-3	HF	0.5ppm		
Hydrogen peroxide	7722-84-1	H2O2	1ppm		
Hydrogen selenide, as Se	7783-07-5	H2Se	0.05ppm		
Hydrogen sulfide	7783-06-4	H2S	1ppm	5ppm	
Iodine	7553-56-2	I2	0.01ppm	0.1ppm	
Iron pentacarbonyl	13463-40-6	C5O5Fe	0.1ppm	0.2ppm	
Isobutanol	78-83-1	C4H10O	50ppm		
Isobutyl acetate	110-19-0	C6H12O2	150ppm		
Isophorone	78-59-1	C9H14O			5ppm
Isopropyl acetate	108-21-4	C5H10O2	100ppm	200ppm	
Isopropylamine	75-31-0	C3H9N	5ppm	10ppm	
Isopropyl ether	108-20-3	C6H14O	250ppm	310ppm	
Mesityl oxide	141-79-7	C6H10O	15ppm	25ppm	
Methacrylic acid	79-41-4	C4H6O2	20ppm		
Methanol	67-56-1	CH4O	200ppm	250ppm	
2-Methoxyethanol(EGME)	109-86-4	C3H8O2	0.1ppm		
2-Methoxyethyl acetate (EGMEA)	110-49-6	C5H10O3	0.1ppm		
(2-Methoxymethylethoxy) propanol(DPGME)	34590-94-8	C7H16O3	100ppm	150ppm	
1-Methoxy-2-propanol	107-98-2	C4H10O2	50ppm	100ppm	
1-Methoxy-2-propanol	107-98-2	C4H10O2	50ppm	100ppm	
1-Methoxy-2-propanol	107-98-2	C4H10O2	50ppm	100ppm	
Methyl acetate	79-20-9	C3H6O2	200ppm	250ppm	
Methyl acetylene	74-99-7	C3H4	1000ppm		
Methyl acrylate	96-33-3	C4H6O2	2ppm		
Methylacrylonitrile	126-98-7	C4H5N	1ppm		
Methylal	109-87-5	C3H8O2	1000ppm		
Methylamine	74-89-5	CH5N	5ppm	15ppm	
Methyl n-amyl ketone	110-43-0	C7H14O	50ppm		
Methyl bromide	74-83-9	CH3Br	1ppm		
Methyl tert-butyl ether(MTBE)	1634-04-4	C5H12O	50ppm		
Methyl n-butyl ketone	591-78-6	C6H12O	5ppm	10ppm	
Methyl chloride	74-87-3	CH3CL	50ppm	100ppm	
Methyl chloroform	71-55-6	C2H3CL3	350ppm	450ppm	
Methyl cyclohexane	108-87-2	C7H14	400ppm		
Methyl ethyl ketone(MEK)	78-93-3	C4H8O	200ppm	300ppm	
Methyl formate	107-31-3	C2H4O2	100ppm	150ppm	
Methyl hydrazine	60-34-4	CH6N2	0.01ppm		
Methyl iodide	74-88-4	CH3I	2ppm		
Methyl isoamyl ketone	110-12-3	C7H14O	20ppm	50ppm	
Methyl isobutyl carbinol	108-11-2	C6H14O	25ppm	40ppm	
Methyl isobutyl ketone	108-10-1	C6H12O	20ppm	75ppm	
Methyl isopropyl ketone	563-80-4	C5H10O	20ppm		
Methyl mercaptan	74-93-1	CH4S	0.5ppm		
Methyl methacrylate	80-62-6	C5H8O2	50ppm	100ppm	
Methyl silicate	681-84-5	C4H12O4Si	1ppm		
α-Methyl styrene	98-83-9	C9H10	10ppm		

Name formula(ACGIH)	CASNo.	Chemical formula	ACGIH 2018		
			TWA	STEL	C
Methyl vinyl ketone	78-94-4	C4H6O			0.2ppm
Morpholine	110-91-8	C4H9NO	20ppm		
Naphthalene	91-20-3	C10H8	10ppm		
Nitric acid	7697-37-2	HNO3	2ppm	4ppm	
Nitric oxide	10102-43-9	NO	25ppm		
Nitrobenzene	98-95-3	C6H5NO2	1ppm		
Nitroethane	79-24-3	C2H5NO2	100ppm		
Nitrogen dioxide	10102-44-0	NO2	0.2ppm		
Nitrogen trifluoride	7783-54-2	NF3	10ppm		
2-Nitropropane	79-46-9	C3H7NO2	10ppm		
Nitrous oxide	10024-97-2	N2O	50ppm		
Nonane	111-84-2	C9H20	200ppm		
Octane, all isomers	540-84-1	C8H18	300ppm		
Octane, all isomers	111-65-9	C8H18	300ppm		
Osmium tetroxide, as Os	20816-12-0	OsO4	0.0002ppm	0.0006ppm	
Ozone	10028-15-6	O3	0.05ppm 0.08ppm 0.1ppm 0.2ppm		
Pentane, all isomers	78-78-4	C5H12	1000ppm		
Pentane, all isomers	109-66-0	C5H12	1000ppm		
2,4-Pentanedione	123-54-6	C5H8O2	25ppm		
Pentyl acetate, all isomers	123-92-2	C7H14O2	50ppm	100ppm	
Phenol	108-95-2	C6H6O	5ppm		
Phenyl mercaptan	108-98-5	C6H6S	0.1ppm		
Phosgene	75-44-5	COCL2	0.1ppm		
Phosphine	7803-51-2	PH3	0.3ppm	1ppm	
Phosphorus oxychloride	10025-87-3	POCL3	0.1ppm		
Phosphorus pentachloride	10026-13-8	PCL5	0.1ppm		
Phosphorus trichloride	7719-12-2	PCL3	0.2ppm	0.5ppm	
n-Propanol(n-Propyl alcohol)	71-23-8	C3H8O	100ppm		
2-Propanol	67-63-0	C3H8O	200ppm	400ppm	
Propionaldehyde	123-38-6	C3H6O	20ppm		
Propionic acid	79-09-4	C3H6O2	10ppm		
n-Propyl acetate	109-60-4	C5H10O2	200ppm	250ppm	
Propylene	115-07-1	C3H6	500ppm		
Propylene dichloride	78-87-5	C3H6CL2	10ppm		
Propylene oxide	75-56-9	C3H6O	2ppm		
Propyleneimine	75-55-8	C3H7N	0.2ppm	0.4ppm	
Pyridine	110-86-1	C5H5N	1ppm		
Silicon tetrahydride	7803-62-5	SiH4	5ppm		
Styrene, monomer	100-42-5	C8H8	20ppm	40ppm	
Sulfur dioxide	7446-09-5	SO2		0.25ppm	
Sulfur hexafluoride	2551-62-4	SF6	1000ppm		
Sulfur tetrafluoride	7783-60-0	SF4			0.1ppm
Sulfuryl fluoride	2699-79-8	SO2F2	5ppm	10ppm	
1,1,2,2,-Tetrabromoethane	79-27-6	C2H2Br4	0.1ppm		
1,1,2,2-Tetrachloro-1,2-difluoroethane	76-12-0	C2F2CL4	50ppm		

Name formula（ACGIH）	CASNo.	Chemical formula	ACGIH 2018		
			TWA	STEL	C
1,1,2,2-Tetrachloroethane	79-34-5	C2H2CL4	1ppm		
Tetrachloroethylene	127-18-4	C2CL4	25ppm	100ppm	
Tetrafluoroethylene	116-14-3	C2F4	2ppm		
Tetrahydrofuran	109-99-9	C4H8O	50ppm	100ppm	
Thionyl chloride	7719-09-7	SOCL2			0.2ppm
Toluene	108-88-3	C7H8	20ppm		
1,2,4-Trichlorobenzene	120-82-1	C6H3Cl3			5ppm
Trichloroethylene	79-01-6	C2HCL3	10ppm	25ppm	
Trichlorofluoromethane	75-69-4	CFCL3			1000ppm
1,2,3-Trichloropropane	96-18-4	C3H5CL3	10ppm		
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	C2F3CL3	1000ppm	1250ppm	
Triethylamine	121-44-8	C6H15N	1ppm	3ppm	
Trifluorobromomethane	75-63-8	CF3Br	1000ppm		
Trimethylamine	75-50-3	C3H9N	5ppm	15ppm	
Trimethyl benzene (mixed isomers)	108-67-8 25551-13-7 (mixed isomers)	C9H12	25ppm		
Trimethyl phosphite	121-45-9	C3H9O3P	2ppm		
Turpentine and selected monoterpenes	8006-64-2	C10H16	20pm		
Turpentine and selected monoterpenes	80-56-8	C10H16	20ppm		
n-Valeraldehyde	110-62-3	C5H10O	50ppm		
Vinyl acetate	108-05-4	C4H6O2	10ppm	15ppm	
Vinyl chloride	75-01-4	C2H3CL	1ppm		
4-Vinyl cyclohexene	100-40-3	C8H12	0.1ppm		
N-Vinyl-2-pyrrolidone	88-12-0	C6H9NO	0.05ppm		
Vinylidene chloride	75-35-4	C2H2CL2	5ppm		
Vinylidene fluoride	75-38-7	C2H2F2	500ppm		
Xylene(o, m & p isomers)	1330-20-7	C8H10	100ppm	150ppm	
Xylene(o, m & p isomers)	95-47-6(ortho)	C8H10	100ppm	150ppm	
Xylene(o, m & p isomers)	108-38-3(meta)	C8H10	100ppm	150ppm	
Xylene(o, m & p isomers)	106-42-3(para)	C8H10	100ppm	150ppm	

5

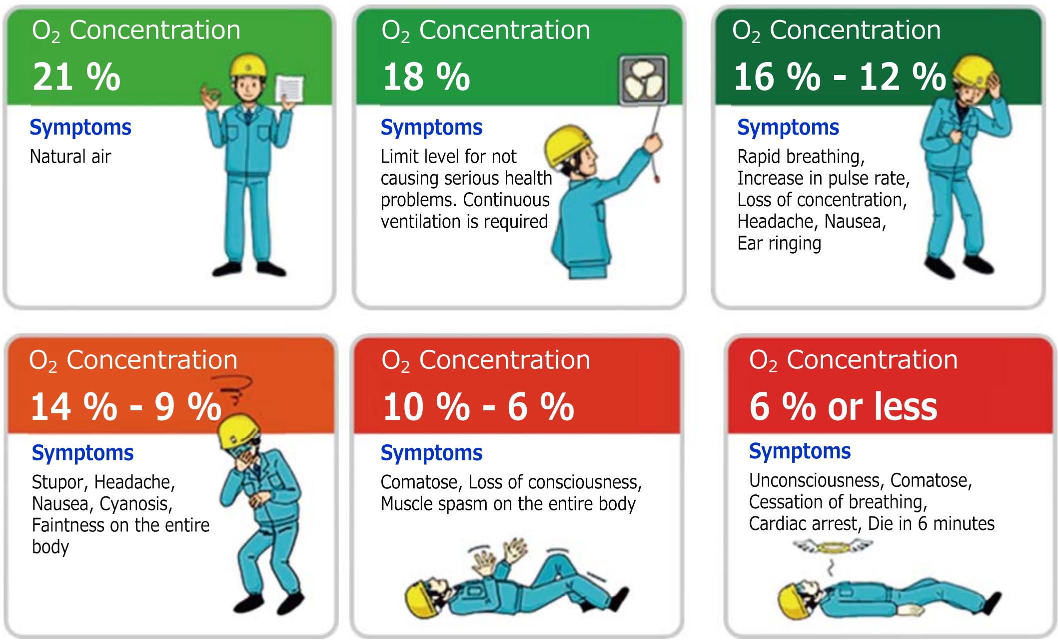
Oxygen Deficiency Hazards

5-1. Oxygen deficiency

Oxygen is an essential substance for maintaining human biological function. Anoxia has serious effects on the human body, the brain in particular. Anoxia is an extremely hazardous state associated with high mortality rates in the workplace. Looking at industrial accidents in Japan related to oxygen deficiency, we see that the majority occur in the manufacturing and construction sectors, with several to several dozens of victims each year.

The Ordinance on Prevention of Anoxia, etc. of the Industrial Safety and Health Act of Japan describes oxygen deficiency as a condition in which the concentration of oxygen in the air is less than 18 %. Gas detectors are used to confirm that oxygen concentrations are at least 18 %.

Oxygen deficiency symptoms



Oxygen deficiency thresholds in different countries

Region	Regulation	Oxygen deficiency threshold
Japan	Industrial Safety and Health Act Ordinance on Prevention of Anoxia, etc.	18.0 %
USA	OSHA Occupational safety and health regulations	19.5 %
Europe (UK)	CoGDEM	19.5 %

* OSHA: Occupational Safety and Health Administration

* CoGDEM: UK Council of Gas Detection and Environmental Monitoring

5-2. Three main causes of oxygen deficiency

1. Consumption of oxygen in the air
   Main causes for oxygen consumption:
   Oxidation of iron and other metals (ironsand, metal pipes, metal tanks), oxidation of paint, biological oxygen consumption (respiration by humans and microorganisms)

2. Discharge or inflow of oxygen-deficient air
   Oxygen-deficient air generated by a wide range of factors can cause anoxia if it is discharged or flows into an oxygen-deficient location due to work specifics, construction methods, or weather conditions.

3. Methane generation or inflow of inert gas
   Oxygen deficiency can be caused by the discharge of methane, present in the natural world, or by leaks from tanks or pipes of inert gases (e.g., nitrogen, carbon dioxide, argon) used in manufacturing industries.

5-3. Excess oxygen

While oxygen is essential to human biological function, continuous exposure to high concentrations or high partial pressures can lead to oxygen poisoning. Oxygen poisoning causes generalized convulsion and loss of consciousness—and, in the worst case, death. In environments where excess oxygen may arise, gas concentrations must be monitored not just for oxygen deficiency (under 18 %), but to prevent excessive concentrations.

6
Typical Areas That Require Gas Detection

6-1. Gas detector market

The gas detector market comprises all markets where gas is used.

1. Laboratories, universities, hospitals

Research facilities using a wide range of gases, including combustible and toxic gases, adopt measures to ensure the safety of research staff, such as detecting gas leaks swiftly by monitoring the environment using Riken Keiki fixed gas detectors.
Aside from gas detectors, analysis systems capable of performing both X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses on site are used for applications like research of cultural properties that cannot be moved.

2. Electronics industry

Plants manufacturing semiconductors and LCD panels use what are known as special material gases (highly toxic and combustible gases), including silane, arsine, and phosphine. With these gases, leaks at even minute concentrations (several ppm to several tens of ppm) are unacceptable.
Plants manufacturing semiconductors and LCD panels may have several hundred or several thousand Riken Keiki gas detectors deployed to protect workers from gas leaks. These detectors contain potentiostatic electrolysis method sensors capable of detecting gas leaks on the order of several ppm.

3. Steel industry

Gases generated as byproducts in steel manufacturing processes (coke gas, blast furnace gas, converter gas) contain high levels of hydrogen and carbon monoxide. These gases are reused as fuel for power generation at steel plants.
Riken Keiki portable gas detectors protect workers inside steel plants from explosion and poisoning hazards.

4. Oil refining and petrochemical industry

The oil refining and petrochemical industry handles a wide range of combustible and toxic gases in its manufacturing processes. Riken Keiki fixed and portable gas detectors are used in applications ranging from detecting combustible and toxic gas leaks from equipment and pipes to process management and working environment measurements.
Fixed toxic gas environmental monitors are also increasingly being used for toxic gas management at plant boundaries.

5. Volcanic and hot spring sites

Volcanic gases are generated near volcanic craters and in areas where hot springs discharge. These volcanic gases contain toxic sulfur dioxide and hydrogen sulfide, which are harmful to humans if inhaled. The concentrations of these gases vary continuously due to volcanic activity and other factors. Riken Keiki's fixed sulfur dioxide and hydrogen sulfide detectors monitor gas concentrations around the clock to protect workers and tourists.

6. Food industry

Nitrogen and carbon dioxide are used in the food industry in packaging processes to prevent the oxidation of food. Since these gases are suffocating gases, Riken Keiki oxygen detectors are installed in food factories to protect workers from anoxia.

7. Construction industry

Underground excavation work of underground tunnel construction and work inside manholes can expose workers to hydrogen sulfide generation and oxygen-deficient conditions caused by oxygen-consuming bacteria found in underground strata. Riken Keiki's portable oxygen detectors and hydrogen sulfide detectors protect workers from hazards posed by oxygen deficiency and hydrogen sulfide poisoning.

8. Firefighting and rescue

Fire and disaster scenes expose personnel to various hazards, including explosions due to combustible gases, oxygen deficiency, carbon monoxide poisoning due to incomplete combustion, and toxic gases like hydrogen sulfide.
Riken Keiki's four-gas personal monitors are used to monitor four different gases simultaneously. They're ideal for situations where the specific hazardous gases present are unknown.

9. Shipping and shipbuilding

Vessels transporting large volumes of crude oil, LNG, or LPG face the risk of combustible gas leaks from their cargo tanks. Riken Keiki's fixed gas detectors monitor for gas leaks. They ensure swift detection and prevent the explosions and marine pollution that leaks may cause.
In addition, Riken Keiki's portable gas detectors are worn by workers during construction work to protect against dangerous oxygen deficiency and toxic gas poisoning.

10. Aerospace

Rocket fuels incorporate hydrogen, a highly explosive combustible gas, and hydrazine, a gas toxic to humans. Monitoring these gases is essential for safety.
Explosion-proof gas detectors are used to ensure safety at locations associated with high explosion risks—for example, areas where rocket fuel is handled.

7

Gas detection technologies

7-1. RIKEN Gas sensor technologies

The Riken Keiki has many gas sensor technologies in order to deal with diverse environments and gas types in a wide range of industries. In this document, we will introduce the following 13 types that are typically used in industry.

1. Catalytic Combustion Method
2. New Ceramic Catalytic Method
3. Semi-Conductor Method
4. Hot Wire Type Semi-Conductor Method
5. Thermal Conductivity Method
6. Potentiostatic Electrolysis Method
7. Membrane-Separated Electrode Method
8. Membrane Type Galvanic Cell Method
9. Non-Dispersive Infrared Method
10. Interferometer Method
11. Chemical Tape Method
12. Photo-Ionization Detector
13 Pyrolysis-Particle Detection Method

7-2. Catalytic Combustion Method

Stationary sensor
Example: HW-6239

1. Brief description

This sensor detects gas based on heat generated by combustible gas burning on an oxidation catalyst. It is the most widely used gas sensor designed specifically for combustible gases.

Category	Detectable gas
Solid	Combustible

2. Structure and principles

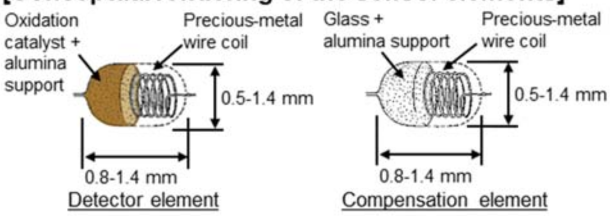
[Structure]

This sensor consists of a detector element and a compensation element. The detector element consists of a coil of a precious-metal (e.g., platinum) wire and an oxidant catalyst—a substance active against combustible gas—sintered on the coil along with an alumina support. The element burns in reaction to any detectable gas. The compensation element consists of a coil of a precious-metal wire and glass—a substance inactive against combustible gas—sintered on the coil along with an alumina support. This element corrects the effect of the atmosphere.

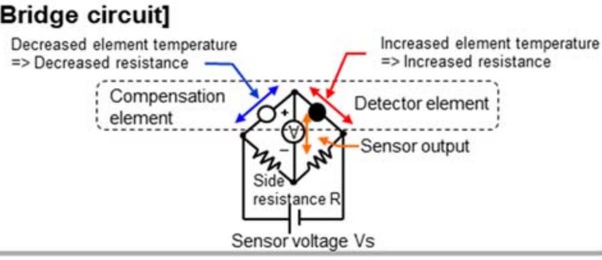
[Principles]

The precious-metal wire coil heats the detector element to 300℃ to 450℃. Then, a combustible gas burns on the surface of the detector element, increasing the temperature of the element. With changes in temperature, the precious-metal wire coil, a component of the element, changes in resistance. The resistance changes almost in proportion to the concentration of the gas. The bridge circuit shown in the right figure allows the sensor to recognize the change in resistance as the voltage to determine the concentration of the gas.

[Conceptual rendering of the sensor elements]



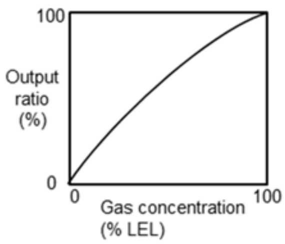
[Bridge circuit]



3. Features (of the sensor HW-6239 as an example)

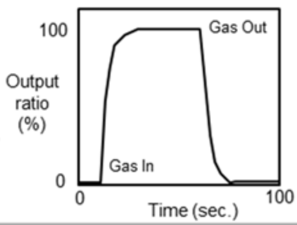
○ Output characteristics

The precious-metal wire coil, the heat source, linearly changes in temperature resistance coefficient. In the lower-explosion-limit (LEL) concentration region, the burning reaction is proportional to the gas concentration. In this region, the output from the sensor slowly changes according to the change in gas concentration.



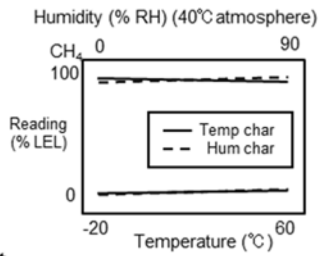
○ Responsiveness

The combustion heat produced on the surface of the detector element transfers to the precious-metal wire coil, changes the resistance of the bridge circuit, and then transforms into signals. With a high reaction rate, this sensor excels in responsiveness, accuracy, and reproducibility.



○ Temperature and humidity characteristics

The materials used in the elements have high electrical resistances and are less likely to be affected by the temperature and humidity in the use environment, allowing the reading to stay almost constant.



○ Catalyst development

The detector element uses a catalyst that promotes burning reaction. Having been developed in-house for gas sensors, this catalyst makes use of our proprietary know-how, providing long-term stability.

4. Detectable gas, molecular formula, model, and detection range (examples)

Detectable gas	Molecular formula	Model #	Detection range
Combustible gases in general	-	HW-6211	0-100% LEL
Methane	CH_4	HW-6239	
Vinyl chloride	C_2H_3Cl	HW-6214	
High-boiler gases	-	HW-6228	

5. Products of this type (examples)

○ Stationary products

... GD-A80, GD-A80D, SD-1 (Type GP), SD-D58･DC (Type GP), SD-2500

○ Portable products

... GP-1000

SD-1 (Type GP)

7-3. New Ceramic Catalytic Method

Stationary sensor
Example: NC-6239

Portable sensor
Example: NC-6264AZP

1. Brief description

This sensor uses a ultra-atomized oxidant catalyst (a new ceramic) to detect gas in a wide range of concentrations from a low level (ppm) to the lower-explosion-limit (LEL). It is an epoch-making sensor independently developed by us as a sensor designed specifically for combustible gas.

Category	Detectable gas
Solid	Combustible

2. Structure and principles

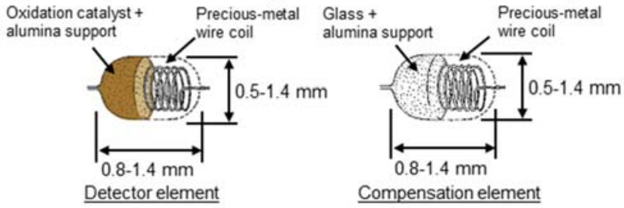
[Structure]

A new ceramic-based sensor consists of a detector element and a compensation element (some models include no compensation element). The detector element consists of a coil of a precious-metal wire and a ultra-atomized oxidant catalyst (a new ceramic)—a catalyst active against combustible gas—sintered on the coil along with an alumina support. The element burns in reaction to any detectable gas. The compensation element consists of a coil of a precious-metal wire and glass—a substance inactive against combustible gas—sintered on the coil along with an alumina support. This element corrects the effect of the atmosphere.

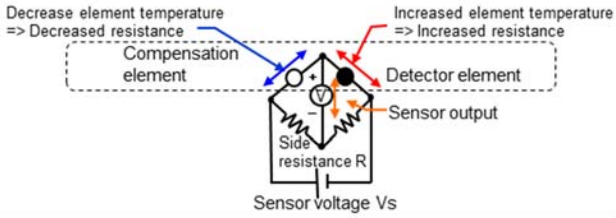
[Principles]

The precious-metal wire coil heats the detector element to 300℃ to 450℃. Then, a combustible gas burns on the surface of the detector element, increasing the temperature of the element. With changes in temperature, the precious-metal wire coil, a component of the element, changes in resistance. The resistance changes almost in proportion to the concentration of the gas. The bridge circuit allows the sensor to recognize the change in resistance as the voltage to determine the concentration of the gas.

[Conceptual rendering of the sensor elements]



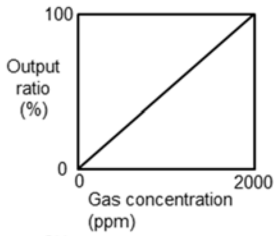
[Bridge circuit]



3. Features(of the sensor NC-6239 as an example)

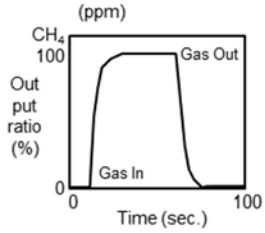
○ Output characteristics

The catalyst used in the detector element provides improved combustion reactivity. This efficiently produces combustion heat, allowing the sensor to detect lower concentrations (ppm) of gases undetectable by catalytic combustion-based sensors.



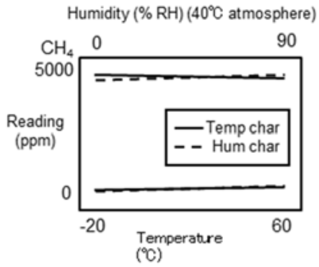
○ Responsiveness

The combustion heat produced on the surface of the detector element transfers to the precious-metal wire coil, changes the resistance of the bridge circuit, and then transforms into signals. With a high reaction rate, this sensor excels in responsiveness, accuracy, and reproducibility.



○ Temperature and humidity characteristics

The materials used in the elements have high electrical resistances and less likely to be affected by the temperature and humidity in the use environment, allowing the reading to stay almost constant.



○ Detectable concentrations

The sensor detects a wide range of concentrations from low levels (ppm) to high levels (% LEL).

4. Detectable gas, molecular formula, model, and detection range (examples)

Detectable gas	Molecular formula	Model #	Detection range
Combustible gases in general	-	NC-6211	ppm level to 100% LEL
Methane	CH_4	NC-6239	
Vinyl chloride	C_2H_3Cl	NC-6214	

5. Products of this type (examples)

○ Stationary products

... GD-A80, GD-A80D, SD-1 (Type NC), SD-D58･DC (Type NC)

○ Portable products

... GP-03, GX-2009, GX-2012, GX-8000

GX-2009

7-4. Semi-Conductor Method

Stationary sensor
Example: SG-8581

1. Brief description

This sensor uses a metal oxide semiconductor, which changes in resistance when it comes into contact with a detectable gas. The sensor detects this change in resistance as the gas concentration. It is a general-purpose sensor that detects all types of gases ranging from toxic gases to combustible gases.

Category	Detectable gas
Solid	Combustible / Toxic

2. Structure and principles

[Structure]

The sensor consists of a heater coil and a metal oxide semiconductor (SnO_2) formed on an alumina tube. The tube is equipped with two Au electrodes at its ends to measure the resistance of the semiconductor.

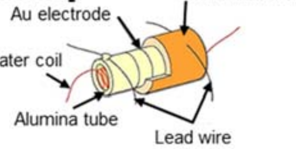
[Principles]

The heater coil heats the surface of the metal oxide semiconductor to 350 to 400℃. With atmospheric oxygen adsorbed on this surface in forms of O^- and O^{2-}, the semiconductor keeps a constant resistance. Then, methane gas or the like comes into contact with the surface and becomes chemisorbed by it, which is in turn oxidized by O^{2-} ions and separated. The reaction occurring on the surface of the sensor is represented as follows:

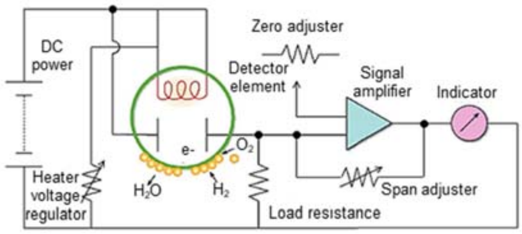
$$CH_4 + 4O^{2-} \rightarrow CO_2 + 2H_2O + 8e^-$$

In short, methane gas adsorbs on the surface of the sensor and takes the absorbed oxygen away; this increases free electrons inside the sensor, reducing the resistance. By measuring the change in resistance, the sensor determines the gas concentration.

[Conceptual rendering of the sensor elements]



[Drive circuit]

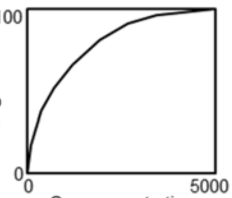


$$H_2 + O^{2-} \rightarrow H_2O + 2e^-$$

3. Features (of the sensor SG-8521 as an example)

○ Output characteristics

The sensor detects changes in the resistance of the semiconductor, meaning that it detects even low concentrations (ppm level) that cannot be detected by new ceramic-based sensors.
The sensor is highly sensitive with a high sensor output level for low concentrations.



○ Aging characteristics

The sensor maintains stability over the long term with a long life. Compared with the catalytic combustion-based sensor, this type sensor is highly resistant to toxicity and severe atmosphere.

○ Detection of toxic gases

Since, in principle, the resistance changes according to changes in the number of electrons and the electron mobility, the sensor detects a variety of gases, including toxic gases, which produce less combustion heat.

○ Gas selectivity

Adding an impurity to the semiconductor material changes the interference effect. This characteristic allows the sensor to selectively detect some gases.

4. Detectable gas, molecular formula, model, and detection range (examples)

Detectable gas	Molecular formula	Model #	Detection range
Solvents Combustible gases in general	-	SG-8511	0-5000 ppm
		SG-8521	
Hydrogen	H_2	SG-8541	0-200 ppm
Methane	CH_4	SG-8581	

5. Products of this type (examples)

○ Stationary products

... GD-A80V, GD-A80DV, GD-70D, SD-1GH, SD-D58･DC･GH

GD-70D

7-5. Hot Wire Type Semi-Conductor Method

Stationary sensor
Example: SH-8616

Portable sensor
Example: SH-8641

1. Brief description

This sensor uses a metal oxide semiconductor, which changes in resistance when it comes into contact with a detectable gas. The sensor detects this change in resistance as the gas concentration. It is a high-sensitivity gas sensor for low concentrations.

Category	Detectable gas
Solid	Combustible / Toxic

2. Structure and principles

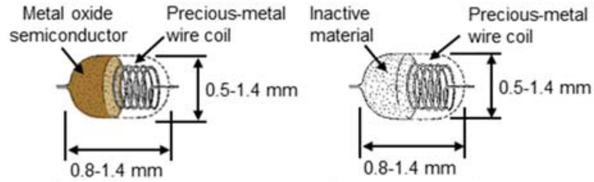
[Structure]

The sensor consists of a detector element, which consists of a coil of a precious-metal (e.g., platinum) wire and a metal oxide semiconductor sintered on the coil, and a compensation element with a material inactive against detectable gases sintered on it.

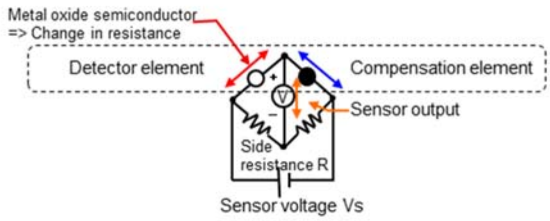
[Principles]

The resistance (R) of the detector element is the combined resistance of the resistance (RS) of the semiconductor and the resistance (RH) of the precious-metal wire coil. The detector element is heated 300℃ to 400℃ by the precious-metal wire coil and keeps a constant resistance. Then, methane gas or the like comes into contact with the detector element and separates the oxygen adsorbed on the surface of the metal oxide semiconductor. This increases the number of electrons that can freely move inside the semiconductor, reducing the resistance of the semiconductor. This results in the reduced resistance of the entire detector element. By allowing the bridge circuit to detect the change in resistance, the sensor determines the gas concentration.

[Conceptual rendering of the sensor elements]



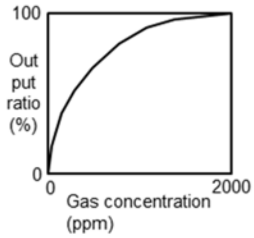
[Bridge circuit]



3. Features (of the sensor SH-8616 as an example)

○ Output characteristics

The sensor detects changes in the resistance of the semiconductor, meaning that it detects even low concentrations (ppm level) that cannot be detected by new ceramic-based sensors.
The sensor is highly sensitive with a high sensor output level for low concentrations.



○ Aging characteristics

The sensor maintains stability over the long term with a long life. Compared with the catalytic combustion-based sensor, this type sensor is highly resistant to toxicity and severe atmosphere.

○ Miniaturization and power saving

The precious-metal wire coil for the heater can be downsized to provide a smaller sensor that requires less power.

○ Gas selectivity

Adding an impurity to the metal oxide semiconductor changes the interference effect. This characteristic allows the sensor to selectively detect some gases.

4. Detectable gas, molecular formula, model, and detection range (examples)

Detectable gas	Molecular formula	Model #	Detection range
Hydrogen	H_2	SH-8612	0-2000 ppm
City gas	-	SH-8616	
Combustible gases in general	-	SH-8616	
		SH-8639	
		SH-8640	
		SH-8641	

5. Products of this type (examples)

○Stationary products

... GD-A80S, GD-A80DS

○Portable products

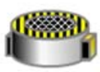
... SP-220, GX-2012GT

GX-2012GT

7-6. Thermal Conductivity Method

Stationary sensor
Example: TE-7559

Portable sensor
Example: TE-7561



Portable sensor
Example: TE-7515

1. Brief description

This sensor detects the difference in thermal conductivity to determine the gas concentration. It is a proven combustible gas sensor that effectively detects high-concentration gases.

Category	Detectable gas
Solid	Combustible

2. Structure and principles

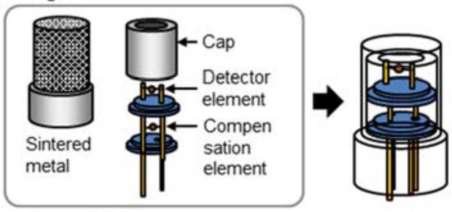
[Structure]

This sensor consists of a detector element and a compensation element. The detector and compensation elements are available in two types: one consists of a coil of a platinum wire and a mixture of glass—a substance inactive against combustible gas—and an alumina support sintered on the coil and the other consists of a coil and an inactive metal or the like coated over the coil. The detector element is designed to allow detectable gases to contact it. The compensation element is enclosed so as not to allow any detectable gas to contact it.

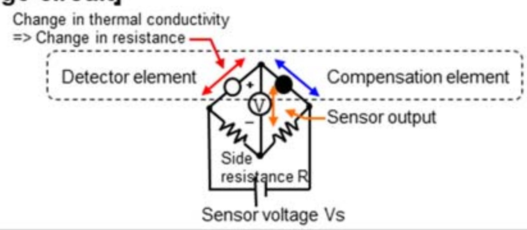
[Principles]

The platinum wire coil heats the detector element to 200℃ to 500℃. Then, a detectable gas comes into contact with the detector element and changes the heat dissipation condition because of the gas-specific thermal conductivity, increasing the temperature of the detector element. With this change in temperature, the platinum wire coil, a component of the element, changes in resistance. The resistance changes almost in proportion to the concentration of the gas. By allowing the bridge circuit to detect the change in resistance, the sensor determines the gas concentration.

[Structure]



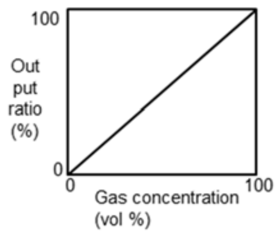
[Bridge circuit]



3. Features (of the sensor TE-7559 as an example)

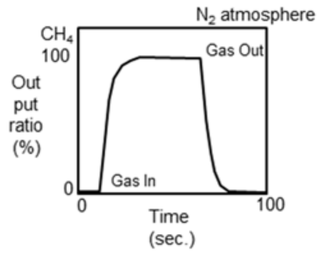
○ Output characteristics

Since the sensor detects changes in the resistance of the platinum wire coil, the output is almost proportional to the concentration until it reaches 100 volume percent. The sensor is suitable for detecting high-concentration gases.



○ Anoxic detection

Since the sensor detects changes in thermal conductivity, it can detect gases even under an anoxic atmosphere. However, it does not detect gases with a small difference in thermal conductivity with the reference gas.



○ Aging characteristics

The sensor physically detects changes in the thermal conductivity of gas, not involving a chemical reaction such as a combustion reaction. This means that it has noting to do with catalyst deterioration or poisoning, providing long-term stability.

○ Detection of incombustible gases

Since the sensor uses gas-specific thermal conductivity, it detects even incombustible gases with a large difference in thermal conductivity, such as high-concentration argon, nitrogen, and carbon dioxide.

4. Detectable gas, model, and detection range (examples)

Detectable gas	Model #	Detection range
Combustible gases in general	TE-7515	0-100 vol %
	TE-7559	
	TE-7560	
	TE-7561	

5. Products of this type (examples)

○ Stationary products

... GD-A80N, GD-A80DN

○ Portable products

... GX-2012, GX-8000

GX-8000

7-7. Potentiostatic Electrolysis Method

Stationary sensor
Example: ES-23 series

Portable sensor
Example: ES-18 series

1. Brief description

This sensor electrolyzes detectable gas using an electrode with the potential kept constant to allow a current to be generated, and then measures the current to determine the gas concentration. It is the gas sensor most suitable for detecting toxic gases. You can specify a particular potential to detect a particular gas.

Category	Detectable gas
Electrochemical	Toxic

2. Structure and principles

[Structure]

The sensor is structured with an electrode (action electrode)—a gas-permeable film with a catalyst (e.g., gold or platinum) placed over it—along with reference and counter electrodes; these electrodes are housed in a plastic container filled with an electrolytic solution.

[Principles]

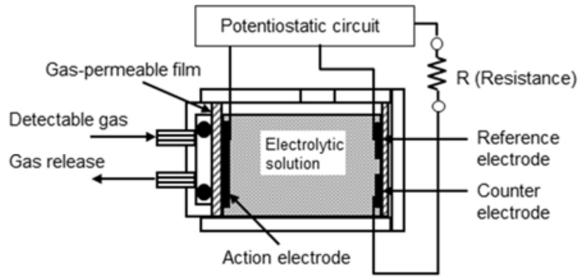
The sensor uses a potentiostatic circuit to keep the potential between the action and reference electrodes constant. The action electrode directly electrolyzes detectable gas. If the detectable gas is H_2S, the following reactions occur:

Action electrode: $H_2S + 4H_2O \rightarrow H_2SO_4 + 8H^+ + 8e^-$

Counter electrode: $2O_2 + 8H^+ + 8e^- \rightarrow 4H_2O$

The current generated by the reactions is proportional to the gas concentration. By measuring the current that flows between the action and counter electrodes, the sensor determines the gas concentration.

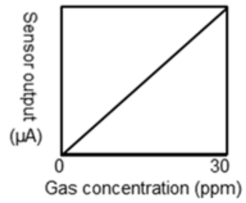
[Structure]



3. Features (of the sensor ES-237iF (H_2S sensor) as an example)

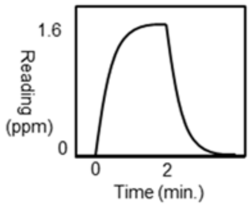
○Output characteristics

The gas concentration is proportional to the current value. The sensor outputs the current value without any change and the gas concentration is, therefore, proportional to the sensor output.



○Responsiveness

The response curve is as shown in the right figure.
The sensor makes gas react based on catalysis reaction to determine the current value.
Since H_2S does not alter the electrode catalyst, the sensor excels in accuracy and reproducibility.

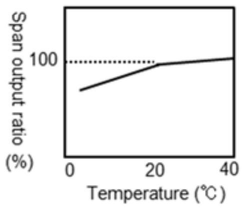


○Aging characteristics

For approximately two years, the sensor keeps its sensitivity at a level approximately 80% of the original level. Since humidity slightly affects the sensitivity, the reading may vary depending on the season.

○ Temperature characteristics

With almost stable readings at high temperatures, the sensor is likely to decrease its sensitivity with a decrease in temperature. Even at 0℃, the sensor maintains its sensitivity at a level not lower than 80%. By performing temperature corrections, it minimizes reading fluctuations.



4. Detectable gas, molecular formula, model, and detection range (examples)

Detectable gas	Molecular formula	Model #	Detection range
Carbon monoxide	CO	ES-23	0-75/150/300 ppm
		ES-2031	0-150 ppm
Hydrogen sulfide	H_2S	ES-237iF	0-1/3/30 ppm
		ES-1827iF	0-3 ppm
Phosphine	PH_3	ES-23DF	0-1 ppm

5. Products of this type (examples)

○Stationary products

... EC-600, GD-70D, SD-1EC

○Portable products

... CO-03, CO-FL1,
GX-2009, GX-2012,
GX-8000, HS-03, SC-01

CO-FL1

7-8. Membrane-Separated Electrode Method

Stationary sensor
Example: ES-K2 series

1. Brief description

Based on the principles of the potentiostatic electrolysis-based sensor, this sensor is structured with a gas-permeable film (separating membrane) and an action electrode completely separated from each other. It is a toxic gas sensor with an excellent selectivity.

Category	Detectable gas
Electrochemical	Toxic

2. Structure and principles

[Structure]

The sensor is structured with an action electrode—a metal electrode with a gas-permeable film placed over it—along with reference and counter electrodes; these electrodes are housed in a plastic container filled with an electrolytic solution. Between the action electrode and the film is a very thin layer of an electrolytic solution.

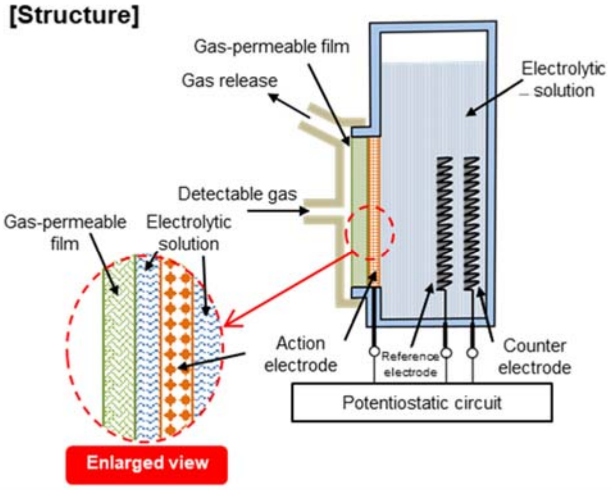
[Principles]

A detectable gas passes through the gas-permeable film and reacts with ions in the electrolytic solution, which produces halogen. If the detectable gas is Cl_2, the following reaction occurs:

$$Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$$

The I_2 generated by this reaction is reduced at the action electrode, causing a current to pass through the circuit. Since this current is proportional to the gas concentration, the sensor measures the current value to determine the gas concentration. Detectable gas reacts with the electrolytic solution before it reacts with the action electrode and therefore no interference occurs with gases that do not react with the electrolytic solution; this provides the sensor with an excellent selectivity.

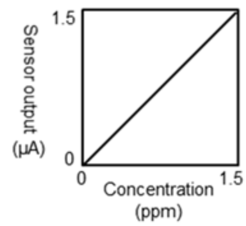
[Structure]



3. Features (of the sensor ES-K233 (Cl_2 sensor) as an example)

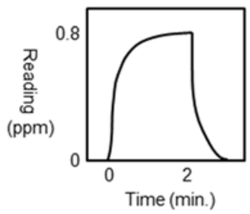
○ Output characteristics

The gas concentration is proportional to the current value. The sensor outputs the current value without any change and the gas concentration is, therefore, proportional to the sensor output.



○ Responsiveness

The sensor responds quickly. Since the electrodes or electrolytic solution is rarely corroded by Cl_2, the sensor excels in accuracy and reproducibility.

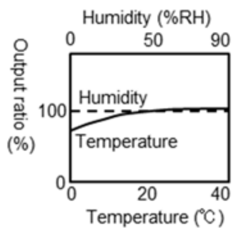


○ Aging characteristics

The sensor does not degrade in performance over time with almost no changes in output. If, however, the gas-permeable film is degraded in gas permeability due to a foreign matter adhering to it, this may lead to reduced output.

○ Temperature and humidity characteristics

High temperatures have almost no effect on the output while low temperatures are likely to reduce the output. Even at 0℃, the sensor maintains its sensitivity at a level not lower than 80%. By performing temperature corrections, it minimizes reading fluctuations. The output is not affected by humidity.



4. Detectable gas, molecular formula, model, and detection range (examples)

Detectable gas	Molecular formula	Model #	Detection range
Chlorine	Cl_2	ES-K233	0-1.5 ppm
Hydrogen fluoride	HF		0-9 ppm
Fluorine	F_2		0-3 ppm
Chlorine trifluoride	ClF_3	ESK-233C	0-1 ppm
Ozone	O_3	ES-K239C	

5. Products of this type (examples)

○ Stationary products

... GD-70D

○ Portable products

... SC-8000, TP-70D

SC-8000

7-9. Membrane Type Galvanic Cell Method

1. Brief description

This is a simple, traditional sensor based on the principles of cells. Requiring no external power supply, the sensor maintains stability over the long term.

Category	Detectable gas
Electrochemical	Oxygen

2. Structure and principles

[Structure]

The sensor is structured with a cathode (precious metal) and anode (lead) placed in an electrolytic solution and with a separation membrane closely attached to the outside of the cathode. With the cathode and anode connected via a fixed resister, it outputs a voltage value.

[Principles]

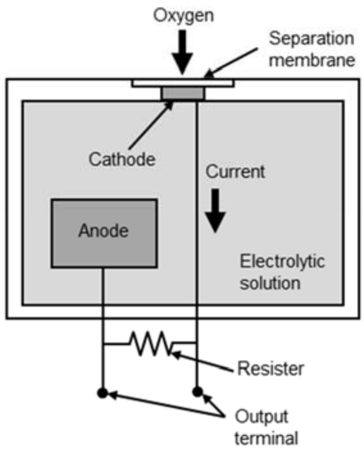
Oxygen passes through the separation membrane and becomes reduced at the cathode; at the same time, at the anode, lead dissolves into the electrolytic solution (becomes oxidized). At the electrodes, the following reactions occur:

Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Anode: $2Pb \rightarrow 2Pb^{2+} + 4e^-$

The current that flows because of the reduction reaction is converted into a voltage by the resister and then output from the output terminal. The sensor output is proportional to the oxygen concentration (partial pressure).

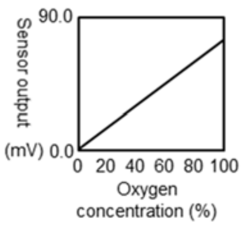
[Structure]



3. Features (of the sensor OS-B11 as an example)

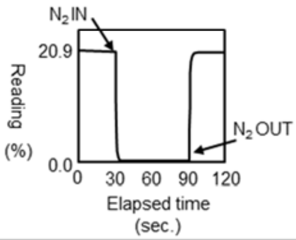
○ Output characteristics

The oxygen concentration is proportional to the current value. The sensor converts the current value into a voltage value before outputting it and the oxygen concentration is, therefore, proportional to the sensor output in the range between 0 and 100%.



○ Responsiveness

With a high response speed, this sensor excels in accuracy and reproducibility.

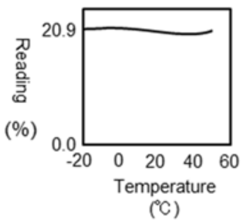


○ Aging characteristics

With a long life, the sensor can be actually used for two to three years.

○ Temperature and humidity characteristics

The sensor uses a thermistor built in it to perform temperature compensation and therefore readings almost do not depend on temperature.



4. Detectable gas, molecular formula, model, and detection range (examples)

Detectable gas	Molecular formula	Model #	Detection range
Oxygen	O_2	OS-B11	0-25%
		OS-BM1	
		OS-BM2	

5. Products of this type (examples)

○ Stationary products

... GD-70D, GD-F3A-A, GD-F4A-A, OX-600, SD-1OX

○ Portable products

... GX-2009, GX-2012, GX-8000 (TYPE O_2 L/N), OX-03, OX-07

OX-07

7-10. Non-Dispersive Infrared Method

Stationary sensor
Example: DE-3313-5

Portable sensor
Example: DE-3123-1

1. Brief description

Based on the fact that many gases absorb infrared rays, this sensor applies infrared light to the measurement cell to detect changes in infrared light caused by the absorption of a detectable gas. It seamlessly detects all infrared light in a particular wavelength range without separating (dispersing) infrared light on a wavelength basis.

Category	Detectable gas
Optical	Combustible Toxic

2. Structure and principles

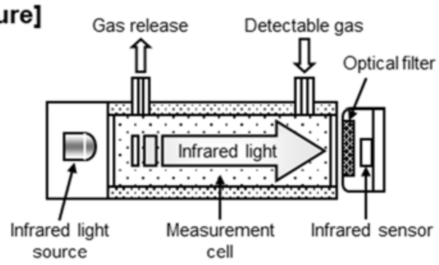
[Structure]

This sensor is structured with an infrared light source and an infrared sensor, between which a measurement cell and an optical filter are placed. The infrared light source emits infrared light, which passes through the measurement cell and optical filter to be detected by the infrared sensor. The optical filter selectively allows the infrared wavelengths that the appropriate detectable gas absorbs to pass through it.

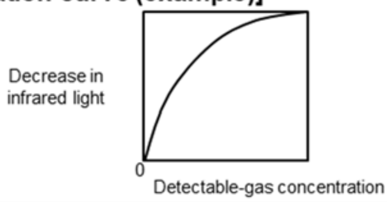
[Principles]

A detectable gas enters the measurement cell and absorbs infrared light. This reduces the amount of infrared light detected by the infrared sensor. Some detectable gases where the concentrations are known are entered to determine the relationship (calibration curve) between the decrease in infrared light amount and the concentration of each detectable gas. When a detectable gas where the concentration is unknown is entered, the sensor uses the calibration curve based on the measured decrease in infrared light amount to determine the gas concentration.

[Structure]



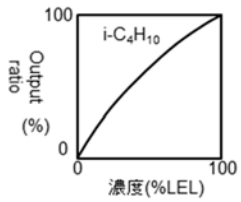
[Calibration curve (example)]



3. Features (of the sensor DE-3313-5 as an example)

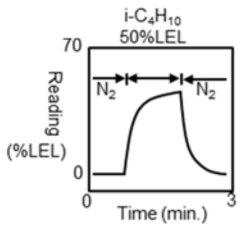
○ Output characteristics

The gas concentration and sensor output are not in proportional to each other but in a relationship as shown by the curve in the right figure. (i-C_4H_{10}: isobutane)



○ Responsiveness

When gas is supplied to the gas sensor at a constant flow rate, the sensor excellently reproduces responses.

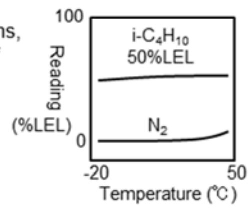


○ Aging characteristics

In an environment with small variations in temperature, the sensor remains stable without showing large deterioration in reading accuracy over time. Depending on the environment, the sensor may significantly deteriorate over time. If this is the case, you can minimize the deterioration by performing gas calibration every six months or so.

○ Temperature and humidity characteristics

By performing temperature corrections, you can minimize the dependency of readings on temperature within the specified temperature range.
When no condensation has formed inside the gas cell, the sensor is almost not affected by humidity.



4. Detectable gas, molecular formula, model, and detection range (examples)

Detectable gas	Molecular formula	Model #	Detection range
HFC-134a	$C_2H_2F_4$	DE-2113-35	0-5000 ppm
Methane tetrafluoride	CF_4	DE-2113-42	0-500 ppm
Sulfur hexafluoride	SF_6	DE-2113-43	
Combustible gases in general	-	DE-3313-5	0-100% LEL
		DE-3123-1	0-100% LEL 0-100 vol %
Carbon dioxide	CO_2	DE-3313-13	0-2000 ppm 0-5000 ppm 0-10000 ppm

5. Products of this type (examples)

○ Stationary products

... RI-257, SD-1RI

○ Portable products

... RX-8000, RX-8500, RX-8700, RI-557

RX-8000

7-11. Interferometer Method

Stationary sensor
Example: FI-23

Category	Detectable gas
Optical	Combustible

1. Brief description

This gas detector, one of the oldest gas sensors of ours, recognizes changes in the refractive index of gas. With a high accuracy, it maintains stability over the long term. In early times, it was used inside coal mines to measure the methane concentration and in recent years, it is widely used to measure solvent concentrations or heat quantities of fuel gases such as natural gas.

2. Structure and principles

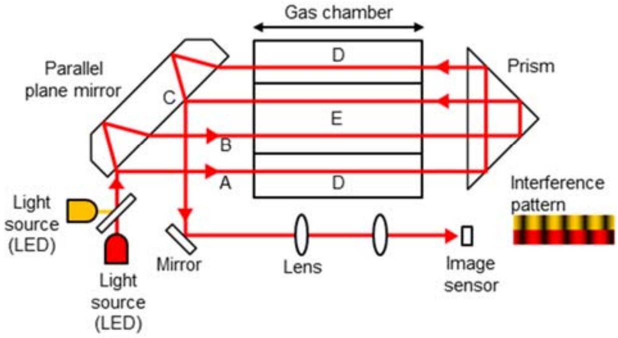
[Structure]

The light source emits light, which is split by a parallel plane mirror into two light rays (A and B) and reflected by a prism. Ray A makes one round trip within the gas chamber, D, where the detectable gas flows, and ray B makes one round trip within the gas chamber, E, where the reference gas flows. The two light rays, A and B, meet each other at point C of the parallel plane mirror, and form an interference pattern on the image sensor through the mirror and lens.

[Principles]

An interference pattern moves in proportion to the difference in the refractive index between the detectable gas and reference gas. The light wave interferometer-based sensor measures the distance the interference pattern has travelled to determine the refractive index of the detectable gas and convert it to a gas concentration or heat quantity.

[Conceptual rendering of the sensor elements]



3. Features

The travel distance of the interference pattern, Δθ, measured by this sensor is represented as the equation below:

$$\Delta\theta = \frac{2\pi L(n_{GAS} - n_{REF})}{\lambda} \times \frac{273.15}{T} \times \frac{P}{101.325}$$

L : Gas chamber length
n_{GAS}: Refractive index of the detectable gas
n_{REF}: Refractive index of the reference gas
λ : Light source wavelength
T : Temperature
P : Pressure

○ Output characteristics

Since the change in the refractive index is proportional to the change in gas concentration, the sensor provides a very high linearity.

○ Responsiveness

The sensor finishes measurement by completing the substitution within the gas chamber with a volume of 0.5 to 5 mL. Some models finish measurement in 5 to 10 seconds with a 90% response.

○ Aging characteristics

The most striking feature of this sensor is that it does not degrade in sensitivity. The sensitivity of the sensor depends only on the gas chamber length, L, and the light source wavelength, λ. Since both of these parameters are invariant, the sensor provides stable sensitivity over the long term. The optical element, even if soiled, does not affect the travel distance of the interference pattern; therefore, the sensor does not degrade in sensitivity so long as it can recognize the pattern.

○ Pressure and temperature characteristics

Although the refractive index of gas varies depending on the temperature, T, and pressure, P, the sensor measures the temperature and pressure to correct them and therefore is not affected by them.

4. Measurement type, detectable gas, molecular formula, and detection range (examples)

Measurement type	Detectable gas	Molecular formula	Detection range
Purity measurement	Hydrogen	H_2	0-100 vol %
	Sulfur hexafluoride	SF_6	
	Carbon dioxide	CO_2	99.50-100.00 vol %
Solvent concentration measurement	Toluene	C_7H_8	0-100% LEL
	Vinyl chloride	C_2H_3Cl	
	Methyl ethyl ketone	C_4H_8O	
Calorimetric measurement	Natural gas	-	25-55 MJ/m³
	Propane air	-	0-75 MJ/m³
	Butane air	-	0-70 MJ/m³

5. Products of this type (examples)

○ Stationary products

... FI-800, FI-815A

○ Portable products

... FI-8000

FI-800

7-12. Chemical Tape Method

Stationary tape
Example: FCL-002E

Category	Detectable gas
Optical	Toxic

1. Brief description

This sensor uses cellulose tape impregnated with a color former. It lets detectable gas enter this tape by allowing it to pass through it or diffuse into it. The sensor electrically measures reflected light based on the tape color caused by the reaction between the color former and detectable gas to quantitatively recognize a very low concentrations of toxic gas.

2. Structure and principles

[Structure]

The sensor has a gas chamber that lets in detectable gas. This chamber is a light-resistant container that is internally arranged and housed so that the light source and light-receiving section can recognize the tape color. The sensor consists of this gas chamber and other components such as a reel mechanism for rewinding tape after each measurement.

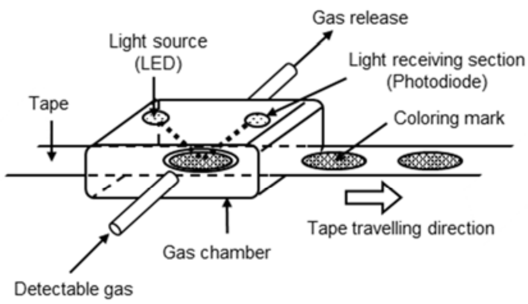
[Principles]

When a detectable gas comes in contact with the tape impregnated with a color former, a chemical reaction occurs, causing the tape to color. For example, if phosphine (PH_3) comes into contact with the tape, silver colloid is produced as shown in the formula below, causing a coloring mark to appear on the white tape.

$$PH_3 + AgClO_4 \rightarrow Ag + H_3PO_4 + 1/2\ Cl_2$$

The sensor applies light to the spot on the tape that has colored to determine the change in reflected light intensity before and after the entry of the detectable gas; thus it accurately quantifies the gas concentration.

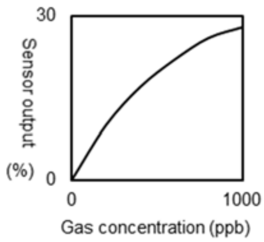
[Structure]



3. Features (of the sensors FP-300 and FCL-002E (PH_3) as examples)

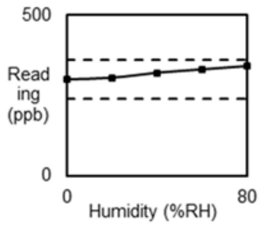
○ Output characteristics

When a detectable gas enters the detection section, the tape starts to color and the output gradually increases. Since the sensor determines changes in color, the output forms a curve.



○ Temperature and humidity characteristics

For PH_3, the tape-based sensors FP-300 or FCL-002E does not depend on temperature. Without greatly depending on humidity as well, this sensor provides accurate reading within the operating temperature and humidity ranges.



○ Aging characteristics

Continuous running tests on the sensor indicate that with no deterioration in gas sensitivity, it provides stable measurement.

○ Features of the tape-based sensor

- Very high sensitivity with excellent selectivity
- Use of cassette tape, which is easy to replace
- Tape feed on a per-measurement basis, which allows no hysteresis
- Coloring caused by detectable gas accumulates on the tape, which allows for detection of very low concentrations of gas

4. Detectable gas, molecular formula, model, and detection range (examples*)

Detectable gas	Molecular formula	Model #	Detection range
Arsine	AsH_3	FCL-001	0-15/150 ppb
Hydrogen selenide	H_2Se		0-200 ppb
Formaldehyde	HCHO	FCL-018	0-0.5/1/5 ppm
Phosphine	PH_3	FCL-002E	0-900 ppb
Diborane	B_2H_6		0-300 ppb
Silane	SiH_4		0-15 ppm
Disilane	Si_2H_6		0-10 ppm

* Tape FP-300 used as an example

5. Products of this type (examples)

○ Stationary products
… FP-300, FP-301

FP-300

7-13. Photo-Ionization Detector

1. Brief description

This gas sensor applies ultraviolet light to the detectable gas to ionize it. This causes an ion current to be generated. The sensor measures this current to determine the gas concentration. It detects a wide range of gases, irrespective of whether they are organic or inorganic. It is generally used to measure ppb to ppm levels of concentration of volatile organic compounds (VOCs).

Category	Detectable gas
Other methods	Toxic

2. Structure and principles

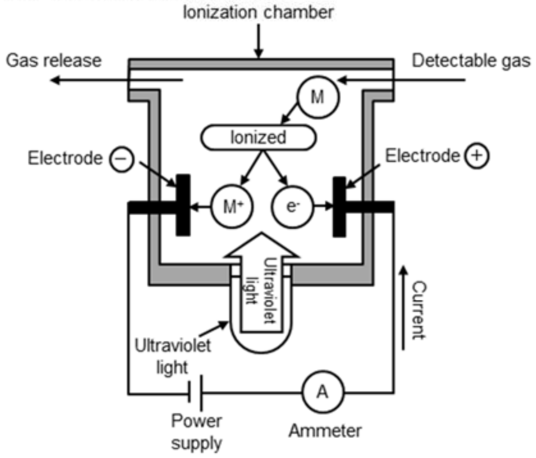
[Structure]

The sensor consists of an ionization chamber for letting in the detectable gas, a ultraviolet lamp for applying light, and positive and negative electrodes for detecting ion currents.

[Principles]

The detectable gas enters the ionization chamber and is exposed to ultraviolet light from the light source (ultraviolet lamp). This causes the gas to release electrons, generating cations. The generated cations and electrons are drawn by the positive and negative electrodes, which causes a current to be generated. Since this current is proportional to the gas concentration, the sensor measures the current value to determine the concentration of the detectable gas. Ionizing a detectable gas requires application of photon energy larger than the ionization energy specific to that gas. Photon energy is expressed in the unit electron volt (eV). This sensor uses a lamp having photon energies such as 10.6 eV and 11.7 eV. The larger the photon energy is, the larger amount of detectable gas the sensor can ionize

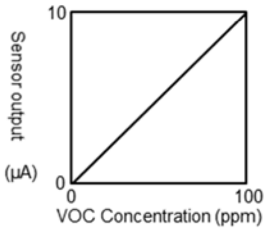
[Structure and principles]



3. Features

○ **Output characteristics**

For a gas with a low concentration of a few hundred ppm, the sensor output is almost proportional to the gas concentration, increasing linearly with the gas concentration.



○ **Ultraviolet lamp**

The photon energy (eV) of a ultraviolet lamp is determined by the combination of the gas contained in the lamp and the material of the lamp window.

Gas contained	Window material	Photon energy (eV)
Xenon	Sapphire	8.4
Krypton	Magnesium fluoride	10.6
Argon	Lithium fluoride	11.7

○ **Ionization energies of typical substances**

By applying photon energy larger than the gas-specific ionization energy to each gas, the sensor ionizes the gas to determine the gas concentration. The sensor typically uses a lamp of 10.6 eV or 11.7 eV.

4. Detectable gas and molecular formula (examples)

Detectable gas (for 10.6-eV lamp)	Molecular formula
Ethylene	C_2H_4
Isopropyl alcohol	C_3H_8O
Vinyl chloride	C_2H_3Cl
Methyl ethyl ketone	C_4H_8O
Perchloroethylene	C_2Cl_4
Trichloroethylene	C_2HCl_3
Benzene	C_6H_6
Styrene	C_8H_8

Detectable gas (for 11.7-eV lamp)	Molecular formula
Carbon tetrachloride	CCl_4
Dichloromethane	CH_2Cl_2
Acrylonitrile	C_3H_3N
Formaldehyde	$HCHO$
Acetylene	C_2H_2
Chloroform	$CHCl_3$
Carbonyl sulfide	COS
Chlorine	Cl_2

5. Products of this type (examples)

○ **Stationary products**

... TVOC

○ **Portable products**

... GX-6000, Tiger, Tiger Select

Tiger

7-14. Pyrolysis-Particle Detection Method

1. Brief description

This gas sensor heats the detectable gas to produce an oxide and measures particles of the oxide using a particle sensor. Maintaining stability over the long term, it exhibits an excellent interference resistance and responsiveness. The particle sensor is based on the same principles as for ionization-based smoke sensors that use radiation.

Category	Detectable gas
Other methods	Toxic

2. Structure and principles

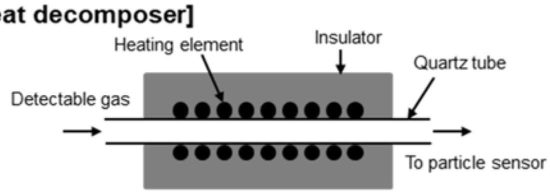
[Structure]

This sensor is typically a combination of a heat decomposer and particle sensor. In the center of the heat decomposer is a quartz tube wrapped with a heating element.
The particle sensor is an integration of a measurement chamber, which continuously generates ion currents using α rays, and a compensation chamber. Detectable gas enters only the measurement chamber, with the compensation chamber open to the atmosphere.

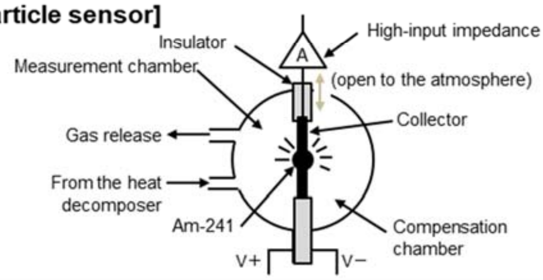
[Principles]

Many of organic metal gases such as TEOS, when heated, produce a particulate oxide. Detectable gas passes through the heat decomposer to become oxidized and enters the particle sensor.
In the measurement chamber of the particle sensor, an alpha-ray source (Americium-241 (Am-241)) is used to ionize air, causing a current to flow. Particles enter the measurement chamber and absorb ions; this decreases the ion current, resulting in reduced sensor output. Based on the reduction in output, the sensor determines the gas concentration. The compensation chamber compensates fluctuations in sensor output caused by temperature, humidity, and/or pressure.

[Heat decomposer]



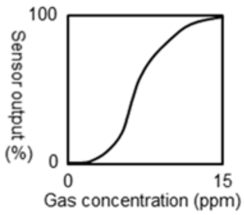
[Particle sensor]



3. Features (of the SSU-1925 (TEOS sensor) based on PLU + GD-70D as an example)

○ Output characteristics

The sensor output depends on the concentration of the particles produced through heat decomposition. The sensor uses a calibration curve so that the gas concentration will be linear with respect to the reading.

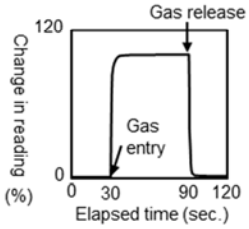


○ Aging characteristics

As the radiation source, the sensor uses Am-241, which has a very long half-life, approximately 400 years, and the sensor consequently hardly deteriorates in performance over time.

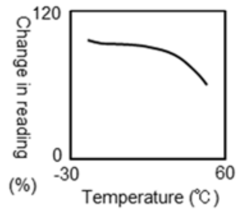
○ Responsiveness

Since the gas that enters the detection section is immediately oxidized in the heat decomposer, the sensor exhibits high response speed and excellent reproducibility.



○ Temperature characteristics

The sensor uses the compensation chamber to compensate temperature and thus exhibits excellent temperature characteristics.



4. Detectable gas, molecular formula, model, and detection range (examples)

Detectable gas	Molecular formula	Model #	Detection range
Tetraethoxysilane (TEOS)	$C_8H_{20}O_4Si$	SS-1923	0-15 ppm
		SSU-1925	

5. Products of this type (examples)

○Stationary products

... GD-70D + PLU-70

8
Selecting Gas Detectors

8-1. Gas detector selection

Gas detection can be based on several different principles. It’s essential to select the correct detection principle for the given target gas type, environment, and purpose.

1. What gas is to be measured?

① Combustible gas (to prevent explosion)
The following five detection methods are mainly used: catalytic combustion method, new ceramic catalytic method, semiconductor method, non-dispersive infrared method, and interferometer method. Catalytic combustion sensors are typically used in the %LEL range. New ceramic catalytic sensors are typically used for detection in the range of 10,000 to several thousand ppm. Semiconductor sensors are used for measurements in the range from several thousand to several tens of ppm. Non-dispersive infrared and interferometer combustible gas sensors typically measure gas at %LEL and vol% concentrations. Non-dispersive infrared and interferometer sensors are physical sensors that do not involve chemical reactions. They enable consistent gas detection even in the presence of substances (e.g., halides, sulfides, and silicone) that would poison catalytic combustion sensors and semiconductor sensors.

② Toxic gas (to prevent poisoning)
Toxic gases generally require high-sensitivity sensors capable of detecting concentrations in the range of several hundred ppm to several ppb. Detection methods include semiconductor method, potentiostatic electrolysis method, pyrolysis-particle detection method, chemical tape method, and PID method. The detection principle is typically selected based on the range that allows detection at alarm setpoints or threshold limit values. Semiconductor sensors detect gas at concentrations on the order of several tens of ppm to several thousand ppm. Potentiostatic electrolysis sensors detect gas at concentrations on the order of several tens of ppm to several tens of ppb. Pyrolysis-particle detection sensors rely on a sensing principle specifically tailored to detecting organic metal compounds within semiconductor material gases like TEOS

(tetraethoxysilane). Chemical tape gas detectors offer the advantages of gas detection at ultra-low concentrations on the order of several ppb. These detectors are minimally affected by interference gases, making them ideal for use in environments where other sensor types would suffer from interference.

③ Oxygen (to prevent anoxia and excess oxygen)
There are two principles used for detecting oxygen: membrane-type galvanic cell method and potentiostatic electrolysis method. Membrane-type galvanic cell sensors are the most widely used type, due to their long-term consistency and resistance to interference. However, these sensors are likely to become regulated by RoHS in the future due to their use of lead (Pb). (They are currently exempt.) A range of lead-free potentiostatic electrolysis sensors are now emerging in light of regulatory trends.

2. Fixed type or portable type?
Select portable gas detectors if the detectors will be used worn or carried by workers. Select fixed gas detectors to monitor for gas leaks at a fixed location.

3. Diffusion type or suction type?
Gas detectors are typically one of two different types, based on detection methods: the diffusion type and the suction type. Suction-type gas detectors feature a built-in pump that draws in gas from likely leakage points (for example, on a line or inside enclosures) to the sensor for detection. Diffusion-type gas sensors are passive gas detectors that detect floating gas that arrives at the sensor.

4. Multi-gas or single-gas detection?
In addition to portable gas detectors that detect a single gas component, there are gas detectors that can detect multiple gases simultaneously. The most basic combination of gases for multi-gas detectors is four components: combustible gas, toxic gas (H_2S or CO), and oxygen. Other gas sensors are available, depending on the particular product, to detect specific target gas types.

9

Fixed Gas Detectors

9-1. Explosion-proof Gas Detector Head

Smart Transmitter/
Gas Detectors

Model: SD-1 series

SD-1/SD-1RI (For combustible gases)

SD-1GH (For combustible/ toxic gases)

SD-1EC (For carbon monoxide/ hydrogen sulfide)

SD-1OX (For oxygen)

Model	SD-1		SD-1RI	SD-1GH
Type	TYPE GP	TYPE NC	–	–
Detection principle	Catalytic combustion	New ceramic	Non-dispersive infrared	Semiconductor
Gas to be detected	Combustible gas			Combustible gas or toxic gas
Detection range	0～100%LEL	Depending on gas to be detected	0～100%LEL	Depending on gas to be detected
Concentration value display	7 segments LED (4 digits) display			
Detection method	Diffusion type			
Alarm accuracy	Within ±25% to the alarm setpoint value			Within ±25% to the alarm setpoint value (combustible gas) Within ±30% to the alarm setpoint value(toxic gas)
Alarm delay time	Within 30 seconds after giving 1.6 times of gas of alarm setpoint value			Within 30 or 60 seconds after giving 1.6 times of gas of alarm setpoint value (depending on gas to be detected)
Power supply	24VDC±10%			
Power consumption	Max. 3.0 W		Max. 2.0 W	Max. 3.1 W
Operating temperature and humidity	−20～+53°C (no sudden change) below 95% RH (non-condensing)			
Explosion-proof construction	Flameproof enclosures (Ex d IIC T5 X)		Flameproof enclosures (Ex d IIC T6 X)	Flameproof enclosures (Ex d IIC T5 X)
External dimension/Weight	Approx. 148 (W) × 161 (H) × 88 (D) mm (projection portions excluded) Approx. 2.0 kg			

Model	SD-1EC	SD-1OX
Detection principle	Electrochemical	Galvanic cell
Gas to be detected	Hydrogen sulfide or carbon monoxide	Oxygen
Detection method	Diffusion type	Diffusion type
Detection range	Hydrogen sulfide: 0 ～ 30 ppm Carbon monoxide: 0 ～ 75 ppm * Changeable	0～25.0vol%
Alarm setpoin value	Depending on gas to be detected	18.0 vol% (1-step alarm)
Alarm delay	Within 30 seconds after giving 1.6 times of gas of alarm setpoint value	Within 5 seconds after giving gas of 10 ～ 11 vol% and letting it detected in hypoxia alarm
Power consumption	Max. 1.1 W	Max. 1.1 W
Operating temperature and humidity	−10～+40°C (no sudden change) 30～80% RH (non-condensing)	−10～+40°C (no sudden change) 95% RH (non-condensing)
Explosion-proof construction	Flameproof enclosures (Ex d IIC T6 X)	Flameproof enclosures (Ex d IIC T6 X)
Dimension/Weight	Approx. 148 (W) × 203 (H) × 88 (D) mm Approx. 2.2 kg	Approx. 148 (W) × 208 (H) × 88 (D) mm Approx. 2.5 kg

Flame-proof Furnace Safety Monitor

Model: SD-2500
Model: GD-A2400

SD-2500 (With concentration display) **GD-A2400** (Without concentration display)

Model	GD-A2400	SD-2500	SD-2600	SD-2700
Detection principle	Catalytic combustion			
Gas to be detected	Combustible gas			
Detection range	0～100%LEL*	0～100%LEL		
Concentration value display	With an instructor/alarm unit		7 segments LED digital (4 digits)	
Detection method	Direct insertion type			
Alarm delay time	Within 30 seconds after giving 1.6 times of gas of alarm setpoint value *1			
Power supply	Supplied by the indicator/ alarm unit	24VDC±10%		24VDC (20～26.4VDC)
Power consumption	—	Max3 W		
Operating temperature and humidity	In-furnace insertion part: 0～160°C (no sudden change) Main body case (ambient temperature): 0～50°C (no sudden change)		In-furnace insertion part: 0～200°C (no sudden change) Main body case: 0～50°C (ambient temperature) (no sudden change)	In-furnace insertion part: 0～250°C (no sudden change) Main body case: 0～50°C (ambient temperature) (no sudden change)
Explosion-proof construction	Flameproof enclosures (Ex d IIC T3)		Flameproof enclosures (Ex d IIC T2)	Non-explosion-proof
Dimension/Weight	Approx. 148 (W) × 167 (H) × 458 (D) mm (projection portions excluded) In-furnace insertion part: ϕ34×250/approx. 4.6 kg			

Combustible/
Toxic Gas Detector Heads

Model: GD-A80 series

GD-A80 (For combustible gases)

GD-A80V
GD-A80S* (For combustible or toxic gases)
* The GD-A80S nameplate is blue.

Model	GD-A80	GD-A80V	GD-A80S	GD-A80N	GD-A80-70
Detection principle	Catalytic combustion or New ceramic	Semiconductor	Hot-wire Semiconductor method	Thermal conductivity	Catalytic combustion or New ceramic
Gas to be detected	Combustible gas	Combustible gas, Toxic gas	Combustible gas, Toxic gas	Combustible gas, Inert gas	Combustible gas
Detection method	Diffusion type				
Transmission cable	Cable such as CVV/4-core	Cable such as CVVS/3-core	Cable such as CVVS/4-core	Cable such as CVVS/4-core	Cable such as CVV/4-core
Transmission distance	Depending on each indicator unit				
Power supply	Supplied by each indicator unit				
Operating temperature and humidity	-20～+53°C(no sudden change) below 95% RH (non-condensing)				-40～+70°C (no sudden change) Below 95% RH (non-condensing)
Explosion-proof construction	Flameproof enclosures (explosion-proof: Ex d IIC T4)				
Dimension/ Weight	Approx. 78 (W) × 154 (H) × 105 (D) mm (projection portions excluded) Approx. 1.0 kg				

Flame-proof Suction Type Gas Detector

Model: GD-D58
Model: SD-D58

GD-D58
(Without concentration indicator)

SD-D58
(With concentration indicator)

Model	GD-D58·AC	GD-D58·AC·GH	GD-D58·DC	GD-D58·DC·GH
Gas to be detected	Combustible gas	Combustible gas, Toxic gas	Combustible gas	Combustible gas, Toxic gas
Detection method	Pump drawing type			
Transmission cable	Cable such as CVV 4-core *1- or 6-core *2	Shielded cable such as CVVS/3-core *1-or 5-core *2	Cable such as CVV 4-core *1- or 6-core *2	Shielded cable such as CVVS 3-core *1- or 5-core *2
Transmission distance	Depending on each indicator unit			
Power supply	100～110VAC±10%·50/60Hz		24VDC (21.6～26.4VDC)	
Operating temperature and humidity	-20～+50°C (no sudden change) Below 95% RH (non-condensing)		-20～+53°C (no sudden change) Below 95% RH (non-condensing)	
Explosion-proof construction	Flameproof enclosures (explosion-proof: Exd II B+H_2T4)			
Dimension/ Weight	Approx. 197 (W) × 286 (H) × 140 (D) mm (projection portions excluded) Approx. 5.8 kg			

Model	SD-D58·AC	SD-D58·AC·GH	SD-D58·DC	SD-D58·DC·GH
Gas to be detected	Combustible gas	Combustible gas, Toxic gas	Combustible gas	Combustible gas, Toxic gas
Concentration value display	7 segments LED degital (4 digits)			
Detection method	Pump drawing type			
Alarm accuracy	Combustible gas: within ±25% of the alarm setpoint value, Toxic gas: within ±30% of the alarm setpoint value.			
Alarm delay time	Within 30 or 60 seconds after giving 1.6 times of gas of alarm setpoint value (depending on gas to be detected. Neither piping delay nor communication delay is included.)			
Transmission cable	Cable such as CVVS 2- or 4-core		Cable such as CVVS 3- or 5-core	
Transmission distance	Depending on each indicator unit			
Power supply	100～110VAC±10%·50/60Hz		24VDC (21.6～26.4VDC)	
Operating temperature and humidity	-20～+50°C (no sudden change), below 95% RH (non-condensing)		-20～+53°C (no sudden change), below 95% RH (non-condensing)	
Explosion-proof construction	Flameproof enclosures (explosion-proof: Exd II B+H_2T4)			
External dimension/ Weight	Approx. 197 (W) × 286 (H) × 140 (D) mm (projection portions excluded) Approx. 5.8 kg			

Optical Interferometric Gas Analyzer

Model: FI-800

Model	FI-800
Measuring principle	Optical interferometric
Measuring object gas	Combustible gas/Solvent vapor/Inert gas
External output	4～20 mA load resistance 300 Ω or less
Concentration value display	LCD digital
Detection method	Drawing type (introduction with external unit)
Alarm display	LED lamp blinking (AL1, AL2)
Alarm contact	Dry contact (AL1, AL2)
Fault alarm	Decrease of flow rate, light intensity and contrast
Power supply	100～220 VAC ±10% 50/60 Hz power consumption: Max. 8 VA
Operating temperature and humidity	-10～+40°C (no sudden change) below 80% RH (non-condensing)
Explosion-proof construction	Flameproof enclosures (Ex d IIB+H_2 T4)
Dimension/Weight	Approx. 220 (W) × 332 (H) × 122 (D) mm (projection portions excluded) Approx. 16 kg

Intrinsically safe explosion-proof enclosure
Oxygen/Toxic Gas Detector Heads

Model: GD-88 series

[Diffusion type]
GD-K88Ai (for toxic gases)
GD-F88Ai (for oxygen)

[Suction type]
GD-K88Di (for toxic gases)
GD-F88Di (for oxygen)

Model	GD-K88Ai	GD-K88Di
Gas to be detected	Toxic gas	
Detection method	Diffusion type	Drawing type (a pump is separately required)
Detection principle	Electrochemical	
Detection range	Depending on gas to be detected	
Concentration value display	7 segments LCD (4 digits)	
Transmission system	4～20 mADC loop power (load resistance 300 Ωor less)	
Power supply	24VDC±10%	
Transmission cable	Shielded cable admitted by explosion-proof construction such as CVVS (2-core), etc.	
Operating temperature and humidity	0～40°C (no sudden change) 30～70% RH (non-condensing)	
Explosion-proof construction	Intrinsic safety (explosion class: Exia II CT4X) ＊When safety holder (barrier) is used	
Safety holder (recommended)	Zener barrier (MTL728ac) Insulation barrier (MTL5541)	
Dimension	Approx. 100(W)×241(H)×48(D) mm (projection portions excluded)	Approx. 220(W)×265(H)×90(D) mm (projection portions excluded)
Weight	approx. 1.0 kg	approx. 2.5 kg

Model	GD-F88Ai	GD-F88Di
Gas to be detected	Oxygen	
Detection method	Diffusion type	Drawing type (a pump is separately required)
Detection principle	Galvanic cell	
Detection range	0～25.0vol%	
Concentration value display	7 segments LCD (4 digits)	
Transmission system	4～20 mADC loop power (load resistance 300 Ωor less)	
Power supply	24VDC±10%	
Transmission cable	Shielded cable admitted by explosion-proof construction such as CVVS (2-core)	
Operating temperature and humidity	-10～+40°C (no sudden change) below 95% RH (non-condensing)	
Explosion-proof construction	Intrinsic safety (Exia II CT4X) ＊When safety holder (barrier) is used	
Safety holder (recommended)	Zener barrier (MTL728ac) Insulation barrier (MTL5541)	
Dimension	Approx. 100(W)×241(H)×48(D) mm (projection portions excluded)	Approx. 220(W)×265 (H)×90(D) mm (projection portions excluded)
Weight	Approx. 1.0 kg	Approx. 2.5 kg

Oxygen Gas Detector Head

Model: GD-F3A-A
GD-F3A-SC-A
GD-F4A-A
GD-F4A-SC-A

Model	GD-F3A-A	GD-F3A-SC-A	GD-F4A-A	GD-F4A-SC-A
Detection principle	Galvanic cell			
Detection method	Diffusion type		Drawing type (a pump is separately required)	
Gas to be detected	Oxygen			
Detection range	0～25.0vol%			
Explosion-proof construction	Intrinsic safety by the combination with the Zener barrier (Ex ia IIC T4 X)			
Cable to be used	Equivalent to CVVS 2-core			
Power supply	—		Depending on the specification of the drawing pump separately used	
Detector head signal	Sensory output Direct signal	Current signal (4～20mADC)	Sensory output Direct signal	Current signal (4～20mADC)

9-2. Non-Explosion-proof Gas Detector Head

Smart Transmitter/Gas Detector

Model: GD-70D

Model	GD-70D	GD-70D-NT	GD-70D-EA
Transmission system	4～20 mADC	DC Power Line Communication	Ethernet /4～20 mADC
Detection principle	Electrochemical, New ceramic, Semiconductor, Galvanic cell or Pyrolysis-particle		
Gas to be detected	Depending on the Detection principle		
Concentration value display	Character LCD display (white backlight) Digital & bar meter display: gas concentration, Alarm setpoint value		
Detection method	Pump drawing type		
Power supply	24VDC±10%	24VDC±10% (dedicated line by blocking filter)	24 VDC ±10% or PoE connection
Power consumption	24 VDC supply: max. 6.5 W PoE supply: max. 8.5 W		
Operating temperature and humidity	0～40°C (no sudden change) 30～70% RH (by the installed sensor unit, and non-condensing)		
Dimension/Weight	Approx. 70(W)×120(H)×145(D) mm (projection portions excluded) Approx. 0.9 kg		

Highly Sensitive Toxic Gas Monitor
(Gas to be detected: Phosphine)

Model: FP-300

Highly Sensitive Toxic Gas Monitor
(Gas to be detected: Formaldehyde)

Model: FP-330

Model	FP-300
Detection principle	Chemical tape method
Gas to be detected	Toxic gas: Semiconductor special material gas
Alarm accuracy	Within ±20% of alarm setpoint value (under the same condition)
Detection tape and time used	1 month (without alarm) Remaining tape quantity indication provided With a prior notice and warning of tape end
Alarm setpoint value (2 steps)	Depending on gas to be detected
External output signal	4～20 mADC (load resistance 300 Ω or less)
Power supply	Desktop: 100～240 VAC ±10% 50/60 Hz Panel mount type: 24 VDC ±10%
Power consumption	Desktop: approx. 16 VA/max. 30 VA (tape feeding) Panel mount type: Approx. 10 W/max. 20 W (tape feeding)
Dimensions	Desktop: Approx. 164(W)×198(H)×263(D) mm Panel mount type: Approx. 164(W)×164 (H)×263(D) mm
Weight	Desktop: Approx. 6.5 kg Panel mount type: Approx. 5.5 kg

Model	FP-330		
Detection principle	Chemical tape method		
Gas to be detected	Formaldehyde		
Detection range	0.000～0.500ppm	0.00～1.00ppm	0.0～5.0ppm
Detection cycle	30min	10min	3min
Detection tape and time used	1 month (without alarm) Remaining tape quantity indication provided With a prior notice and warning of tape end		
External output signal	4～20 mADC (load resistance 300 Ω or less)		
Power supply	100 VAC ±10% 50/60 Hz		
Power consumption	48 VA or less		
Dimensions	Approx. 164(W)×198(H)×263(D) mm		
Weight	Approx. 6.5 kg		

Indoor Oxygen Monitor

Model: OX-600

Indoor Carbon Monoxide Monitor

Model: EC-600

Model	OX-600	EC-600
Gas to be detected	Oxygen	Carbon monoxide
Detection method	Diffusion type or remote detection method	
Detection principle	Galvanic cell	Electrochemical
Detection range	0～25.0 vol% (1 digit: 0.1 vol%)	0～150 ppm (1 digit: 1 ppm)
Concentration value display	LCD digital display (3 digit 7 segment/3 color backlight: green, orange and red) *1	
Length of remote cable	3 m, 5 m, 10 m, 20 m	
Kind of alarm	Gas alarm: 2 step alarm (fault alarm pattern/cancel with reset switch) Fault alarm: System abnormal, sensor abnormal (non latching (auto-reset))	
Alarm setpoint value	1st: 19.0vol% 2nd: 18.0vol%	1st: 50ppm 2nd: 100ppm
Alarm history record	10 records from the latest (least concentration and generated date)	
External output	4～20 mADC (non-insulated, load resistance 300 Ω or less) or 0～1 VDC (non-insulated) *2	
Alarm contact	Dry contact 1a or 1b each, Contact capacity 125 VAC 1 A or30 VDC 1 A (resistance load)	
Operating temperature and humidity	-10～+40°C (no sudden change), below 90% RH (non-condensing)	0～+40°C (no sudden change), below 90% RH (non-condensing)
Power supply	100 VAC ±10% 50/60 Hz or 24 VDC ±10% or 2 size AA alkaline battery	
Power consumption	AC specification: Max. 5 VA DC specification: Max. 3 W	
Continuous operating time (dry battery specification)	approx. 1 year (25°C, without Alarm, backlight off)	
Dimensions	Main body: Approx. 80(W) × 120(H) × 35.5(D) mm Remote sensor: Approx. 40(W) × 96 (H) × 35.5(D) mm (projection portions excluded)	
Weight	AC specification: Approx. 200 g, DC specification: Approx. 180 g Dry battery specification: Approx. 230 g Remote sensor: Approx. 55 g (cable excluded)	

9-3. Indicator/alarm unit

Multi-channel Gas Monitoring Systems

Model: RM-5000 series

Multi-case

Single case

Model	GP-5001 NC-5001(W)	NP-5001	SP-5001	GH-5001	EC-5002 EC-5002i	OX-5001	OX-5002 OX-5002i	RM-5002 RM-5002i RM-5003	RM-5003T	Buzzer unit TAN-5000(L)
Detection principle of suited detector head	Catalytic combustion New ceramic	Thermal conductivity	Hot-wire semi-conductor	Semi-conductor	Electrochemical Pyrolysis- particle	Galvanic cell		General measure-ment signal	Semi-conductor	–
Gas for indication	Combustible gas	Combustible gas, Inert gas	Combustible gas, Toxic gas		Toxic gas	Oxygen		Combustible gas, Toxic gas, Oxygen, etc.	Carbon monoxide	–
Detector head signal	Direct signal of sensor output				Current signal (4～20mADC)	Sensory output Direct signal	Current signal (4～20mADC)		Current signal (4～30mADC)	–
Transmission distance to the detector head	Within 2.0 km with CVV 2.0 mm^2 cable	Within 2.0 km with CVVS 2.0 mm^2 cable	Within 2.0 km with CVV 2.0 mm^2 cable	Within 2.0 km with CVVS 2.0 mm^2 cable		Within 600 m with CVVS 2.0 mm^2 cable	Within 2.0 km with CVVS 2.0 mm^2 cable	Depending on detector head to be connected.		–
Concentration value display	Character LCD (digital and bar meter 〈3 colors: green, orange, red〉)									–
Operating temperature and humidity	-10～+40°C (no sudden change), below 10～90% RH (non-condensing)									
Alarm contact	Dry contact 1a or 1b each (2 step independent) De-energized in a normal state (energized at an alarm state) or energized in a normal state (de-energized at an alarm state)									
Power supply	24VDC (21.6～26.4VDC)									
Power consumption	Max. 7 W (detector head included)				Max. 3 W (detector head included)	Max. 2 W (detector head included)	Max. 3 W (detector head included)	Max. 2 W (detector head excluded)	Max. 5 W (detector head excluded)	Max. 2 W
Dimensions	Approx. 29.6 (W) × 120 (H) × 92 (D) mm (projection portions excluded)									
Weight	Approx. 100 g (only for unit)									approx. 80 g

Combustible Gas Detector

Model: GP-147

Model	GP-147
Detection principle of suited detector head	Catalytic combustion type, New ceramic type
Gas for indication	Combustible gas
Detector head signal	0～6～12 VDC (10 mA or less) [standard] or 4～20 mADC (load resistance 300 Ω or less) [option]
Transmission distance to the detector head	Within 300 m with CVV 0.75 mm^2 cable Within 500 m with CVV 1.25 mm^2 cable Within 500 m with CVV 2.0 mm^2 cable
Concentration value display	Character LCD (bar meter display of 2 colors (red and green))
Operating temperature and humidity	-10～+50°C (no sudden change), 10～90% RH (non-condensing)
Alarm contact	Dry 1a contact [standard] or 1b contact [option] (contact capacity: 250 VAC 1 A)
Power supply	100～120 VAC or 200～240 VAC Input automatic switching between 50/60 Hz
UPS (uninterrupted power supply)	Lead battery 12 V 2.3 Ah × 2 pieces * With backup point selecting function
Dimension/Weight	2 point type: Approx. 305(W)×290(H)×73(D) mm/approx.3.9kg 4 point type: Approx. 395(W)×290(H)×73(D) mm/approx.5.0kg 6 point type: Approx. 485(W)×290(H)×73(D) mm/approx.5.8kg 8 point type: Approx. 575(W)×290(H)×73(D) mm/approx.6.6kg 10 point type: Approx. 665(W)×290(H)×73(D) mm/approx.7.4kg 12 point type: Approx. 755(W)×290(H)×73(D) mm/approx.8.2kg

Single-Channel Gas Monitors

Model: RM-6000 series

Model	GP-6001 NC-6001 (W)	SP-6001	GH-6001	EC-6002	OX-6001	OX-6002	RM-6002	RM-6003	RM-6003T
Detection principle of suited detector head	Catalytic combustion New ceramic	Hot-wire Semiconductor	Semiconductor	Electro-chemical Pyrolysis-particle	Galvanic cell		General measurement signal		Carbon monoxide (CO)
Gas for indication	Combustible gas	Combustible gas, Toxic gas		Toxic gas	Oxygen		Combustible gas, Toxic gas Oxygen, etc. (general measurement signal)		Semiconductor detector head (GD-A44V)
Detector head signal	Direct signal of sensor output			Current signal (4～20mADC)	Direct signal of sensor output		Current signal (4～20mADC)		Current signal (4～30mADC)
Alarm display	1st: ALM1 red lamp blinking or lighting (after reset) and buzzer sounding 2nd: ALM2 red lamp blinking or lighting (after reset) and buzzer sounding								
Alarm contact	Dry contact 1a or 1b each (2 step independent) De-energized in a normal state (energized at an alarm state) or energized in a normal state (de-energized at an alarm state)								
Power supply	AC specification: 100～240 VAC ±10% 50/60 Hz, DC specification: 24 VDC ±10% (21.6～26.4 VDC) [option]								
Power consumption (pump excluded) *	Max.15VA Max.8.5W		Max.11.5VA Max.6W	Max.7.5VA Max.3.5W	Max.6.5VA Max.3W	Max.7.5VA Max.3.5W	Max.7.5VA Max.3.5W		Max.10.5VA Max.7.5W
External output	4～20 mADC (non-insulated, load resistance 300 Ω or less)/digital transmission: RS-485 [option]								
Dimension/Weight	Approx. 110 (W) × 190 (H) × 54 (D) mm (projection portions excluded) wall type: 580 g, embedding type: 650 g								

10

Portable Gas Detectors

10-1. Multi Gas Detector (Multi-sensor)

Four Gas Personal Monitor

Model: GX-3R

Five Gas Personal Monitor

Model: GX-3R Pro

Model	GX-3R			
Detection method	Diffusion type			
Gas to be detected	HC / CH4	O2	H2S	CO
Detection principle	New ceramic	Electrochemical		
Detection range	0～100% LEL	0～40.0vol%	0～200.0ppm	0～2000ppm
1digit	1% LEL	0.1vol%	0.1ppm	1ppm
Alarm setpoint value	1st 10%LEL 2nd 25%LEL 3rd 50%LEL OVER 100%LEL	1st 19.5vol% 2nd 18.0vol% 3rd 23.5vol% OVER 40.0vol%	1st 5.0ppm 2nd 30.0ppm 3rd 100.0ppm TWA 1.0ppm STEL 5.0ppm OVER 200.0ppm	1st 25ppm 2nd 50ppm 3rd 1200ppm TWA 25ppm STEL 200ppm OVER 2000ppm
Operating temperature and humidity	-40～ +60°C at a constant condition (intermittent) 0～95%RH non-condensing (intermittent)			
Power supply	Lithium ion battery			
Continuous operating time *	Approx. 40 hours (with long-battery, at 25°C, no alarm, no lighting) Approx. 25 hours (at 25°C, no alarm, no lighting)			
Dimension / Weight	Approx. 58(W)×65(H)×26(D)mm (projection portions excluded) / Approx. 100g			
Explosion proof class	Ex ia IIC T4 Ga			
Protection level	IP66/68 equivalent			

*Depends on sensor type.

TYPE List

TYPE		Gas to be Detected
4 gas	TYPE A	LEL / O2 / H2S / CO
3 gas	TYPE B	LEL / O2 / H2S
	TYPE C	LEL / O2 / CO
	TYPE CH *	LEL / O2 / CO
2 gas	TYPE D	LEL / O2
	TYPE E	O2 / H2S
	TYPE F	O2 / CO
	TYPE FH *	O2 / CO
	TYPE I	LEL / CO
	TYPE IH *	LEL / CO
1 gas	TYPE K	H2S

* Reduced H2 interference CO sensor

Model	GX-3R Pro
Detection method	Diffusion type
Gas to be detected	Refer to the following "List of Gas to be Detected".
Detection principle	
Detection range	
1digit	
Language	Japanese/English/French/Spanish/Portuguese/German/Italian/ Russian/Korean/Chinese (SC & TC)
Operating temperature and humidity	-40～ +60°C at a constant condition (intermittent) 0～95%RH non-condensing (intermittent)
Power supply	Lithium ion battery unit BUL-3R or Dry battery unit BUD-3R (2 AAA alkaline dry batteries)
Continuous operating time *	Approx. 40 hours (with long-battery, at 25°C, no alarm, no lighting) Approx. 25 hours (at 25°C, no alarm, no lighting)
Dimension	BUL-3R in use : Approx. 73(W)×65(H)×26(D)mm (projection portions excluded) BUD-3R in use : Approx. 73(W)×65(H)×34(D)mm (projection portions excluded)
Weight	BUL-3R in use : Approx. 120g BUD-3R in use : Approx. 140g
Explosion proof class	Ex ia IIC T4 Ga
Protection level	IP66/68 equivalent
Bluetooth	Bluetooth 4.2 (Bluetooth Low Energy)

*Depends on sensor type.

List of Gas to be Detected

Gas to be detected	Detection principle	Detection range	1 digit
Combustible gas (HC/CH4)	New ceramic	0～100%LEL	1%LEL
Oxygen (O2)	Electrochemical	0～40.0vol%	0.1vol%
Hydrogen sulfide (H2S)		0～200.0ppm	0.1ppm
Carbon monoxide (CO)		0～2000ppm	1ppm
Sulfur dioxide (SO2)		0～100.00ppm	0.05ppm
Carbon dioxide (CO2)	Non-dispersive infrared	0～10.00vol% 0～10000ppm	0.01vol% 20ppm

Portable Multi Gas Detector

Model: GX-6000

Model	GX-6000
Alarm type	Gas alarm: 2-step alarm, TWA, STEL, OVER alarm Fault alarm: system error, sensor error, battery voltage drop, calibration defect, decreased flow Other: Panic alarm, Man-down alarm*1
Alarm display	Gas alarming: blinking lamp, buzzer continuous modulated sound, gas concentration display and blinking alarm details, vibration Fault alarming: blinking lamp, buzzer on and off, displayed fault details Other: blinking lamp, buzzer continuous modulated sound
Warning buzzer sound pressure	95 dB(A) or higher (30 cm) (with the protection cover)
Detection method	Pump drawing type
Drawing flow rate	0.45 L/min or more (open flow rate)
Display	LCD digital (full dot display)
Display language	English / Japanese / French / Spanish / Portuguese / German / Italian / Russian / Korean
Power supply	Lithium-ion battery unit or dry battery unit <Three size AA alkaline batteries*2>
Continuous operating time	Lithium-ion battery unit: approx. 14 hours (25°C, fully charged, without alarm nor illumination) Dry battery unit: approx. 8 hours (25°C, new dry battery, without alarm nor illumination)
Operating temperature	-20 ～ +50℃
Operating relative humidity	Below 95% RH (non-condensing)
Dimension	Approx. 70(W) × 201(H) × 54(D) mm (projection portions excluded)
Weight	Approx. 500 g (lithium-ion battery unit is used) / Approx. 450 g (dry battery unit is used)
Protection level	IP67 equivalent
Explosion proof class	Ⅱ 1G Ex ia ⅡC T4 Ga
Certifications and Approvals	ATEX Explosion-proof authorized, IECEx authorized, CE Marking approved, TIIS Explosion-proof authorized
Function	LCD backlight, data logger, peak value display, log data display, several languages displayed, screen inversion, LED light

*1 Normally the man-down alarm function is set to OFF. To use this function, please contact RIKEN KEIKI.
*2 To meet requirements of explosion-proof capabilities, use dry batteries described in Certificates of Conformity of the Explosion-proof Construction of Electric Equipment and Devices.

Personal Four Gas Monitors

Model: GX-2012 series

Model	GX-2012/GX-2012GT								
Detection method	Pump drawing type								
Gas to be detected	HC/CH4			O_2		H_2S		CO	
Detection principle	Hot-wire semiconductor	New ceramic/ Thermal conductivity		Galvanic cell		Electrochemical			
Detection range	0~500ppm(HC) <510~2000 ppm>(HC) 0~2000 ppm(CH4) <2010~5000 ppm>(CH4)	0～100% LEL/ ～100vol%*		0～25.0vol% (～40.0vol%)		0～30.0ppm		0～150ppm (～500ppm)	
Alarm setpoint value		1st 2nd OVER	10%LEL 50%LEL 100%LEL	L Alarm LL Alarm OVER	19.5vol% 23.5vol% 40.0vol%	1st 2nd TWA STEL OVER	5.0ppm 30.0ppm 10.0ppm 15.0ppm 30.0ppm	1st 2nd TWA STEL OVER	25ppm 50ppm 25ppm 200ppm 500ppm
Operating temperature and humidity	-20 ～ +50°C and below 95% RH (no condensing)								
Power supply	Dedicated dry battery unit <AA alkaline dry batteries x 3> [BUD-2012] (Dedicated lithium ion battery unit [BUL-2012(G1)] can also be used)								
Continuous operating time	BUD-2012: About 15 hours (25°C, no alarm, and no lighting) BUL-2012(G1): About 10 hours (25°C, no alarm, no lighting, and battery fully charged)								
Dimension	Approx. 71 (W) x 173 (H) x 43 (D) mm (projection portions excluded)								
Weight	Approx. 360 g (When BUD-2012 is used)/Approx. 360 g (When BUL-2012(G1) are used)								
Explosion-proof class	Ⅱ1G Ex ia ⅡC T4 Ga								
Protection level	IP67 equivalent								

Portable
Multi Gas Monitor

Model:
GX-8000

TYPE		Gas to be detected
5 gas	TYPE A	HC or CH4(%LEL, vol%) / O2 / H2S / CO
4 gas	TYPE B	HC or CH4(%LEL, vol%) / O2 / H2S / CO
3 gas	TYPE C	HC or CH4 or C2H2(%LEL) / O2 / H2S
	TYPE D	HC or CH4(%LEL) / O2 / CO
	TYPE E	HC or CH4 or H2(%LEL, vol%) / O2
2 gas	TYPE F	HC or CH4 or C2H2(%LEL) / O2

Model	GX-8000							
Detection method	Pump drawing type							
Gas to be detected	$HC/CH_4/H_2/C_2H_2$		O_2		H_2S		CO	
Detection principle	New ceramic/ Thermal conductivity		Galvanic cell		Electrochemical			
Detection range	0～100% LEL/ ～100vol%*		0～40.0vol%		0～100.0ppm		0～500ppm	
1 digit	1% LEL/1vol%		0.1vol%		0.5ppm		1ppm	
Alarm setpoint value	1st 2nd OVER	10% LEL 50% LEL 100% LEL	L Alarm H Alarm OVER	19.5vol% 23.5vol% 40.0vol%	1st 2nd TWA STEL OVER	5.0ppm 30.0ppm 5.0ppm 5.0ppm 100.0ppm	1st 2nd TWA STEL OVER	25ppm 50ppm 25ppm 200ppm 500ppm
Operating temperature and humidity	-20 ～ +50°C and below 95% RH (no condensing)							
Power supply	Lithium-ion battery unit (standard) or dry battery unit <3 AA alkaline battery> (option)							
Continuous operating time	Lithium-ion battery unit: Approx. 12 hours (fully charged, 25°C, without alarm nor illumination) Dry battery unit: Approx. 6 hours (25°C, without alarm nor illumination)							
Dimension/ Weight	Approx. 154(W)×81(H)×127(D) mm (projection portions excluded) Approx. 1.1 kg (lithium-ion battery unit is used) and Approx. 1.0 kg (dry battery unit is used)							
Explosion-proof class	Ⅱ1G Ex ia ⅡC T4 Ga							
Protection level	IP67 equivalent							

GP-1000
(For LEL detection)

NC-1000
(For ppm detection)

NP-1000
(For VOL detection)

Portable Combustible Gas Detectors

Model:
GP-1000 series

GP-1000/NC-1000 List of Gas to be detected

No.	List of Gas kind	Display	Lower Explosive Limit LEL	Reading from methane in a different way	Reading from isobutane in a different way
1	Methane	CH4	5.0vol%	—	×
2	Isobutane	i-C4H10	1.8vol%	○	—
3	Hydrogen	H2	4.0vol%	○	○
4	Methanol	CH3OH	5.5vol%	○	○
5	Acetylene	C2H2	1.5vol%	○	○
6	Ethylene	C2H4	2.7vol%	○	○
7	Ethane	C2H6	3.0vol%	○	×
8	Ethanol	C2H5OH	3.3vol%	○	○
9	Propylene	C3H6	2.0vol%	○	○
10	Acetone	C3H6O	2.15vol%	○	○
11	Propane	C3H8	2.0vol%	○	×
12	Butadiene	C4H6	1.1vol%	○	○
13	Cyclopentane	C5H10	1.4vol%	○	○
14	Benzene	C6H6	1.2vol%	○	○
15	n-hexane	n-C6H14	1.2vol%	○	○
16	Toluene	C7H8	1.2vol%	○	○
17	Heptane	n-C7H16	1.1vol%	○	○
18	Xylene	C8H10	1.0vol%	○	○
19	Ethyl acetate	EtAc	2.1vol%	○	○
20	IPA	IPA	2.0vol%	○	○
21	MEK	MEK	1.8vol%	○	○
22	Methyl methacrylate	MMA	1.7vol%	○	○
23	Dimethyl ether	DME	3.0vol%	○	○
24	Methyl isobutyl ketone	MIBK	1.2vol%	○	○
25	Tetrahydrofuran	THF	2.0vol%	○	○

Note 1) The alarm accuracy and response time, etc. are confirmed only by the calibration gas.
Note 2) Please contact RIKEN KEIKI in the case that calibration with other than methane, isobutane and hydrogen is required.
Note 3) Please note that switching of kind of detection gas is impossible if the calibration is implemented using other than methane and isobutane.

Model	GP-1000	NC-1000	NP-1000
Detection method	Pump drawing type		
Gas to be detected	Combustible gas and others		
Detection principle	Catalytic combustion	New ceramic	Thermal conductivity
Detection range	0～100% LEL <Automatic range switching> Low range: 0～10%LEL High range: 0～100%LEL	0～10000ppm <Automatic range switching> Low range: 0～1000ppm High range: 0～10000ppm	0～100 vol% <Automatic range switching> Low range : 0～10vol% High range : 0～100vol%
Alarm setpoint value	1st 10%LEL 2nd 50%LEL	1st 250ppm 2nd 500ppm	Factory setting : OFF
Operating temperature and humidity	-20 ～ +50°C and below 95% RH (non-condensing)		
Power supply	4 AA alkaline battery		
Continuous operating time	Approx. 20 hours* (new dry battery, 25°C, without alarm nor illumination, and pump Low mode)		
Dimension/ Weight	Approx. 80(W) × 124(H) × 36(D) mm (projection portions excluded) Approx. 260 g (dry battery is excluded).		
Explosion proof class	Ex ia IIC T4		
Protection level	IP67 equivalent		

*Different depending on the specification

NP-1000 List of Gas to be detected

No.	List of Gas kind	Display
1	Methane	CH4
2	Propane	C3H8
3	Isobutane	i-C4H10
4	Argon	Ar
5	Helium	He
*	Hydorogen	H2

*Hydrogen is detected by NP-1000 H2 version. H2 version cannot convert the reading to other gases.

NP-1000 List of Base Gas

No.	List of Gas kind	Display
1	Air	Air
2	Nitrogen	N2
3	Carbon dioxide	CO2

10-2. Single Gas Detector (Single-sensor)

Portable Oxygen Monitor

Model: OX-08

Model	OX−08
Detection method	Diffusion type
Gas to be detected	O2
Detection principle	Galvanic cell
Detection range	0～40.0vol%
1 digit	0.1vol%
Alarm setpoint value	Gas alarm 18.0vol% OVER 40.0vol%
Operating temperature and humidity	−20～ +50℃, 10～95%RH (no condensing)
Power supply	2 AAA alkaline battery
Continuous operating time	Approx. 20000 hours (25°C without alarm nor illumination)
Dimension/ Weight	Approx. 68(W) × 150(H) × 49(D) mm (projection portions excluded) Approx. 290 g (dry battery included)
Explosion proof class	Ex ia IIC T4 Ga

Personal Single Gas Monitors

Model: 03 series

GP-03 (For combustible gases) OX-03 (For oxygen) HS-03 (For hydrogen sulfide) CO-03 (For carbon monoxide)

Model	GP−03	OX−03	CO−03	HS−03
Detection method	Diffusion type			
Gas to be detected	HC / CH4	O2	CO	H2S
Detection principle	New ceramic	Galvanic cell	Electrochemical	Electrochemical
Detection range	0～100%LEL	0～40.0vol%	0～500ppm	0～100.0ppm
1 digit	1%LEL	0.1vol%	1ppm	0.5ppm
Alarm setpoint value	1st 10%LEL 2nd 50%LEL OVER	L alarm 19.5vol% H alarm 23.5vol% OVER 40.0vol%	1st 25ppm 2nd 50ppm TWA 25ppm STEL 200ppm OVER 500ppm	1st 5.0ppm 2nd 30.0ppm TWA 10.0ppm STEL 15.0ppm OVER 100.0ppm
Operating temperature and humidity	−20～ +50℃ Below 90%RH (no condensing)	−20～ +50℃ Below 95%RH (no condensing)	−20～ +50℃ 16～85%RH (no condensing)	
Power supply	2 AAA alkaline battery			
Continuous operating time	Approx. 35 hours (25°C, without alarm nor illumination)		Approx. 3000 hours (25°C without alarm nor illumination)	
Dimension/ Weight	Approx. 54(W) × 67(H) × 24(D) mm / Approx. 80 g			

Portable Toxic
Gas Monitor

Model: SC-8000

Model	SC-8000
Detection method	Pump drawing type
Gas to be detected	Refer to the list of target gases above
Detection principle	Electrochemical
Detection range	
1 digit	Depending on gas to be detected
Alarm setpoint value	
Operating temperature and humidity	-10～ +40°C, 30～70% RH (no condensing)
Power supply	Dry battery unit <3 AA alkaline battery> (standard) or lithium-ion battery unit (option)
Continuous operating time	Dry battery unit: For approx. 18 hours (25°C, without alarm nor illumination) Lithium-ion battery unit: For approx. 25 hours (fully charged, 25°C, without alarm nor illumination)
Dimension/ Weight	Approx. 154(W) × 154(H) × 81(D) mm (projection portions excluded) Approx. 1.0 kg (dry battery unit used) and Approx. 1.1 kg (lithium-ion battery used)
Explosion proof class	Ex ia IIC T4
Protection level	IP67 equivalent

List of Gas to be detected

PH3	Br2	Cl2	H2Se	HI
AsH3	NO	O3	ClF3	H2S
SiH4	NO2	F2	HCN	SO2
B2H6	HF	NH3	PF3	
HCl	CO	HBr	GeH4	

Optical
Gas Indicator

Model: FI-8000

Model	FI-8000	
Type	TYPE P	TYPE A
Measuring method	Automatic drawing type with built-in pump	Manual drawing type with hand aspirator
Gas to be detected	Anaestheic gas / Fumigation gas / Combustible gas / Calorific value etc.	
Measuring principle	Optical inferferometric	
Measuring range	Depending on the measuring object gas	
Indication accuracy	±3% of reading (under the same condition) *	
Operating temperature and humidity	-20 ～ +50°C and below 95% RH (non-condensing)	
Power supply	Dry battery unit <3 AA alkaline battery> (standard) or lithium-ion battery unit (option)	
Continuous operating time	Approx. 12 hours (new dry battery, 25°C, without illumination)	Approx. 16 hours (new dry battery, 25°C, without illumination)
Dimension/ Weight	Approx. 154(W) × 81(H) × 127(D) mm (projection portions excluded) Approx. 1.1 kg (dry battery unit is used) / Approx. 1.2 kg (lithium-ion battery unit is used)	
Explosion proof class	Ex ia IIC T4	
Protection level	IP67 equivalent	

* The indication accuracy is different depending on the measuring object gas.

Portable Gas Leak Checkers

Model: SP-220 series

Explosion-proof
- TYPE M For City gas (CH_4)
- TYPE L For LPG
- TYPE ML For both City gas (CH_4) and LPG
- TYPE F For CFC gas
- TYPE H2 For Hydrogen and combustible gas

Non Explosion-proof
- TYPE FUM For Fumigation gas
- TYPE SC For Semiconductor material gas and general gas

Model	SP-220						
Type	TYPE M	TYPE L	TYPE ML	TYPE F	TYPE H2	TYPE FUM	TYPE SC
Detection method	Pump drawing type						
Gas to be detected	City gas	LPG	City gas / LPG (switch)	Refer to the "List of gas to be detected" above			
Calibration gas	CH4	i-C4H10	CH4/i-C4H10 *	i-C4H10	H2/CH4 *	PH3	
Detection principle	Hot-wire semiconductor						
Detection range	10～10000ppm			Depending on gas to be detected			
Alarm setpoint value	Initial value: 30 ppm (possible to set by 5 steps of 10, 30, 150, 500, and 2000 ppm)					Depending on gas to be detected	
Operating temperature and humidity	-20 ～ +55°C and below 95% RH (non-condensing)						
Power supply	2 AA alkaline battery						
Continuous operating time	Approx. 13 hours (20°C, without alarm nor illumination)						
Dimension/ Weight	Approx. 43(W) × 200(H) × 39(D) mm (the taper nozzle is excluded) Approx. 215 g (dry battery is excluded).						
Explosion proof class	Ex ia IIC T4					Non Explosion-proof	
Protection class	IP55 equivalent						

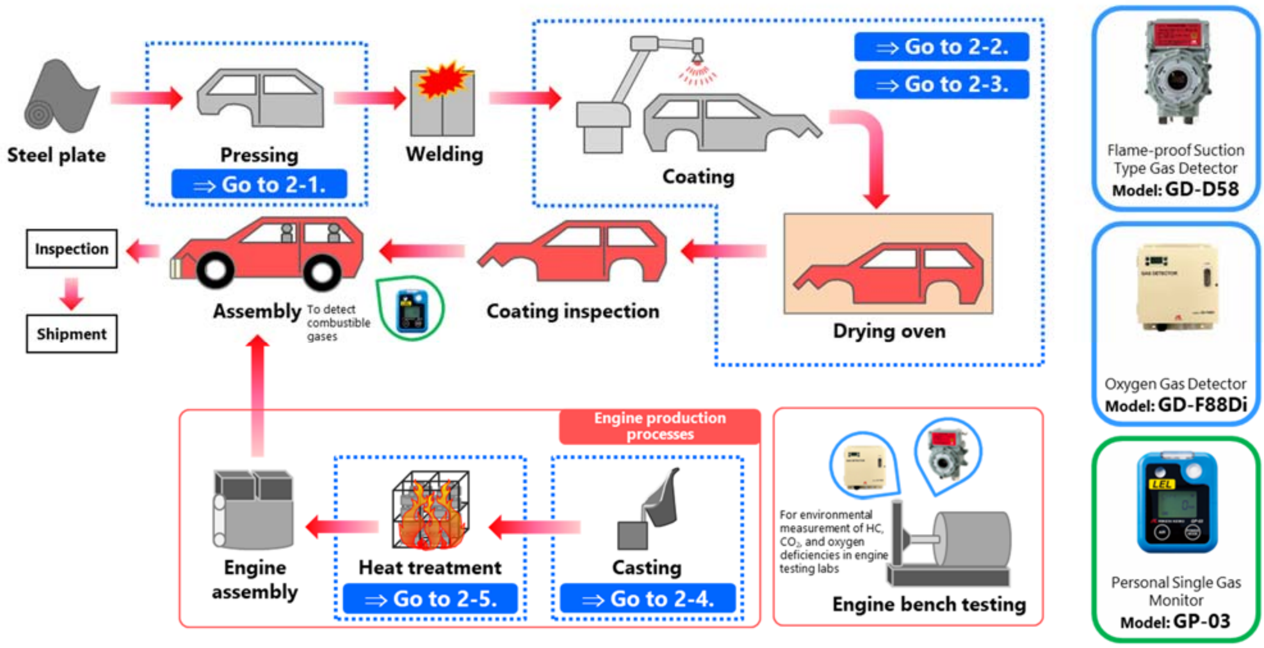
＊Two-gas calibration

11
Typical Applications for Portable Gas Detectors

11-1. Applications in Automotive Market

1. Entire flow of processes at automobile manufacturing plant

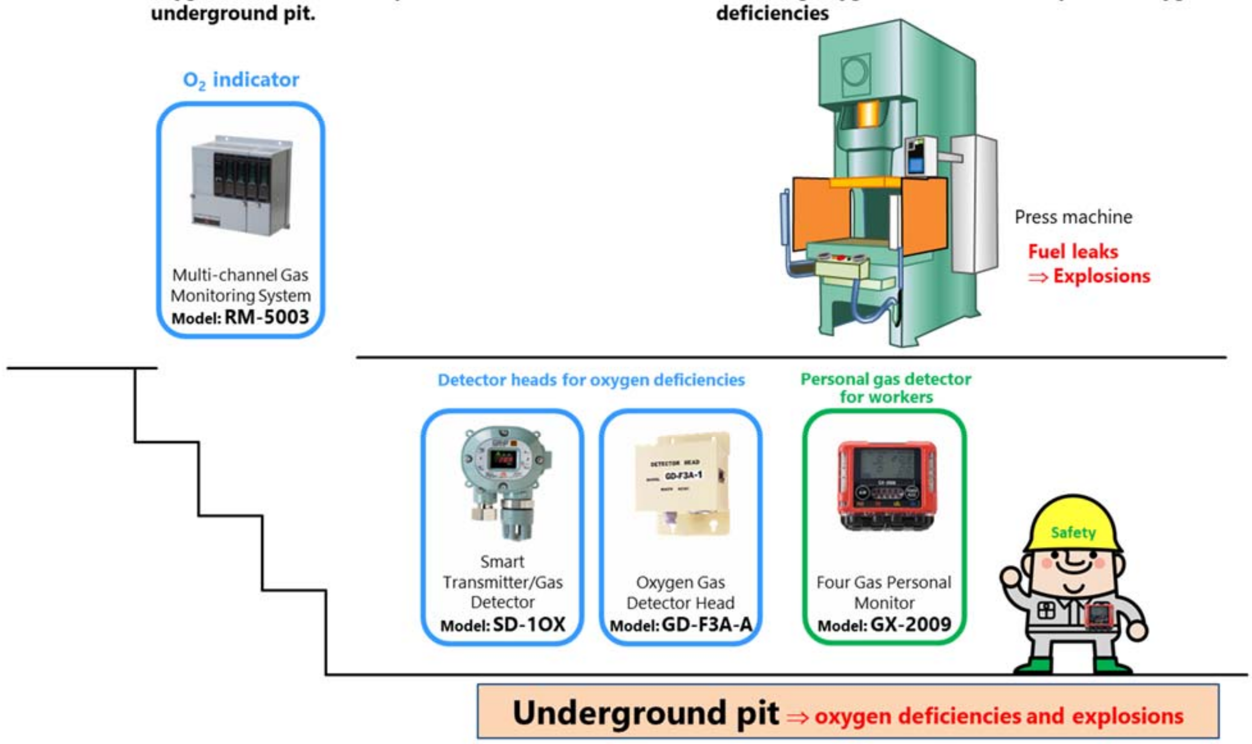
The figure below shows the risks posed by combustible and toxic gas leaks in automobile manufacturing processes and examples of gas detector and alarm installations.
The following pages discuss the details of each process.



2-1: Pressing

Description: In the pressing process, a large press machine or similar equipment is used to press the body.

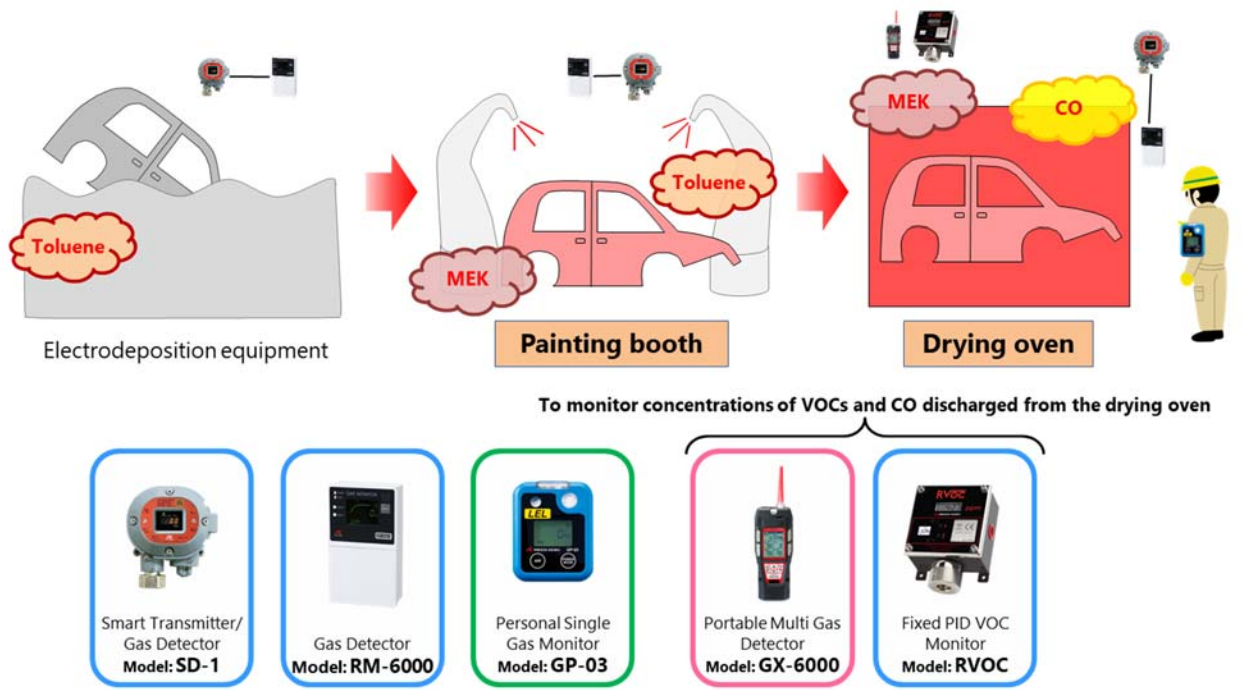
Hazardous risks: **Fuel from the press machine may leak and cause oxygen deficiencies or explosions in the underground pit.** ⇒ **Detecting combustible gases to prevent explosions Detecting oxygen concentration to prevent oxygen deficiencies**



2-2: Coating and drying (1)

Description: Paint is applied in various ways in coating and drying processes. The body is coated by electrodeposition or spray painting and dried in a drying oven.

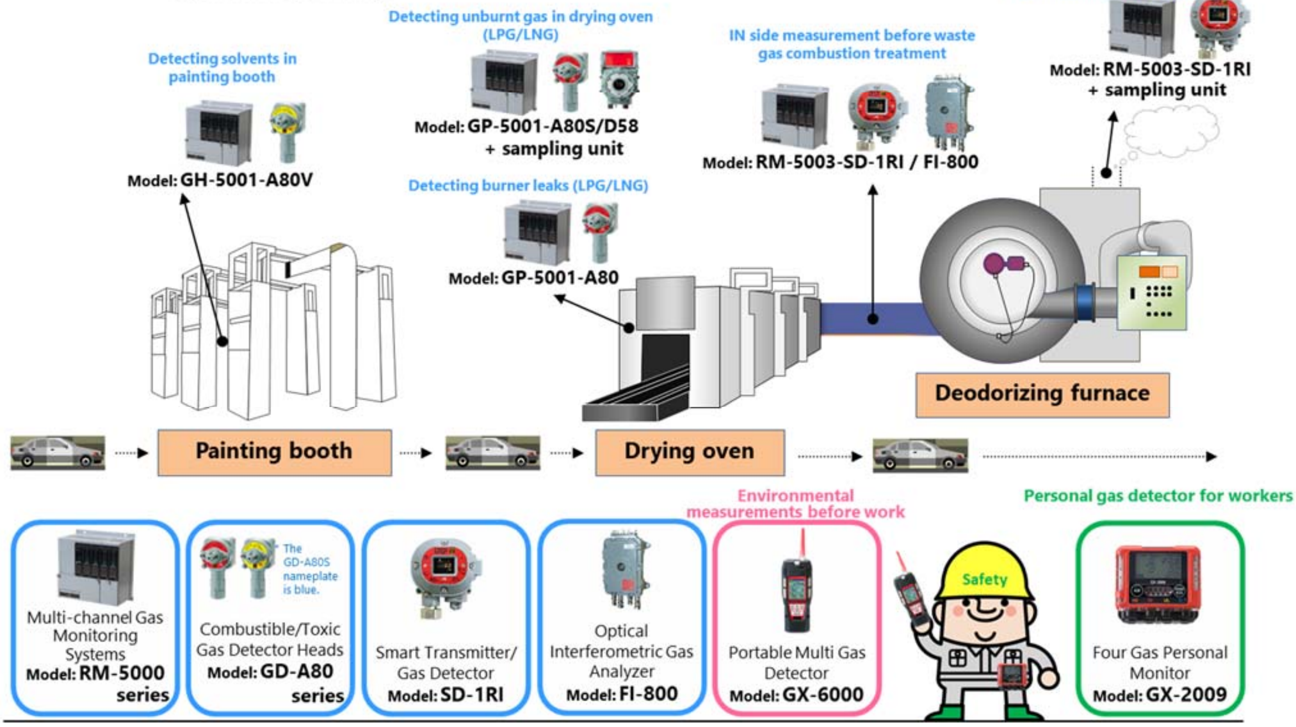
Hazardous risks: **Organic solvents used in the electrodeposition equipment and painting booth may cause explosions. CO poisoning may occur in the drying oven.** ⇒ **Detecting combustible gases to prevent explosions Detecting CO to prevent poisoning**



2-3: Coating and drying (2)

Description: Paint is applied in various ways in coating and drying processes. The body is coated by electrodeposition or spray painting and dried in a drying oven.

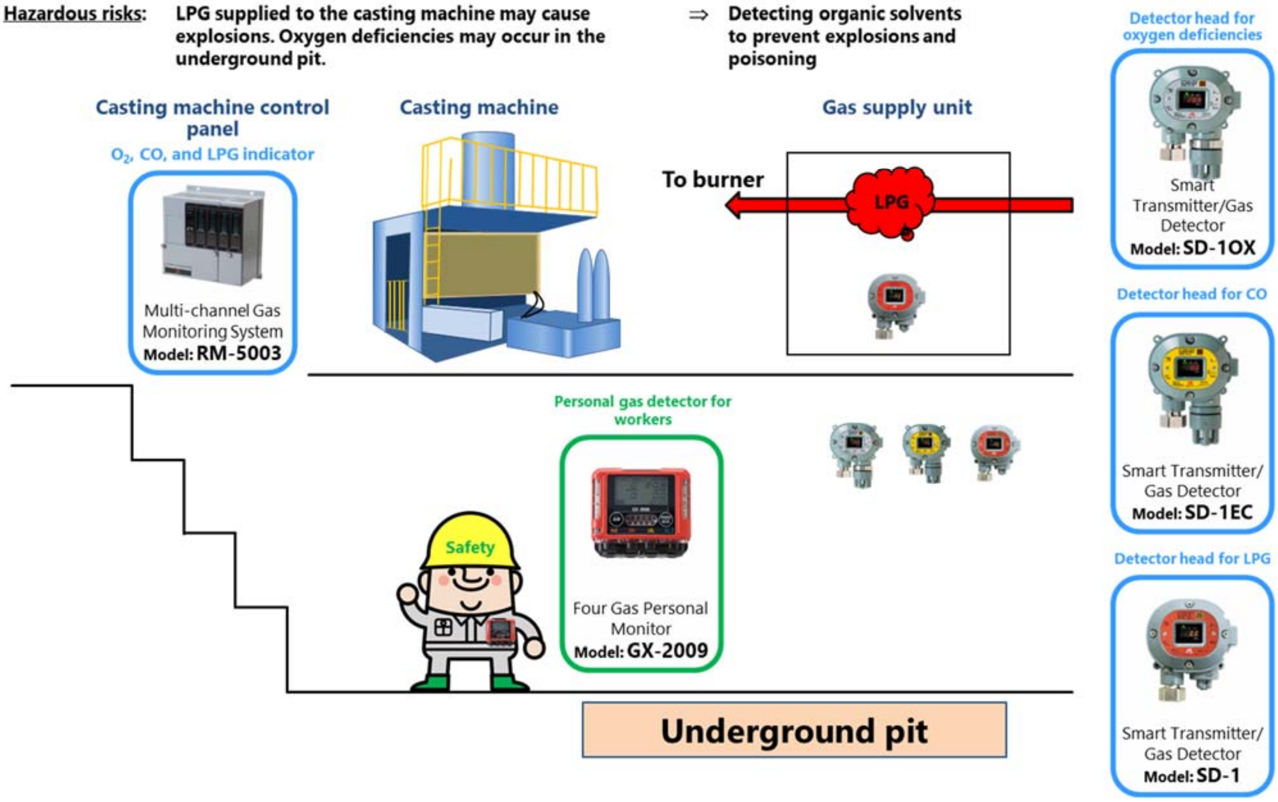
Hazardous risks: **Organic solvents used in the painting booth, drying oven, and deodorizing furnace may result in explosions or poisoning.** ⇒ **Detecting organic solvents to prevent explosions and poisoning**



2-4: Casting

Description: A casting machine is used to produce engines and other cast products. In a casting machine, fuel is supplied from the gas supply unit to the melting furnace to melt aluminum.

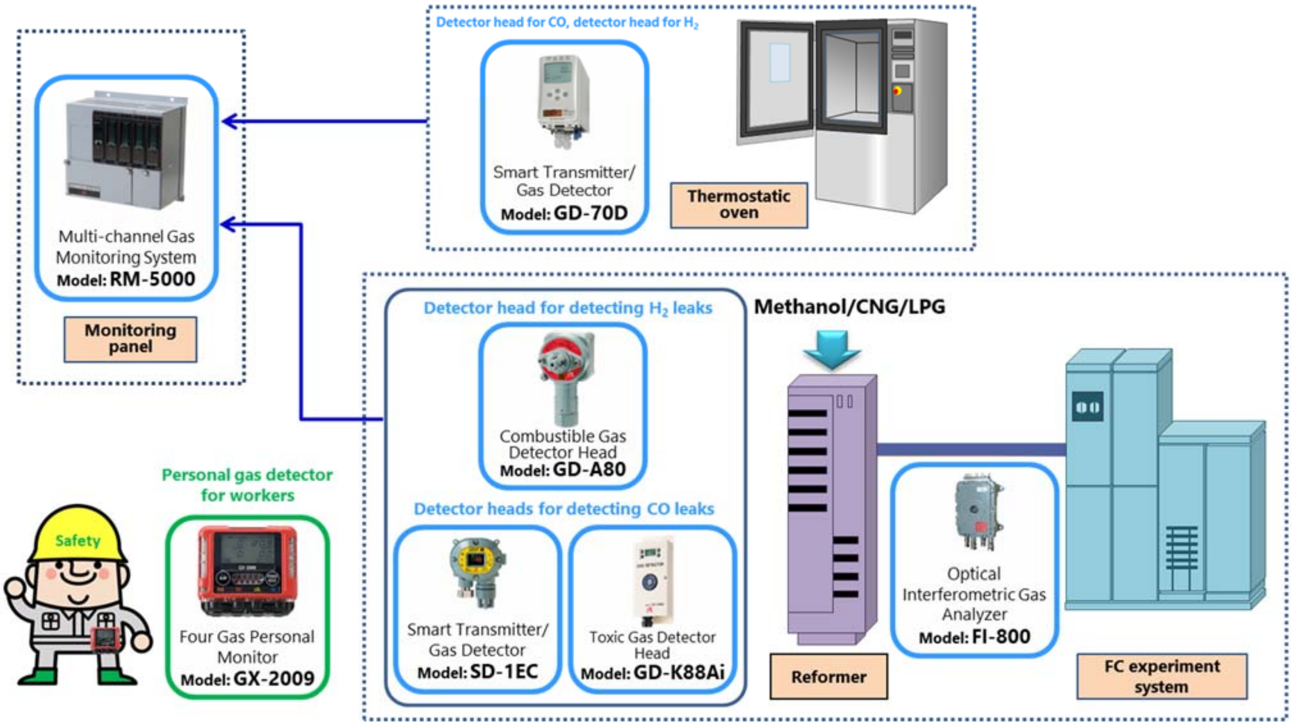
Hazardous risks: **LPG supplied to the casting machine may cause explosions. Oxygen deficiencies may occur in the underground pit.** ⇒ **Detecting organic solvents to prevent explosions and poisoning**



3. Laboratory

Description: In laboratories, various parts are tested in thermostatic ovens and other equipment. FC experiment systems and reformers are also tested.

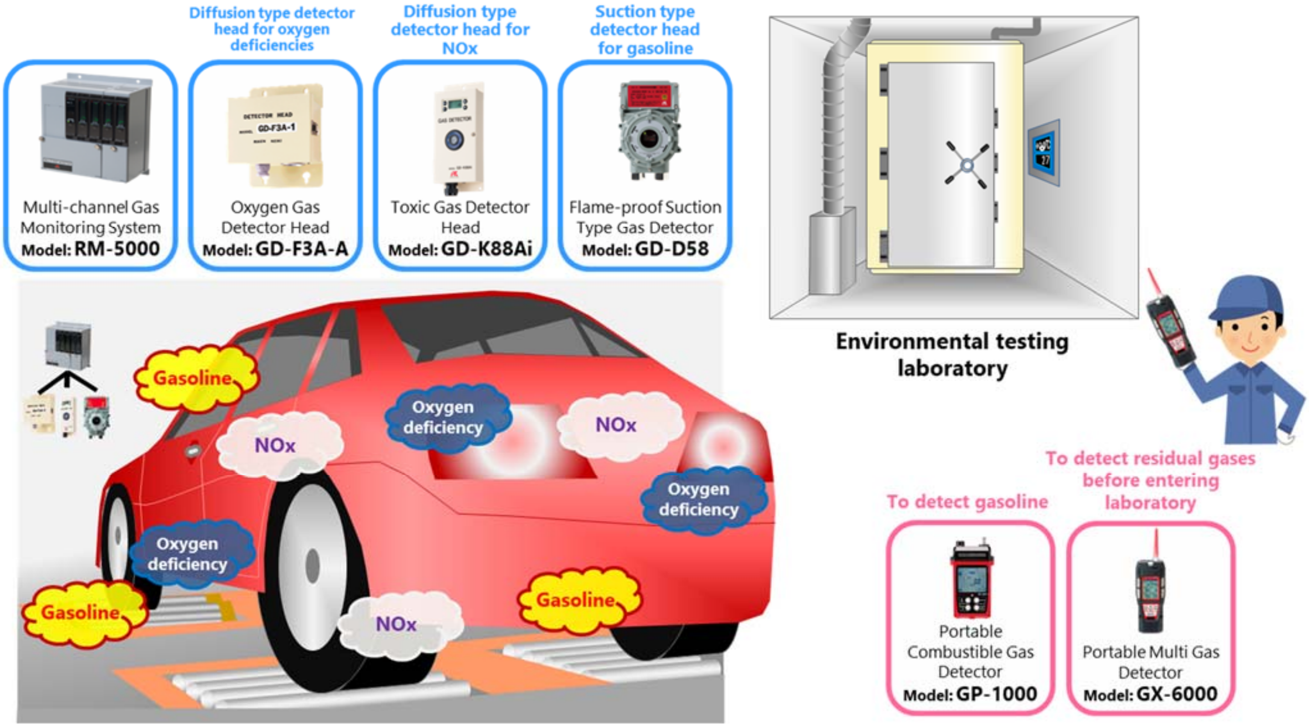
Hazardous risks: **H_2 and fuel leaks from the FC experiment systems and reformers during experiments may cause explosions. The CO in the exhaust gas may lead to poisoning.** ⇒ **Detecting H_2 and other combustible gases to prevent explosions. Detecting CO to prevent poisoning**



4. Engine laboratory and environmental testing laboratory

Description: Various tests are performed in engine and environmental testing labs, including engine experiments using actual vehicles and environmental tests.

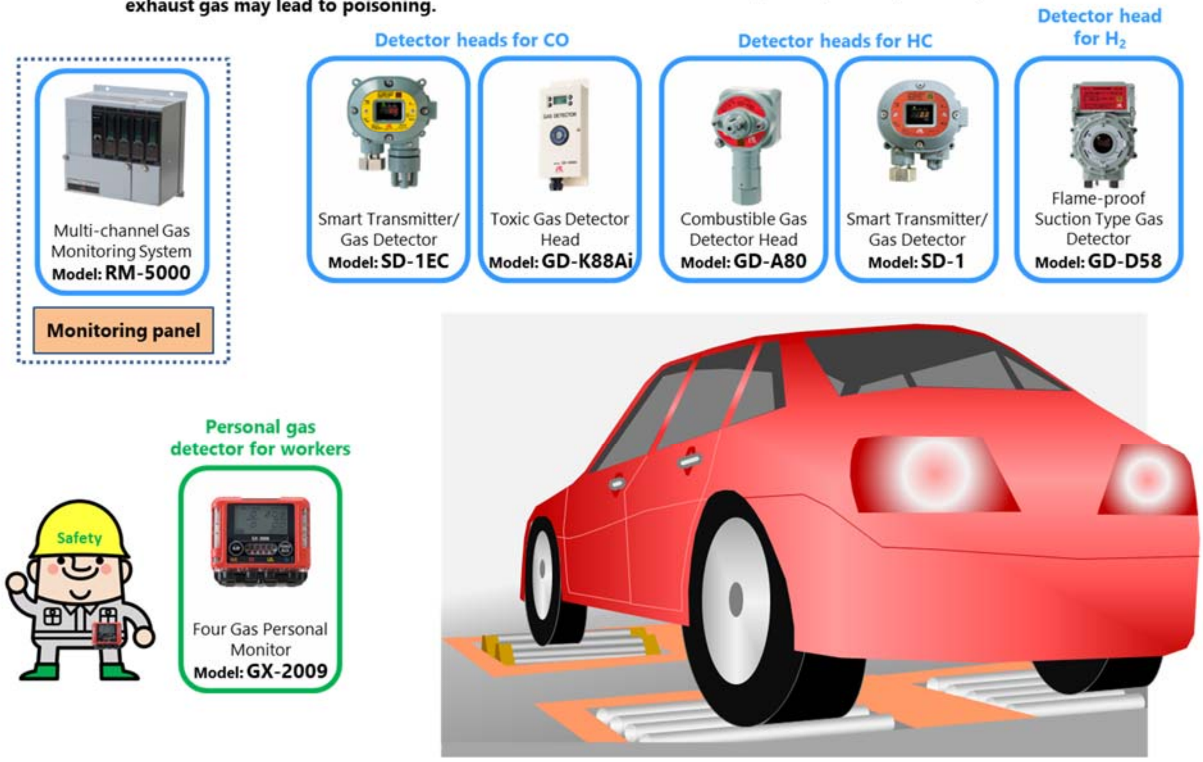
Hazardous risks: **Fuel leaks from vehicles during tests in engine and environmental testing labs may cause explosions. CO in exhaust gas may lead to poisoning.** ⇒ **Detecting combustible gases to prevent explosions. Detecting CO to prevent poisoning**



5. Vehicle testing laboratory

Description: Driving tests are performed in the vehicle testing lab using actual vehicles.

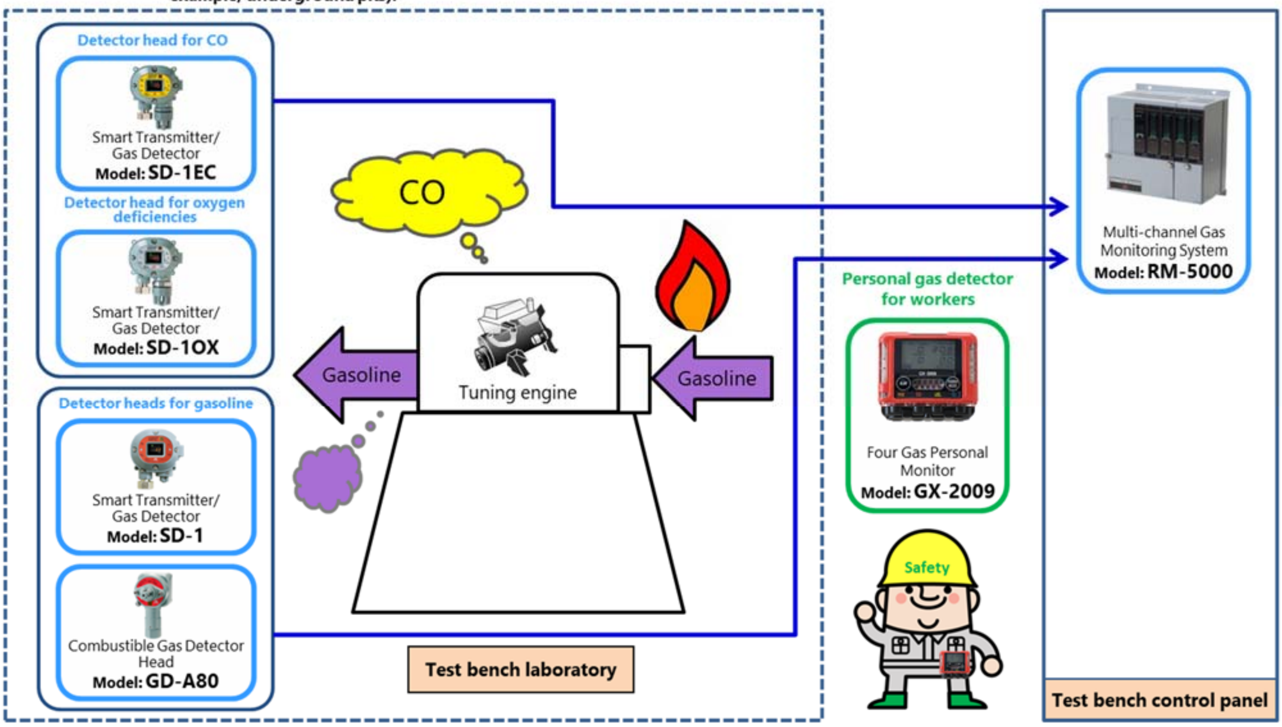
Hazardous risks: **Fuel leaks from the vehicle during tests in the vehicle testing laboratory may cause explosions. CO in the exhaust gas may lead to poisoning.** ⇒ **Detecting combustible gases to prevent explosions**
Detecting CO to prevent poisoning



6. Test bench

Description: Performance and durability tests of a tuning engine are performed in the test bench lab.

Hazardous risks: **Engine fuel leaks can generate combustible gases and may cause explosions.**
CO in the exhaust gas from engine combustion may lead to poisoning.
Oxygen deficiencies may occur during work in a closed space (for example, underground pits).
⇒ **Detecting combustible gases to prevent explosions**
Detecting CO to prevent poisoning
Detecting oxygen concentration to prevent oxygen deficiencies

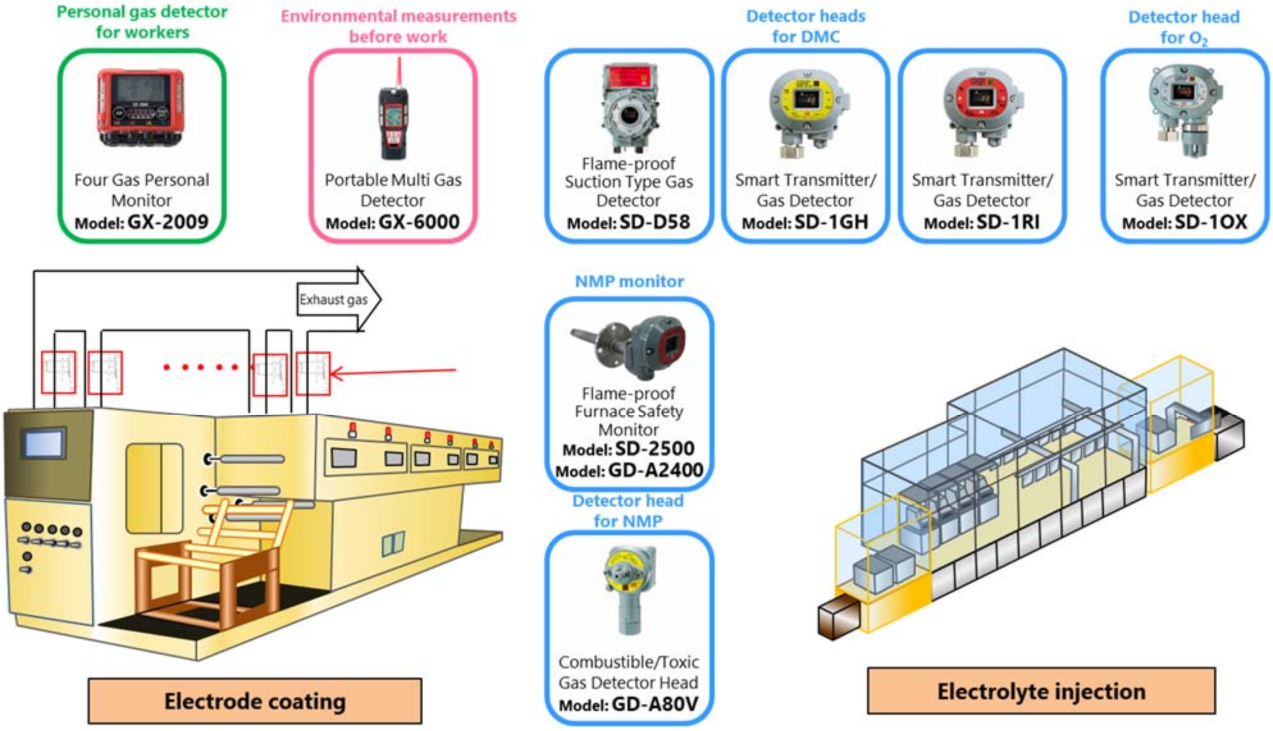


7. Lithium battery production

Description: Lithium battery production processes involve electrode coating and electrolyte injection.

Hazardous risks: Electrode coating processes can generate explosive NMP (N-methylpyrrolidone). Electrolyte injection processes can generate explosive DMC (dimethyl carbonate). Such gases may explode or generate oxygen deficiencies.

⇒ NMP and DMC detectors to prevent explosions
Measuring oxygen concentration to prevent oxygen deficiencies

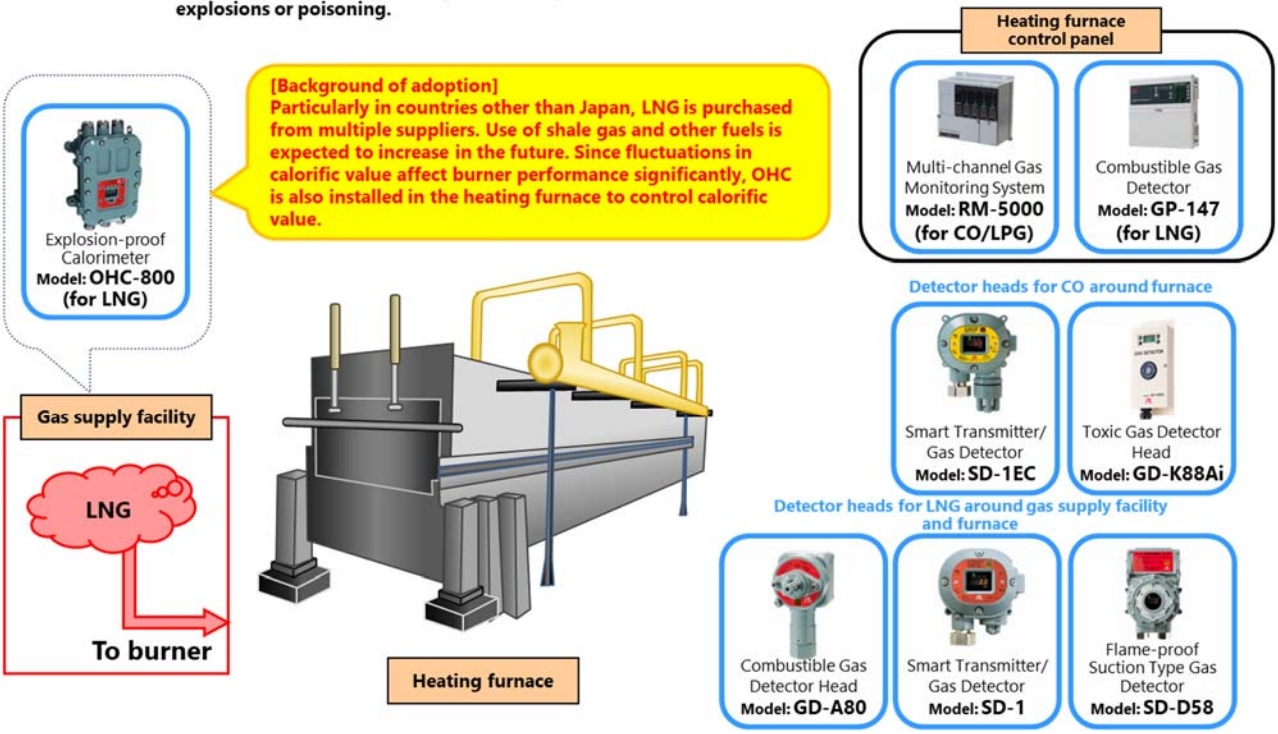


8. Heating furnace

Description: Heating furnaces are used to heat steel materials in automobile manufacturing.

Hazardous risks: Since fluctuations in the calorific value of the supplied fuel affect burner performance significantly, the calorific value must be controlled. Fuel (LNG) leaks and CO generation near the heating furnace may lead to explosions or poisoning.

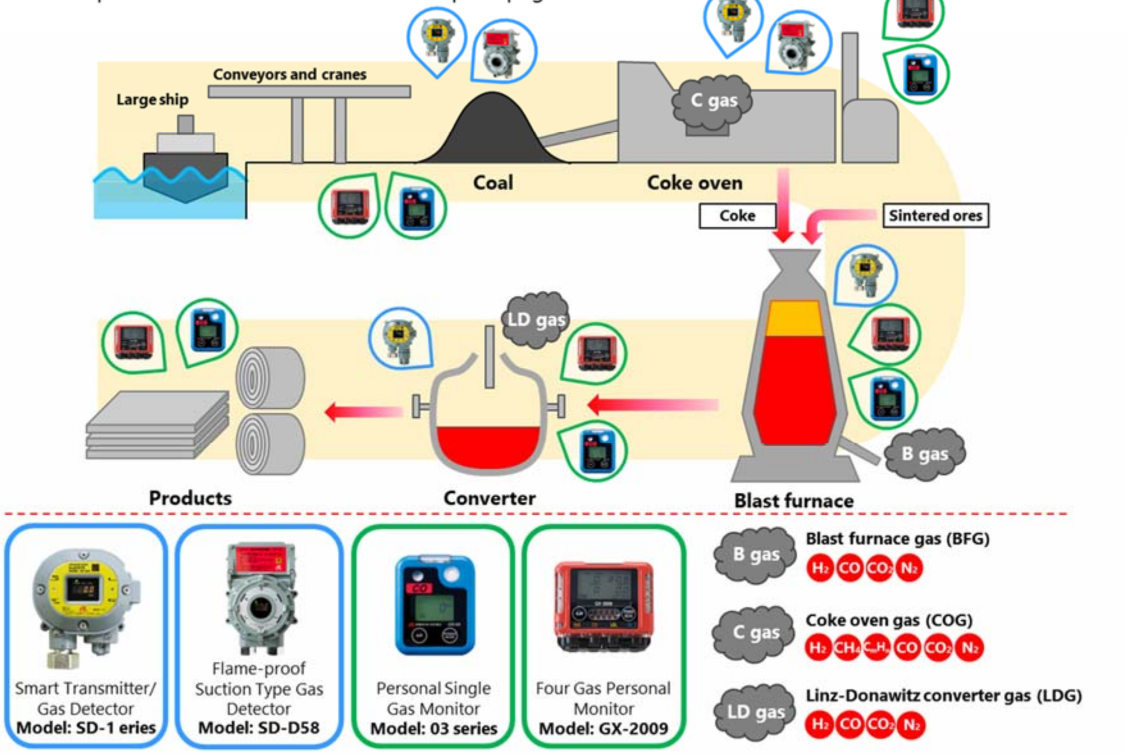
⇒ Controlling calorific value with a calorimeter
Detecting CO to prevent poisoning
Detecting combustible gases to prevent explosions



11-2. Applications in Steel Market

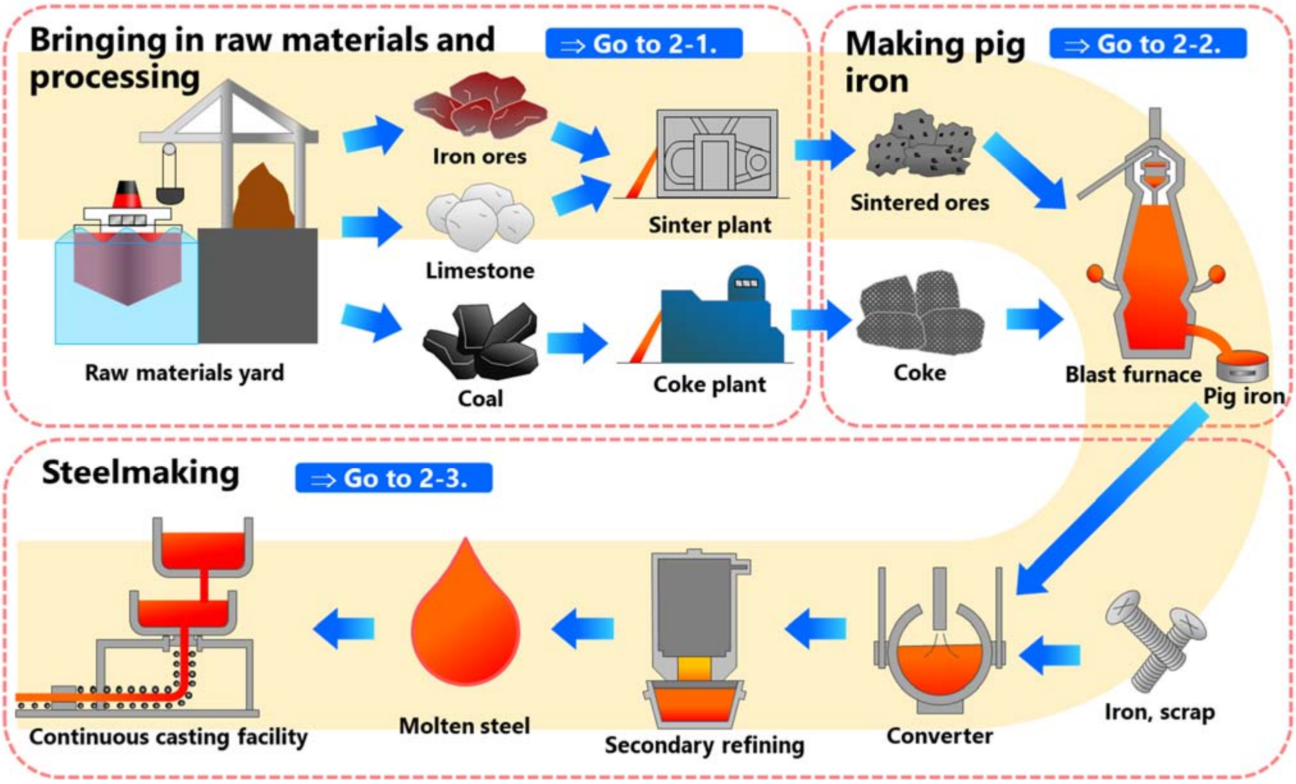
1. Entire flow of processes in steel market

The figure below shows the risks posed by B gas, C gas, and LD gas leaks in steelmaking processes and gives examples of disaster prevention and security equipment installations.
The details of each process are described on the subsequent pages.



2. Details of each process (from carrying-in of raw materials to steelmaking)

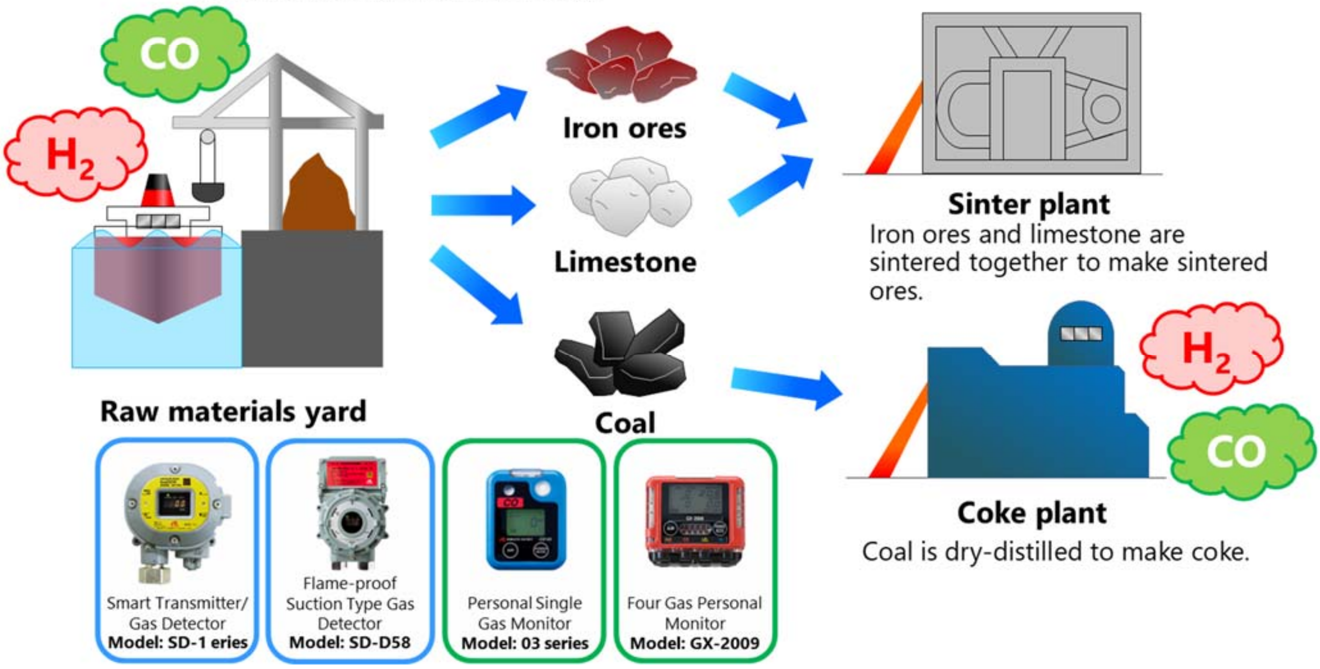
This page shows the details of each process from the time raw materials are brought in through steelmaking. The subsequent pages show applications relevant to each process.



2-1. Bringing in raw materials and processing

Description: Iron ores and coal (coke), the main raw materials of iron, are transported and delivered on large ships. As pretreatment for making pig iron, iron ores must be sintered with limestone to make sintered ores, or coal must be dry-distilled at high temperatures to make coke.

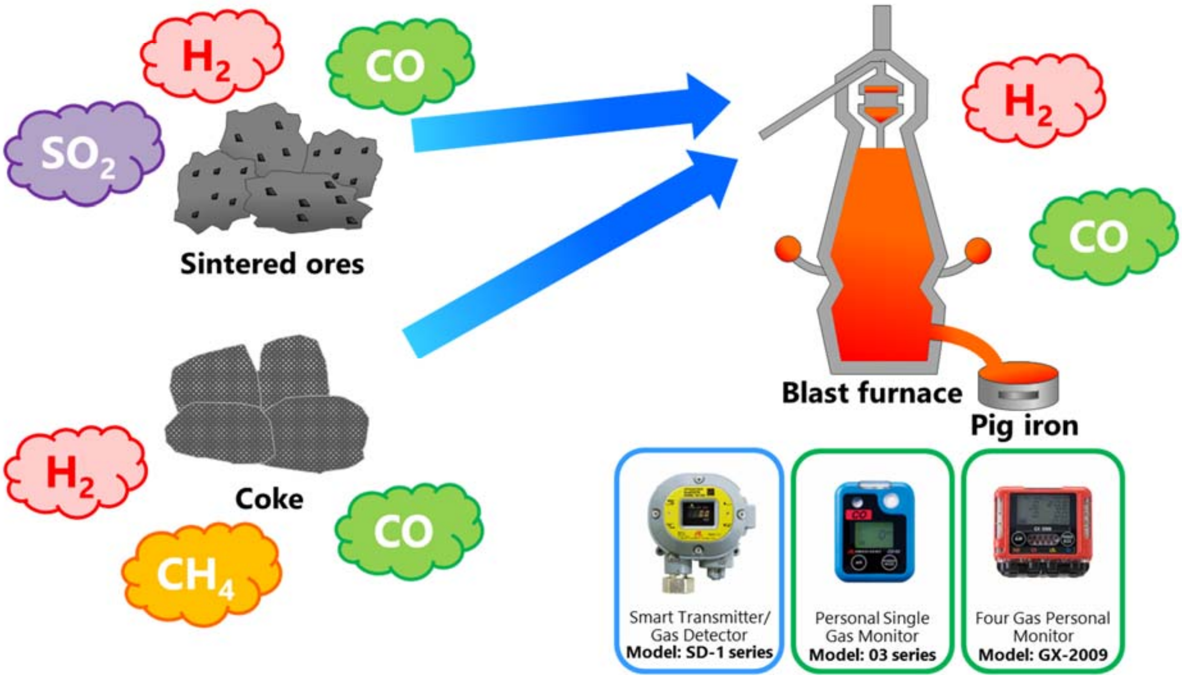
Hazardous risks: **Significant volumes of hydrogen (H2) and carbon monoxide (CO) generated in raw materials yards and coke plants can cause explosions or poisoning.** ⇒ **Detecting flammable gases, detecting CO to prevent poisoning, and early flame detection**



2-2. Pig iron making

Description: In a blast furnace, iron ores, limestone, and coke (made from coal) are alternately supplied from the top. Heated air is injected through a nozzle called the tuyere in the lower area. The furnace interior reaches temperatures of approximately 2,200°C. The molten iron becomes pig iron.

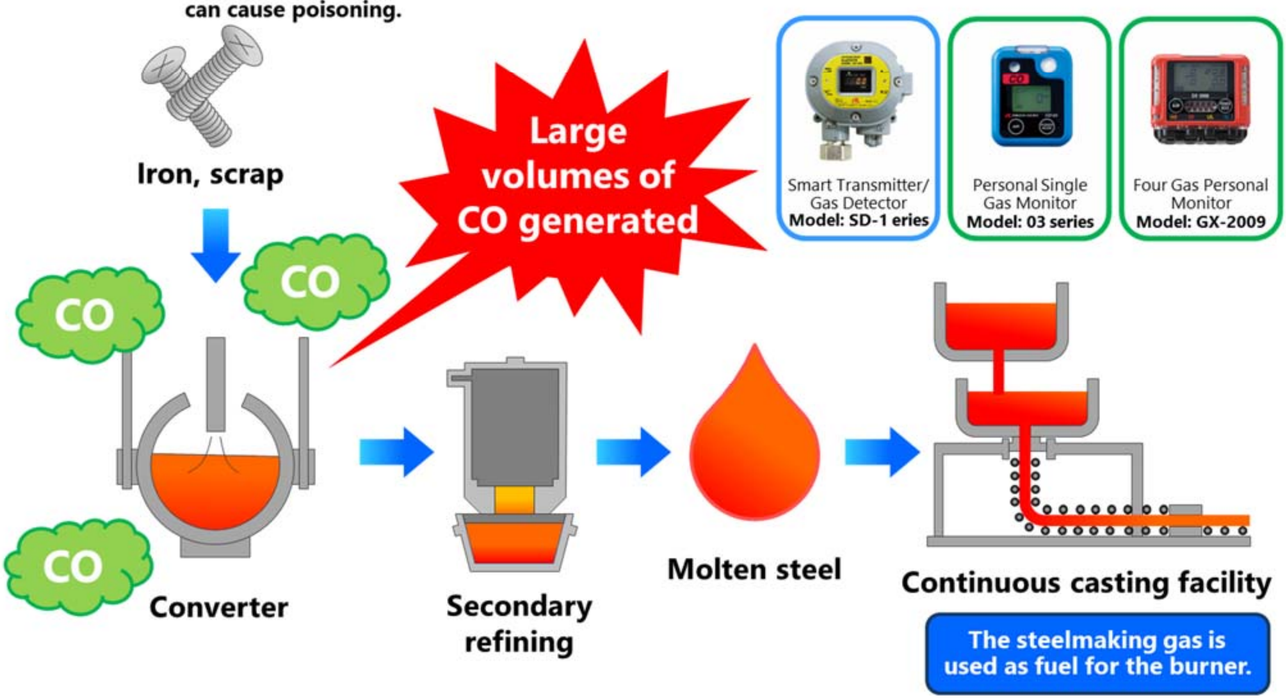
Hazardous risks: **Hydrogen (H_2), methane (CH_4), carbon monoxide (CO), sulfur dioxide (SO_2), and other gases generated from the sintered ores, coke, and blast furnace can cause explosions or poisoning.** ⇒ **Detecting combustible gases and CO and SO_2 to prevent poisoning**



2-3. Steelmaking

Description: Impurities like sulfur and phosphor are removed from the pig iron, which is then transferred to the converter. The iron content approaches 99% once oxygen is injected into the converter to remove carbon. In secondary refining, impurities are further removed to produce steel. Steel is characterized by its toughness and ease of processing.

Hazardous risks: Carbon monoxide (CO) leaking from the converter can cause poisoning. ⇒ Detecting CO to prevent poisoning



3. By-product gases in steelworks

Description: Three major types of by-product gases are generated in steelworks.
The examples below give the composition of the by-product gases. (By-product gases are reused as fuel on the premises.)

Hazardous risks: By-product gases generated in steelworks may cause explosions or poisoning. ⇒ Detecting combustible gases and toxic gases to prevent poisoning

① COG (Coke oven gas)

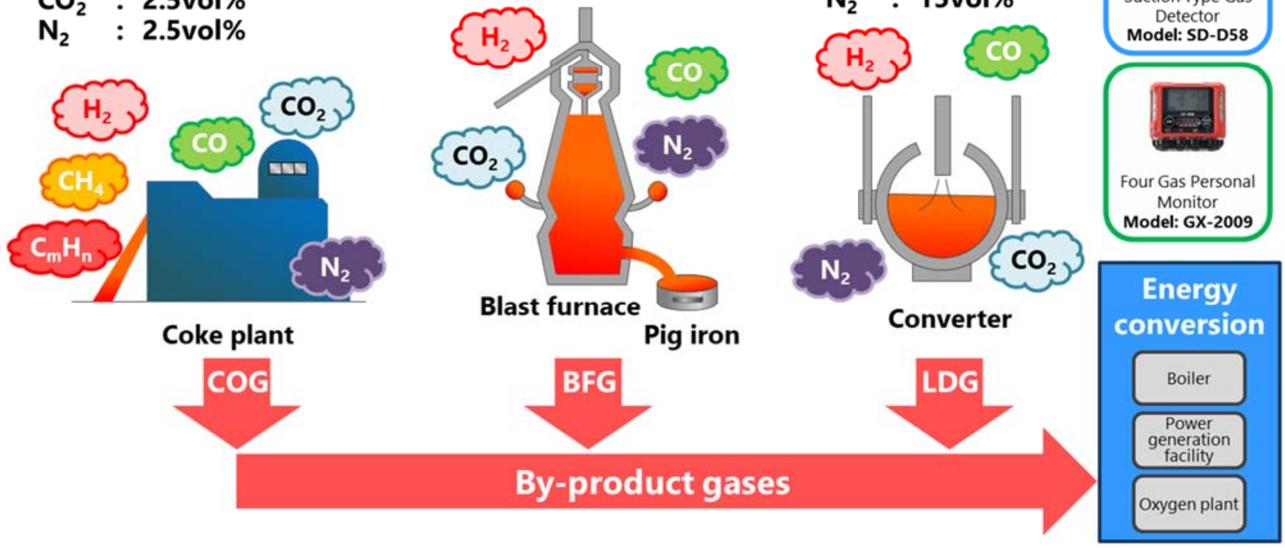
H_2 : 56vol%
CH_4 : 30vol%
C_mH_n : 3vol%
CO : 6vol%
CO_2 : 2.5vol%
N_2 : 2.5vol%

② BFG (Blast furnace gas)

H_2 : 4vol%
CO : 22.5vol%
CO_2 : 22.5vol%
N_2 : 51vol%

③ LDG (Linz-Donawitz converter gas)

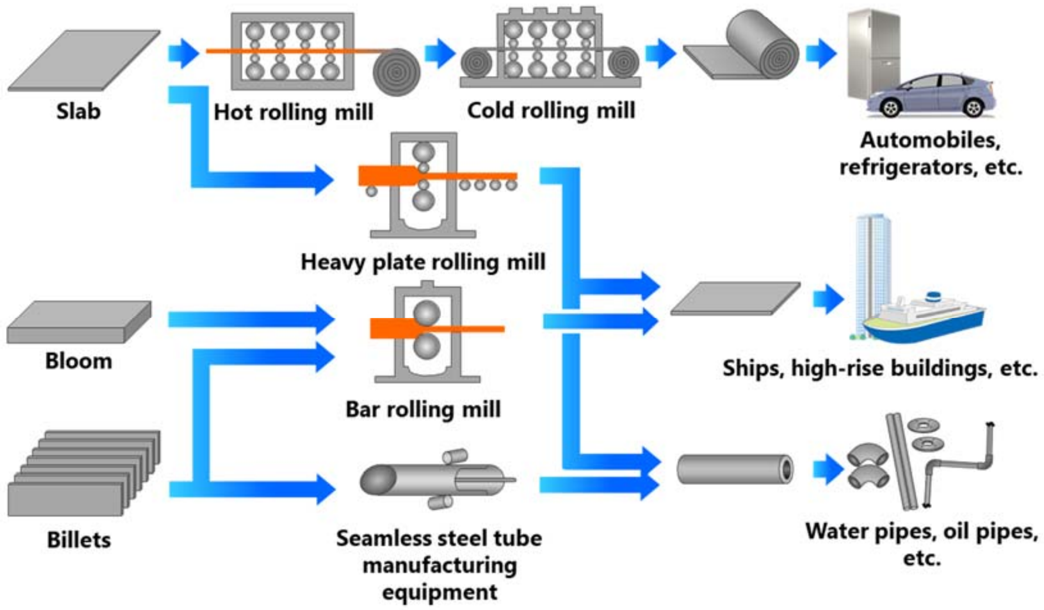
H_2 : 1vol%
CO : 68vol%
CO_2 : 16vol%
N_2 : 15vol%



4. Steel rolling process

Description: Steel is processed into plates varying from thin plates of 1 mm or less to thick plates of up to 40 cm. In addition to processing into plates, the strength, properties, and ease of processing may be adjusted. The steelmaking gas is used as fuel gas. Oxygen shortages may occur in the underground pits and other locations.

Hazardous risks: **Leaks of steelmaking gas used as the fuel gas may cause explosions or poisoning.** ⇒ **Detecting combustible gases and carbon monoxide (CO) to prevent poisoning**



Personal Single Gas Monitor
Model: 03 series

Four Gas Personal Monitor
Model: GX-2009

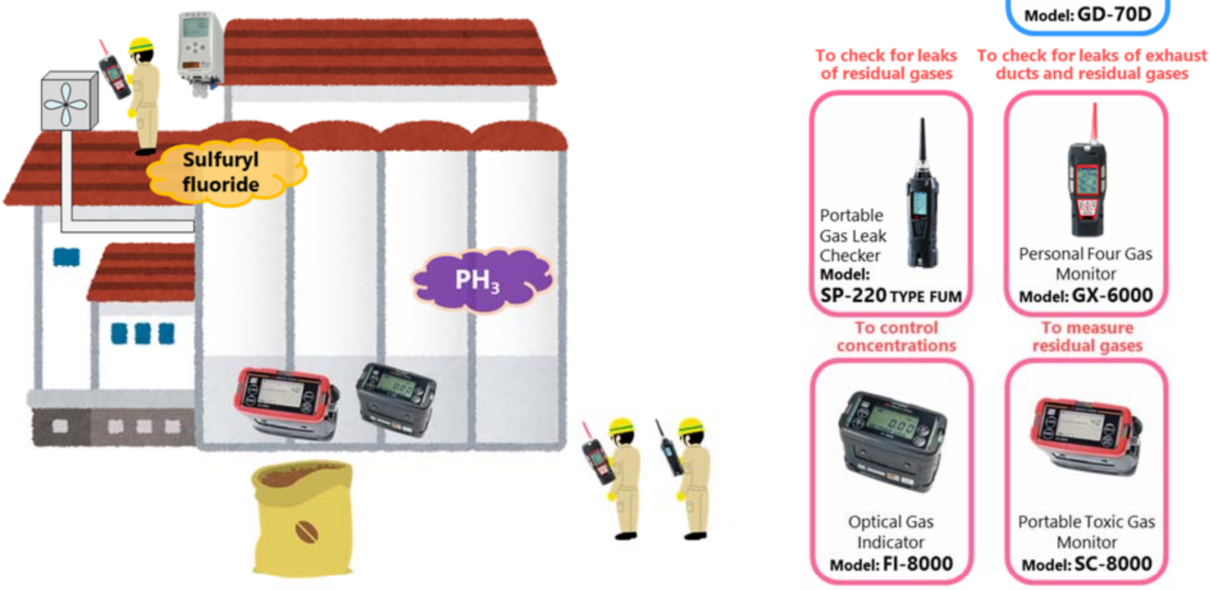
11-3. Applications in Fumigation Market

2-1: Fumigating agricultural products (1)

Description: Living creatures in bagged or bulked agricultural products (e.g., grain, coffee, and pulses) stored in silos or warehouses damage the quality of agricultural products. Thus, these products are fumigated using substances such as hydrogen phosphide (PH3: produced by the reaction of aluminum phosphide and airborne moisture) and sulfuryl fluoride. The airtightness of silos is checked by filling with CO_2.
* Use of methyl iodide and methyl formate is also being considered for the fumigation of silos and warehouses in the future.

Hazardous risks:

PH_3 and sulfuryl fluoride may cause poisoning.	⇒	**Detecting PH_3 and sulfuryl fluoride to prevent poisoning**
Leaks of CO_2 used to check the airtightness of silos may cause poisoning.	⇒	**Detecting CO_2 to prevent poisoning**

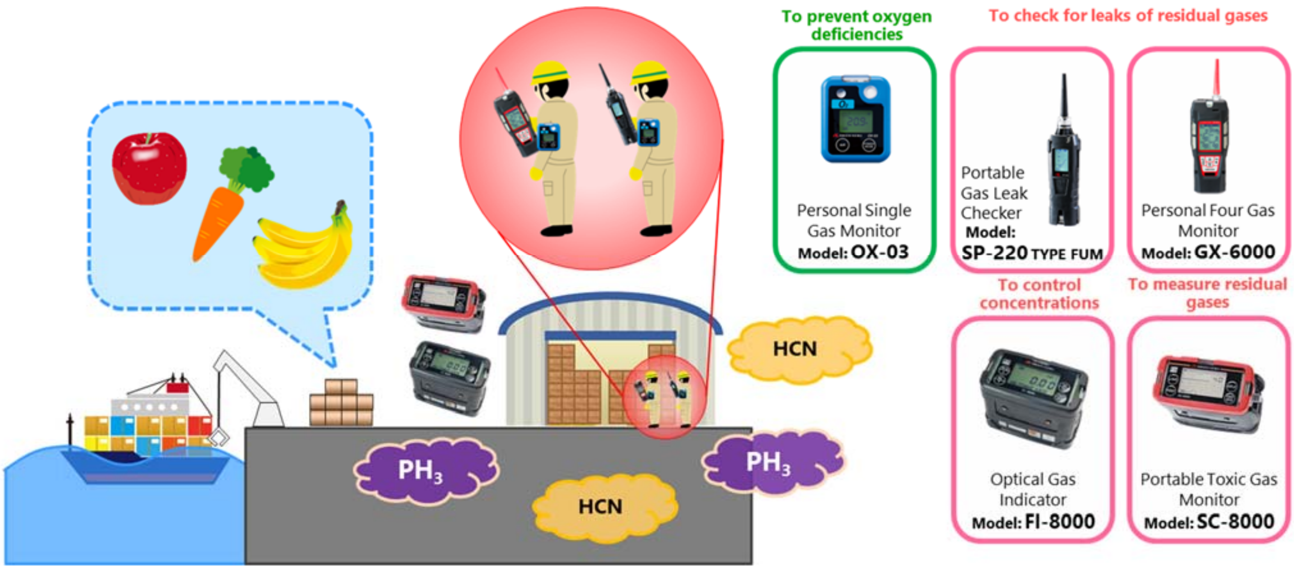


2-2: Fumigating agricultural products (2)

Description: Food (fruits and vegetables), grain, and similar goods transported as cargo (e.g., freight containers) on board cargo ships are quarantined when they are landed. If the quarantine identifies the presence of pest organisms, the cargo is disinfected by fumigating the landed cargo in warehouses, silos, or freight containers. Typically, HCN is used to fumigate fruits and vegetables in warehouses, while hydrogen phosphide (PH_3: generated by the reaction of aluminum phosphide and airborne moisture) is used to fumigate grain on board cargo ships.

Hazardous risks:

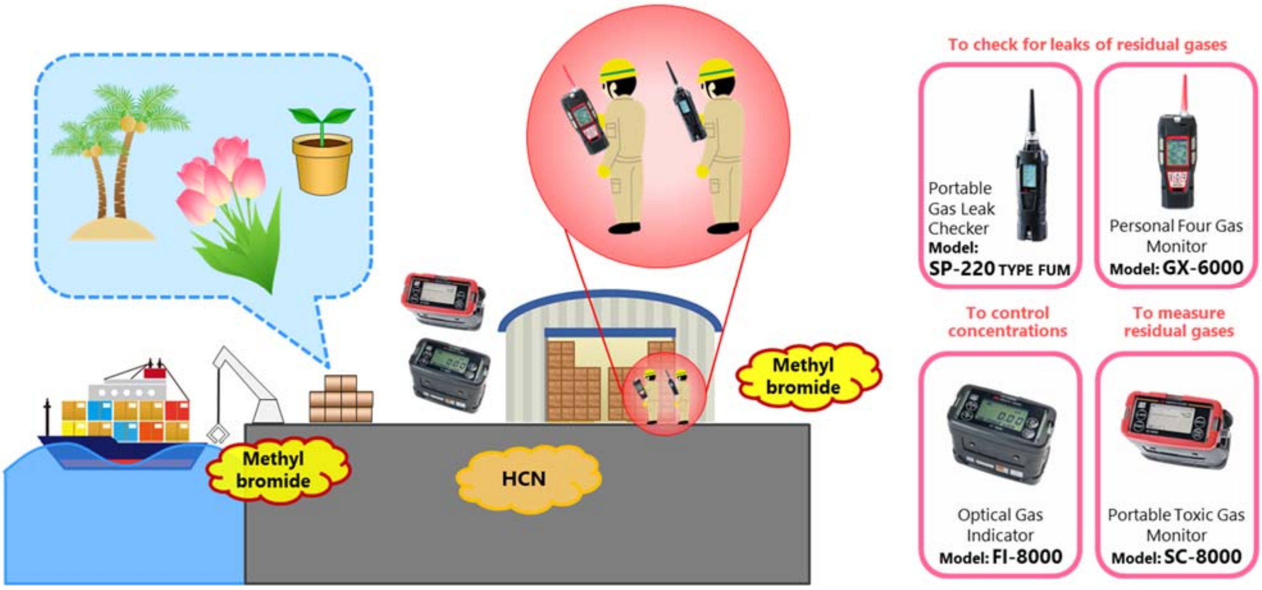
PH_3 remaining in freight containers or silos may cause poisoning.	⇒	**Checking residual concentrations of PH_3 in freight containers or silos to prevent PH_3 poisoning**
HCN remaining in warehouses may cause poisoning.	⇒	**Checking residual concentrations of HCN in warehouses to prevent HCN poisoning**
Rotting grain may cause oxygen deficiencies.	⇒	**Measuring oxygen concentrations to prevent oxygen deficiencies**



2-3: Fumigating agricultural products (3)

Description: Plants (trees, flowers, and seedlings), fruits, vegetables, and similar goods in cargo holds (e.g., freight containers) on board cargo ships are quarantined when they are landed. If pest organisms are found during the quarantine period, they are typically disinfected by fumigating the landed cargo in warehouses, silos, or freight containers. Typically, hydrogen cyanide (HCN) and methyl bromide (CH_3Br) are used to fumigate such agricultural products.
* Wood is fumigated with methyl bromide while on board the cargo ship with the hatch closed.

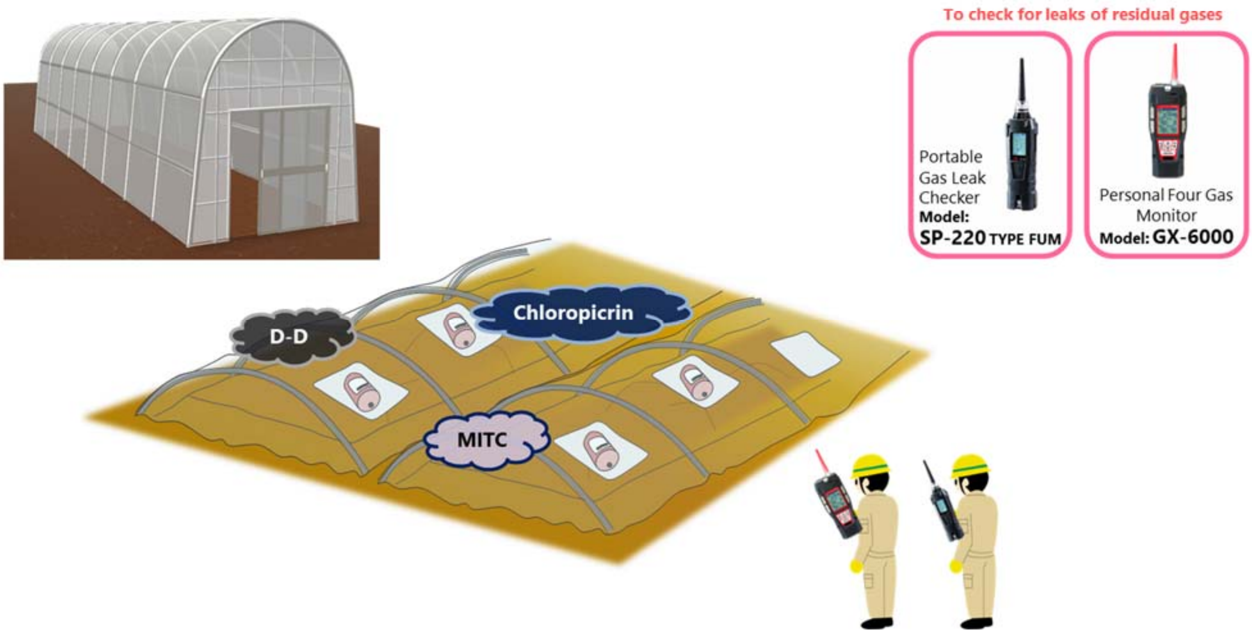
Hazardous risks: **HCN and CH_3Br may cause poisoning.** ⇒ **Detecting HCN and CH_3Br to prevent poisoning**



2-4: Fumigating farmland soil

Description: Continuous cropping of the same farmland enhances the propagation of pathogenic bacteria, nematodes, and viruses that can damage crops. The land needs to be treated by fumigation. Chloropicrin, dichloropropene (D-D), and MITC (methyl isocyanate) are typically used for soil fumigation.

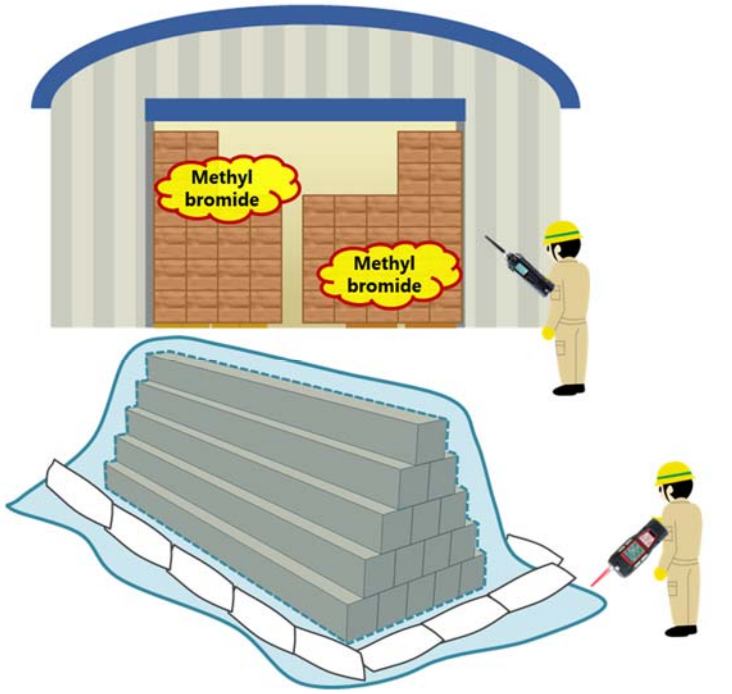
Hazardous risks: **Chloropicrin, D-D, and MITC may cause poisoning.** ⇒ **Detecting chloropicrin, D-D, and MITC to prevent poisoning**



2-5: Fumigating wood, packaging materials, and building materials

Description: Widely used as packaging or building materials, unprocessed wood can be infected by pest organisms. Any pest organisms found during the plant quarantine period are treated, typically by fumigation. Methyl bromide is often used for wood fumigation.
* Use of methyl bromide is prohibited for wood produced, distributed, or used in Japan.

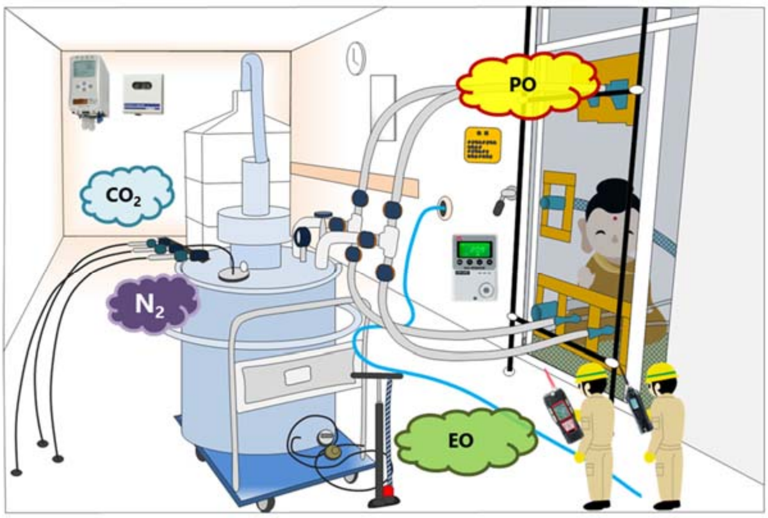
Hazardous risks: **Methyl bromide may cause poisoning.** ⇒ **Detecting methyl bromide to prevent poisoning**



2-6: Fumigating cultural assets and art objects

Description: Cultural assets and art objects are often exposed to daily changes in the environment and can degrade or sustain damage due to mold or pest organisms. As a countermeasure, they are often subjected to fumigation with propylene oxide (PO) or ethylene oxide (EO). In growing numbers of cases, fumigation with carbon dioxide or nitrogen is replacing fumigation with chemicals.

Hazardous risks: **PO and EO may cause poisoning. Carbon dioxide and nitrogen may cause poisoning or oxygen deficiencies.** ⇒ **Detecting PO, EO, and carbon dioxide to prevent poisoning Measuring oxygen concentrations to prevent oxygen deficiencies**



2-7: Fumigation for medical applications

Description: In facilities used to breed laboratory animals, biotechnology clean rooms, and laboratories that handle pathogens and pathogenic microorganisms, indoor sterilization is generally performed by formaldehyde (HCHO) fumigation.

Hazardous risks: **Formaldehyde may cause poisoning.** ⇒ **Detecting formaldehyde to prevent poisoning**

To control concentrations

Highly Sensitive Toxic Gas Monitor
Model: FP-330

To control concentrations

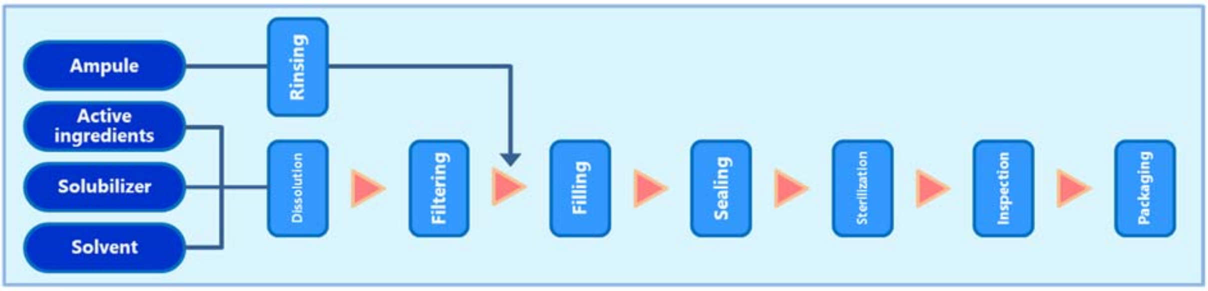
Formaldehyde Gas Detector
Model: FP-31

11-4. Applications in Pharmaceutical Market

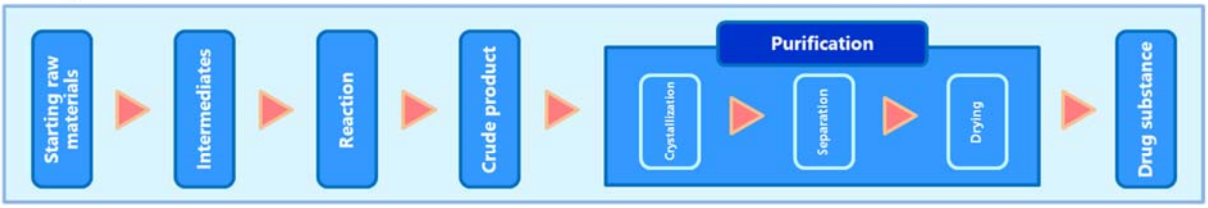
1. Overall flow of processes in pharmaceutical manufacturing plant

Solid drug

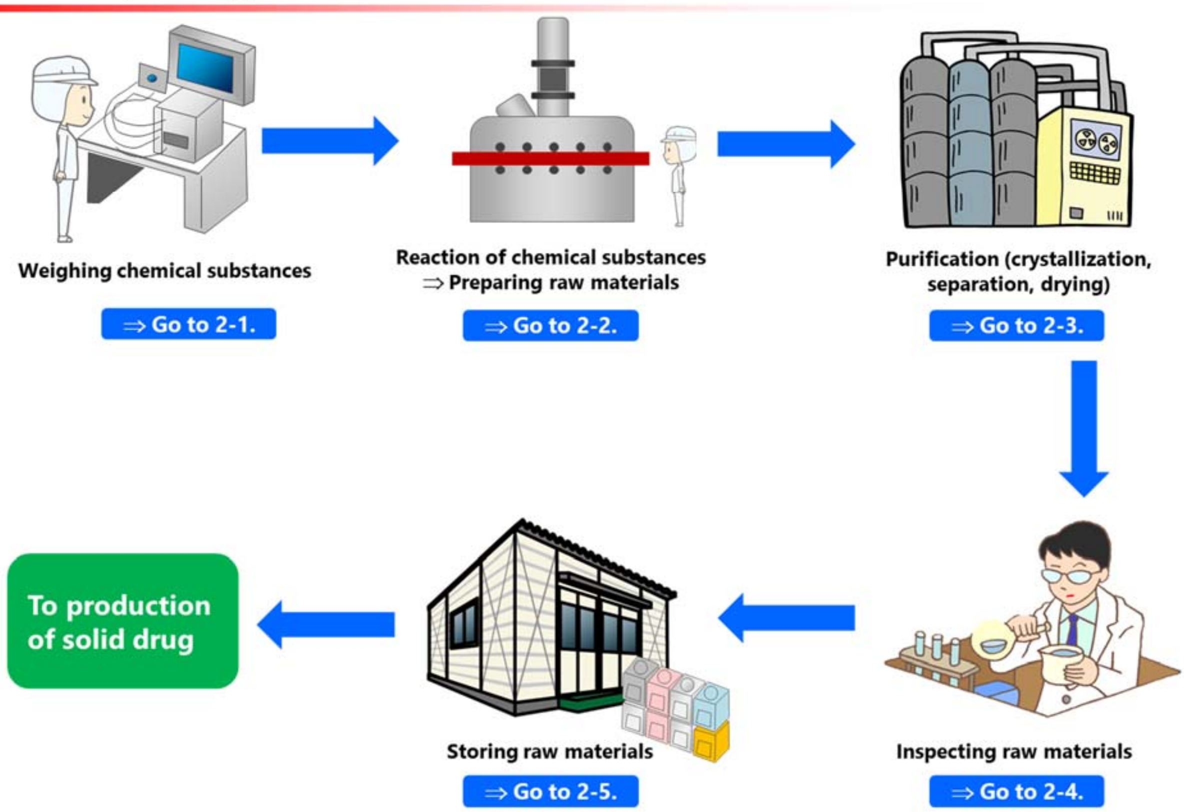
Injections



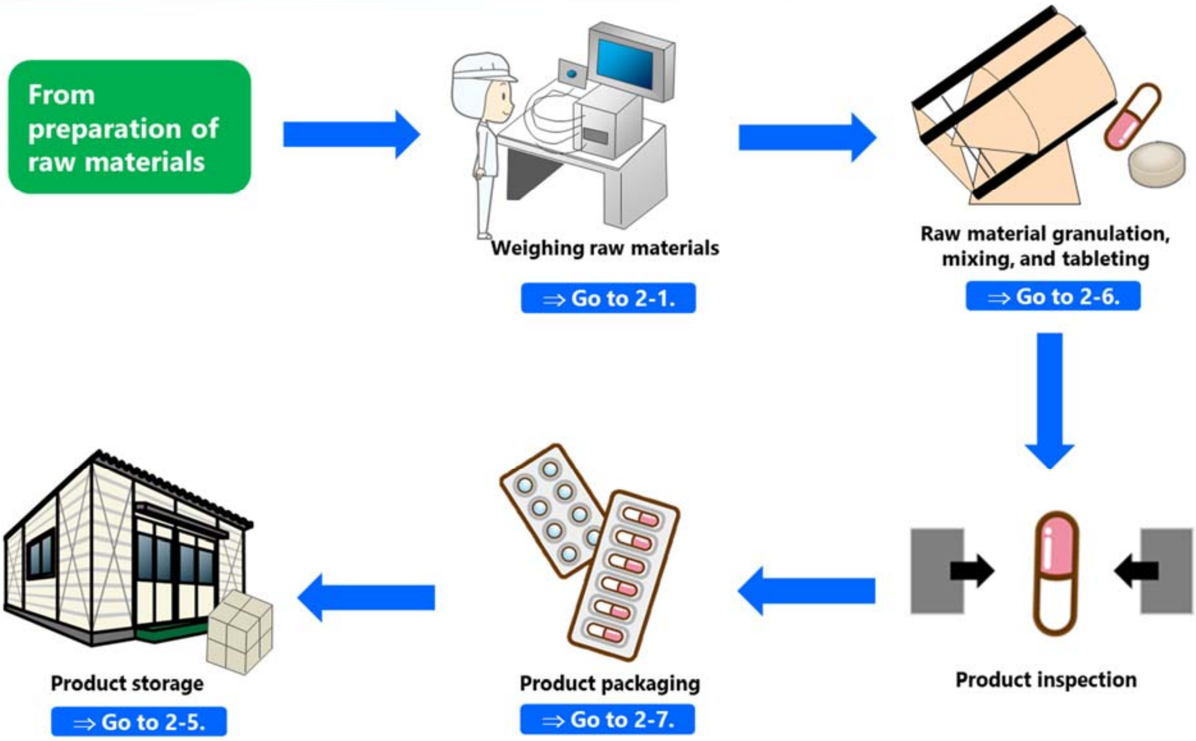
Drug substance



1-1: Preparing raw materials



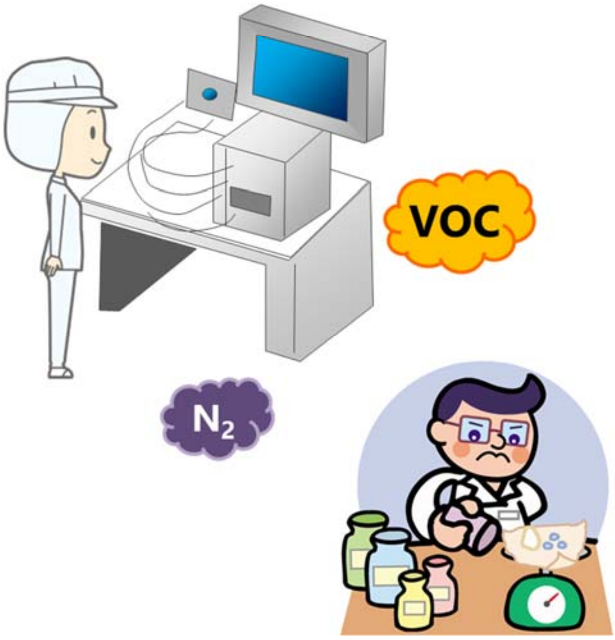
1-2: Producing solid drug



2-1: Weighing

Description: Volatile organic compounds (VOCs) are sometimes used when preparing raw materials or in the weighing process in producing the solid drug. Weighing is also performed with nitrogen substitution.

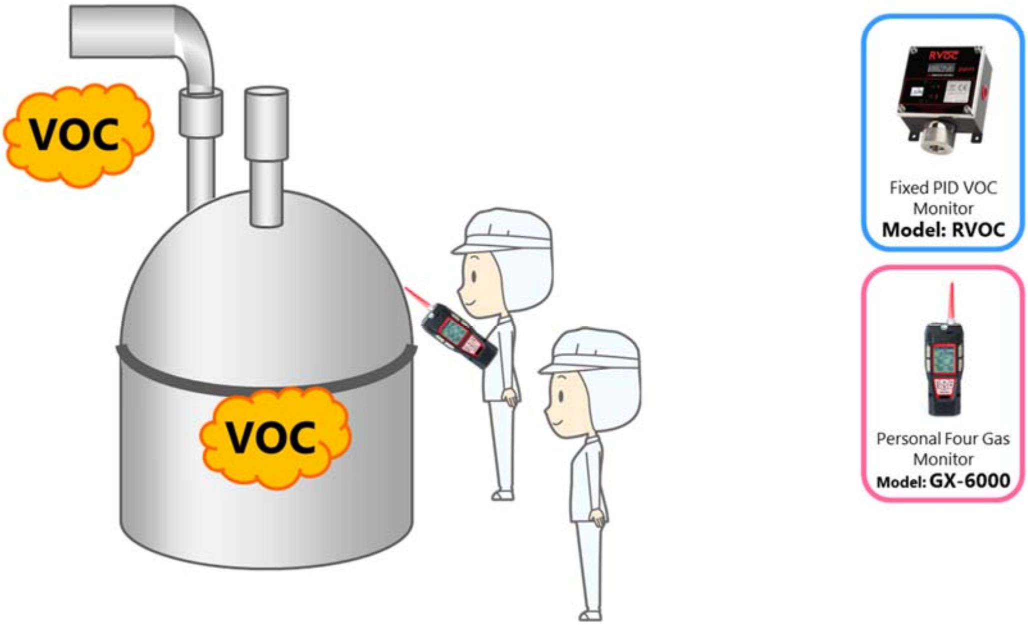
Hazardous risks: **VOCs may lead to poisoning, while nitrogen leaks may cause oxygen deficiencies.** ⇒ **Detecting VOCs to prevent poisoning**
Detecting oxygen concentration to prevent oxygen deficiencies



2-2: Reaction of chemical substances and preparing raw materials

Description: In reaction processes in which raw materials are placed in a reaction tank and mixed, the raw materials are heated and cooled to initiate the chemical reactions that create the required compounds.

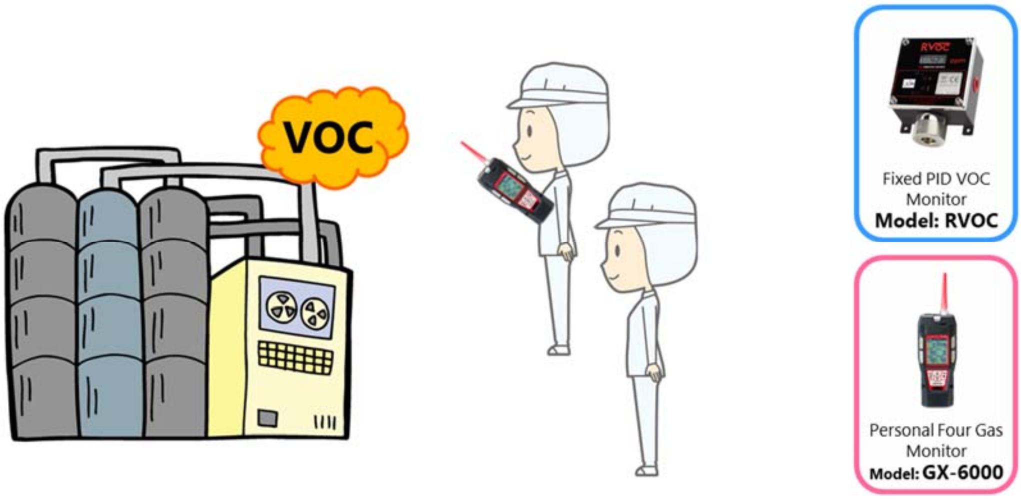
Hazardous risks: The volatile organic compounds (VOCs) generated in the reactions may lead to poisoning. ⇒ **Detecting VOCs to prevent poisoning**



2-3: Purifying raw materials

Description: The purification processes involve crystallization, separation, and drying. In the crystallization process, the compound is cooled and crystallized. In the separation process, the crystallized solution containing crystals is separated in a centrifugal separator to remove excess liquid and extract crystals. The separated crystals are dried in a vacuum dryer.

Hazardous risks: Volatile organic compounds (VOCs) occurring in the crystallized solution may lead to poisoning. ⇒ **Detecting VOCs to prevent poisoning**

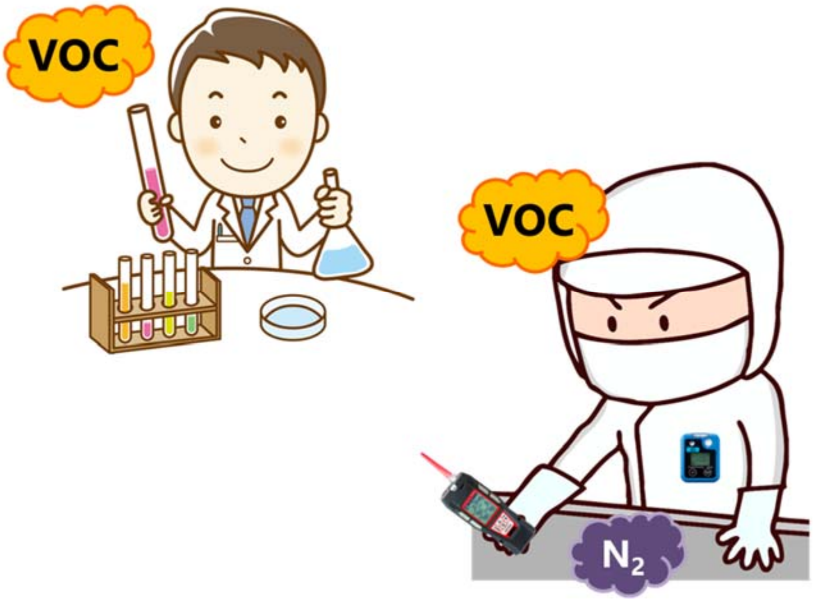


2-4: Inspecting raw materials

Description: The drug substance obtained is subjected to various analyses and tests to rigorously assess quality and safety.

Hazardous risks: **The volatile organic compounds (VOCs) used in the analyses and tests can lead to poisoning. Leaks of gases used in the analyzer or processes under nitrogen substitution such as those in a glove box may cause oxygen deficiencies.**

⇒ **Detecting VOCs to prevent poisoning**
Measuring oxygen concentrations to prevent oxygen deficiencies

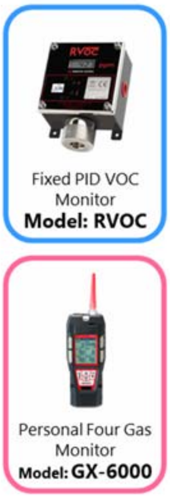


2-5: Storage

Description: The raw materials, completed ingredients, and final products are stored in suitable environments at temperatures from -80°C to room temperature.

Hazardous risks: **Scattering of raw materials and ingredients (such as volatile organic compounds) due to inappropriate storage may lead to poisoning. Insufficient ventilation in the storage warehouse may cause oxygen deficiencies.**

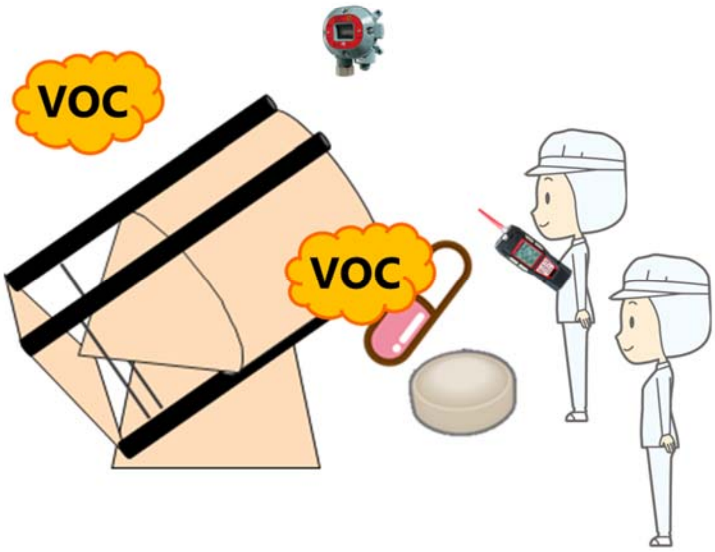
⇒ **Detecting VOCs to prevent poisoning**
Measuring oxygen concentrations to prevent oxygen deficiencies



2-6: Raw material granulation, mixing, and tableting

Description: The solid drug is produced through raw material granulation, mixing, and tableting.

Hazardous risks: **The volatile organic compounds (VOCs) generated during the processes may cause explosions or poisoning.** ⇒ **Detecting VOCs to prevent poisoning and explosions**



Fixed PID VOC Monitor
Model: RVOC

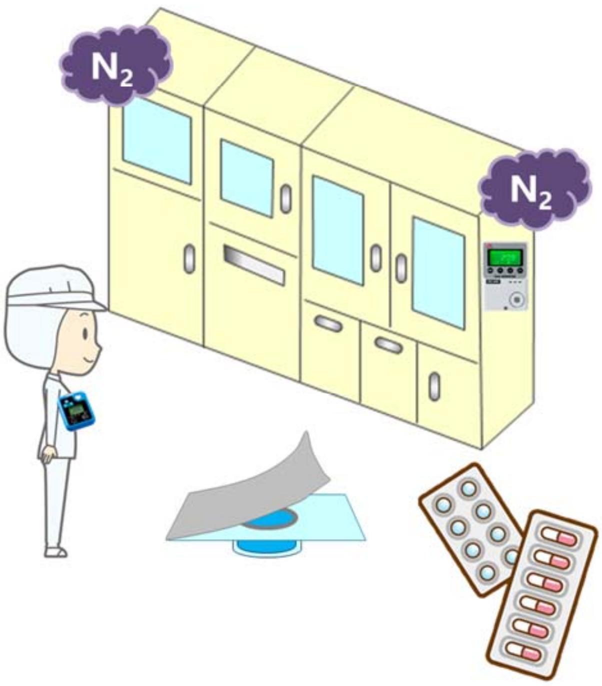
Smart Transmitter/ Gas Detector
Model: SD-1

Personal Four Gas Monitor
Model: GX-6000

2-7: Product packaging

Description: Some products that have passed inspection and are being packaged are nitrogen packed.

Hazardous risks: **N_2 leaks during nitrogen packing may result in oxygen deficiencies.** ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**

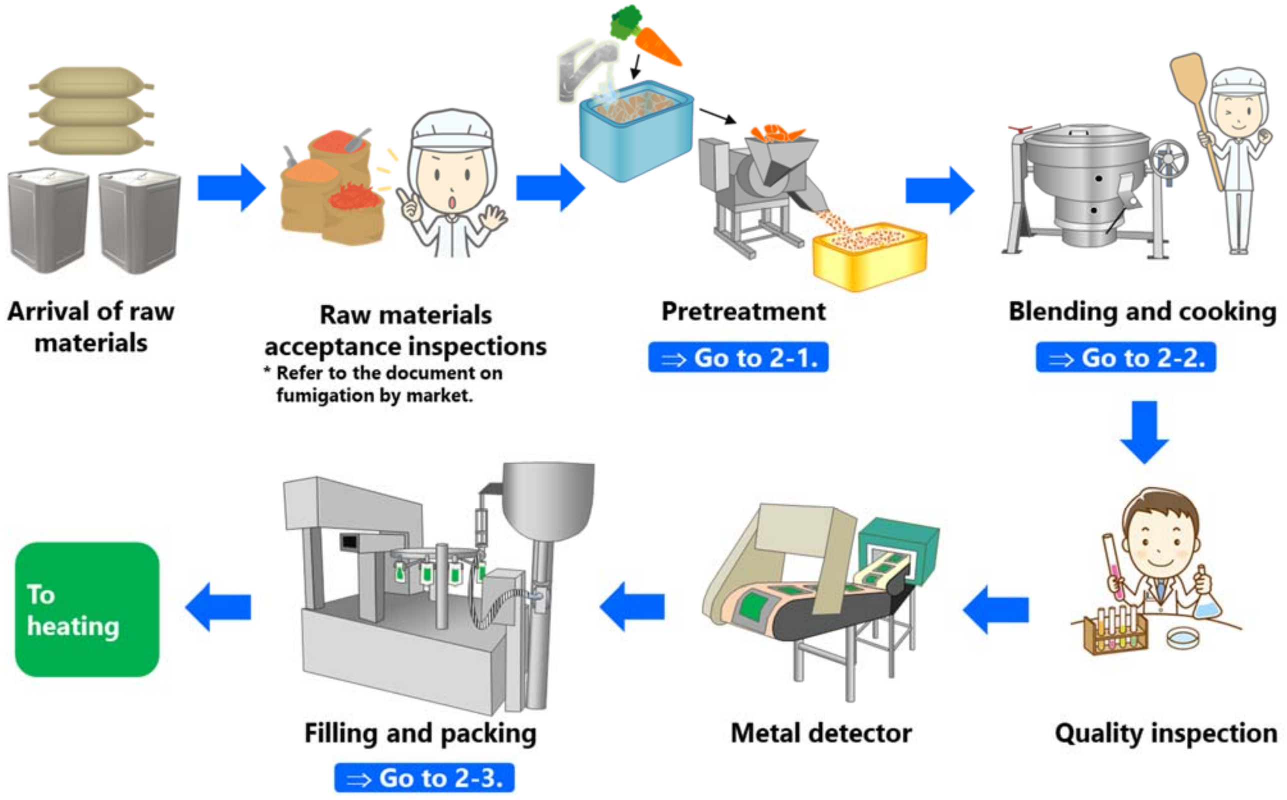


Indoor Oxygen Monitor
Model: OX-600

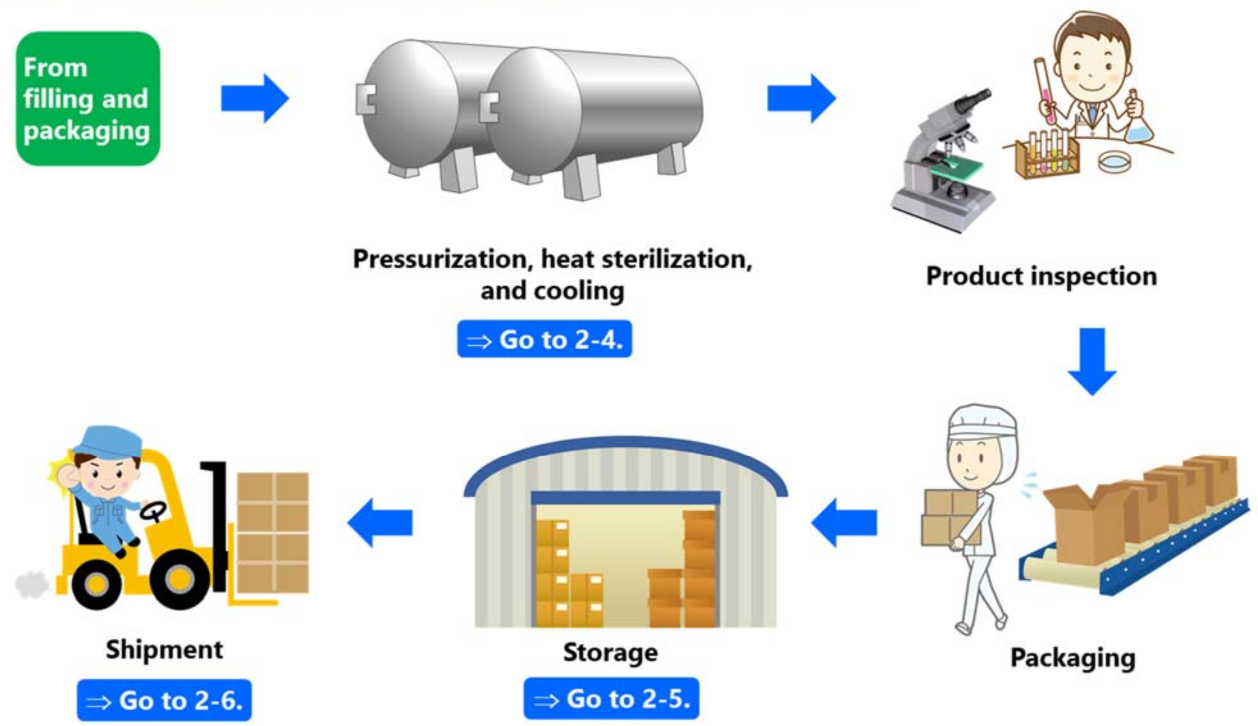
Personal Single Gas Monitor
Model: OX-03

11-5. Applications in Food Product

1-1: Arrival of raw materials to filling and packing



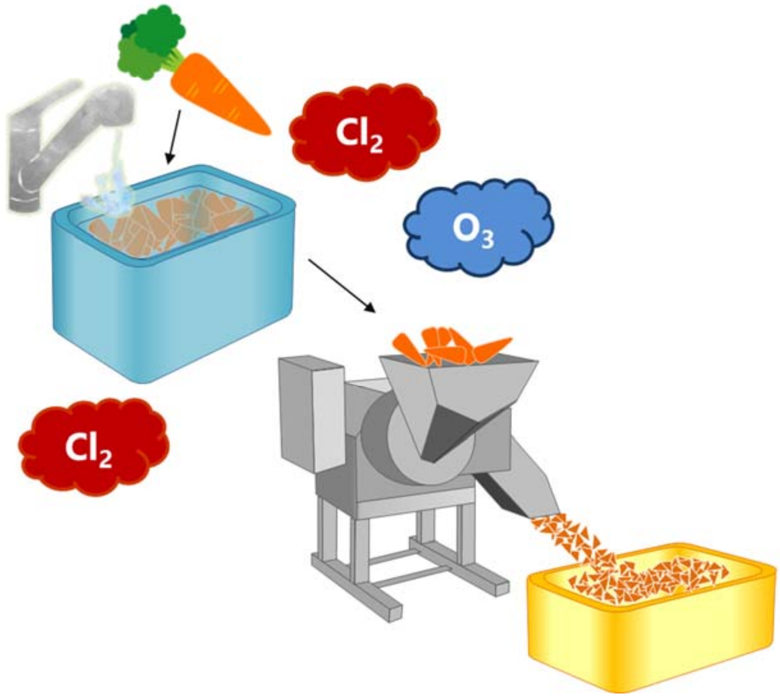
1-2: From pressurization to shipment



2-1: Pretreatment

Description: The materials are pretreated by washing and cutting.

Hazardous risks: **Sodium hypochlorite (specifically, the chlorine generated therefrom) and ozone used to wash and sterilize raw materials may result in cases of poisoning.** ⇒ **To prevent poisoning due to the chlorine and ozone generated**

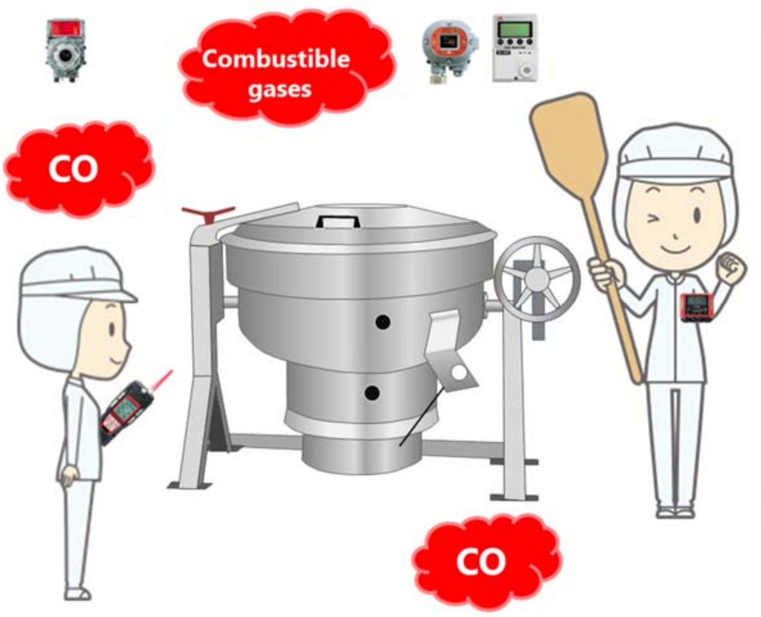


2-2: Blending and cooking

Description: The materials and seasoning are weighed and placed in a cooking vessel, then heated and cooked by sauteing, boiling, mixing, and stewing.

Hazardous risks: **During heating and cooking processes, CO generated from the materials and cooking combustion may cause CO poisoning.** ⇒ **Detecting CO to prevent poisoning**

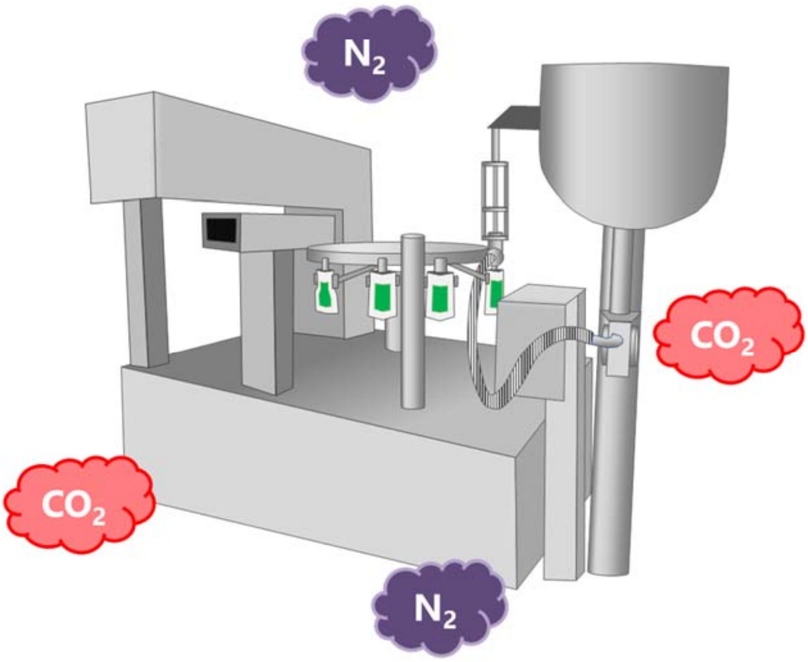
LPG and town gas generated from the cooking equipment used to heat the materials may cause explosions. ⇒ **To prevent explosions caused by LPG and town gas leaks**



2-3: Filling and packaging ①

Description: After the cooked food passes through the metal detector, the filling machine fills the retort pouch with a predetermined amount of food, degases the pouch, and seals the pouch by melting with heat. At the same time, it prints the best-before date.
* Supplementary information: De-aerated ice may be used to maintain freshness even during storage.

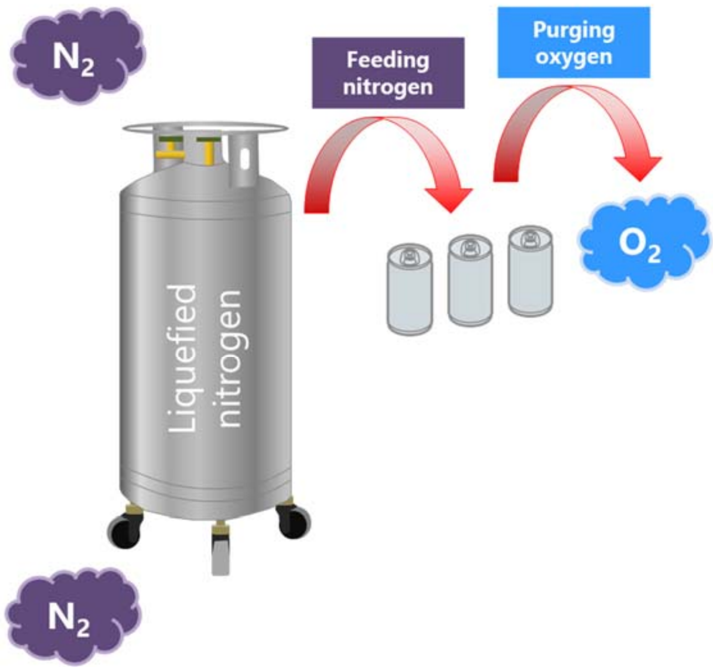
Hazardous risks: Nitrogen and carbon dioxide leaks during vacuum sealing may cause oxygen deficiencies. ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**



2-3: Filling and packaging ②

Description: In the filling and packaging process, oxygen is purged by feeding nitrogen to maintain freshness and enable long-term storage. Liquefied nitrogen is used as the source of this nitrogen.

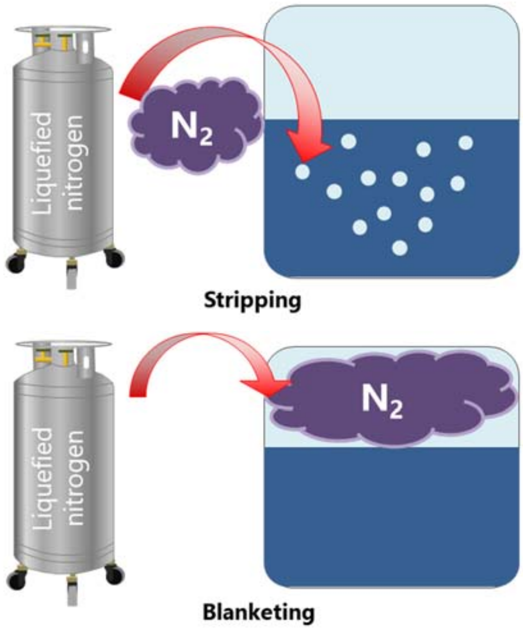
Hazardous risks: Purging oxygen with liquid nitrogen to seal the aluminum may cause oxygen deficiencies. ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**



2-3: Filling and packaging ③

Description: To maintain food quality, the oxygen dissolved during processing must be removed. The dissolved oxygen is removed by stripping, which introduces high-purity nitrogen gas into processing water to remove oxygen from the processing water. Nitrogen gas can also be used to prevent the oxidation of oil and other ingredients by blanketing, which isolates the product or raw materials from air to prevent quality deterioration.

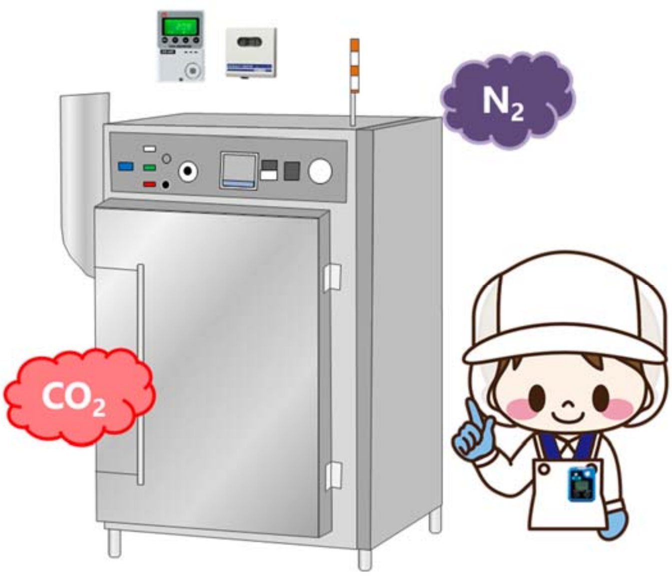
Hazardous risks: **Nitrogen used in stripping and blanketing may cause oxygen deficiencies.** ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**



2-4: Pressurization, heat sterilization, and cooling ①

Description: According to the Food Sanitation Act, for retort food whose pH exceeds 4.6 and whose water activity exceeds 0.94, all microorganisms in the product must be killed by heating the central portion at 120°C for 4 minutes or by other equivalent or more effective methods. If the food cannot be heated, it can be sterilized by cooling. These processes render the product preservable at room temperature.

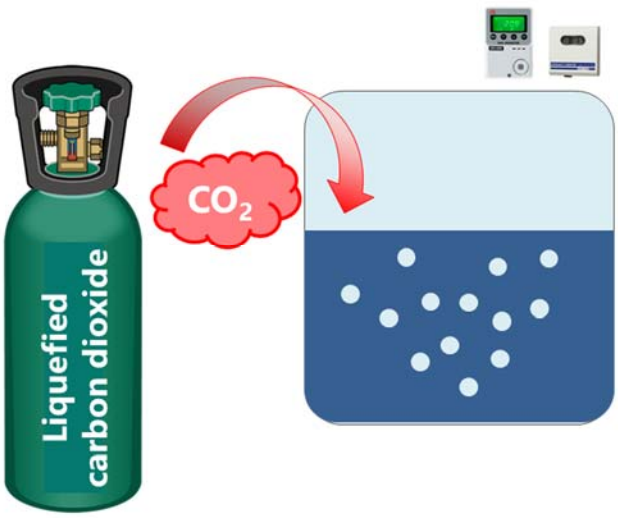
Hazardous risks: **Using liquid nitrogen or carbon dioxide gas for instant freezing may cause oxygen deficiencies or cause CO_2 poisoning.** ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**
Measuring CO_2 concentrations to prevent poisoning



2-4: Pressurization, heat sterilization, and cooling ②

Description: According to the Food Sanitation Act, for retort food whose pH exceeds 4.6 and whose water activity exceeds 0.94, all microorganisms in the product must be killed by heating the central portion at 120°C for 4 minutes or by other equivalent or more effective methods. One method is sterilization/bacteriostasis using liquefied carbon dioxide.

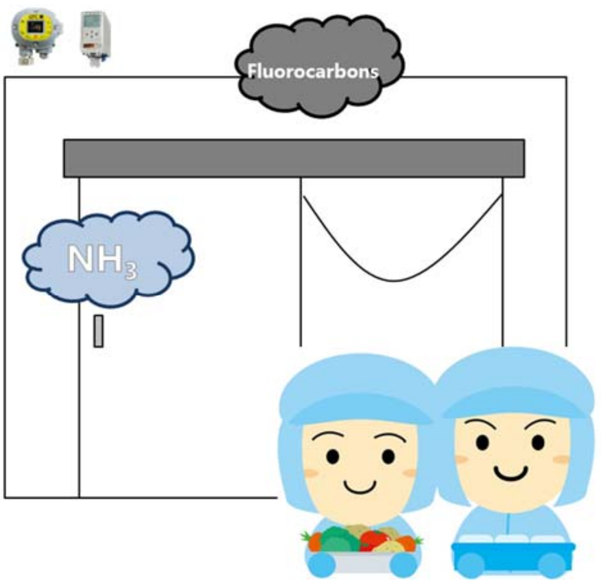
Hazardous risks: **Sterilization and bacteriostasis with carbon dioxide may cause oxygen deficiencies or cause CO_2 poisoning.** ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**
Measuring CO_2 concentrations to prevent poisoning



2-5: Storage ①

Description: Fluorocarbons and ammonia are sometimes used as coolants for the refrigerated storage of raw materials, prepared materials, and products.

Hazardous risks: **Using fluorocarbons and ammonia as coolants for refrigerated storage poses the risk of poisoning.** ⇒ **Measuring fluorocarbon and ammonia concentrations to prevent poisoning**



2-5: Storage ②

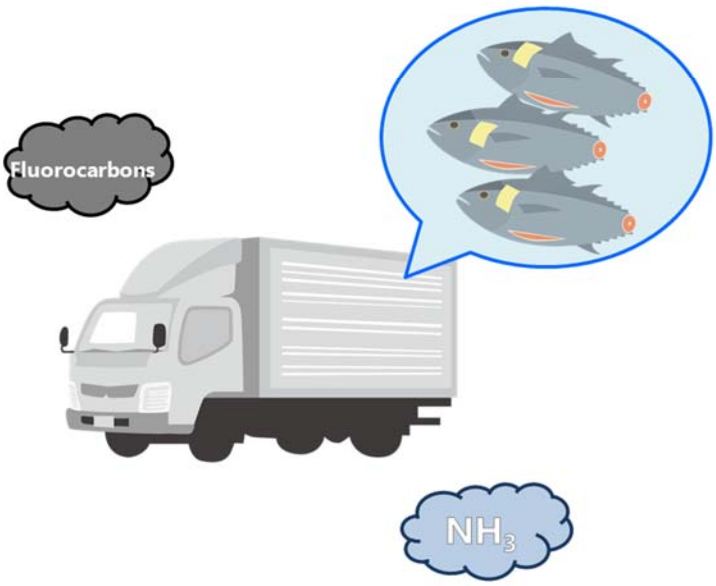
Description: Controlled atmosphere (CA) storage adjusts concentrations of atmospheric oxygen, nitrogen, and carbon dioxide (by pressure control) and minimizes breathing of the stored fruits and vegetables to suppress loss of freshness during storage.

Hazardous risks: **Leaks of nitrogen and carbon gas used during the CA storage may cause oxygen deficiencies or poisoning.** ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**
Measuring CO_2 concentrations to prevent poisoning

2-6: Transportation ①

Description: Fluorocarbons and ammonia are the most popular coolants for the refrigerators and freezers used in truck transportation.

Hazardous risks: **The gases generated from the fluorocarbons and ammonia used as coolant in truck transportation may result in cases of poisoning or oxygen deficiencies.** ⇒ **Measuring fluorocarbon and ammonia concentrations to prevent poisoning**
Measuring oxygen concentrations to prevent oxygen deficiencies

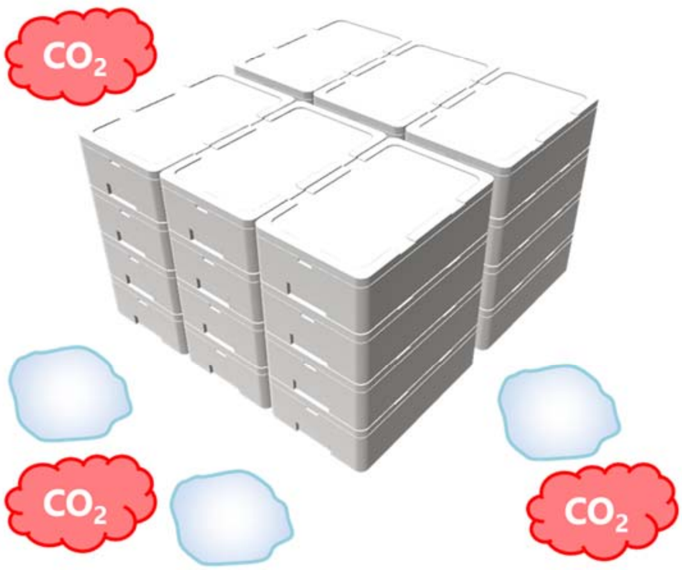


2-6: Transportation ②

Description: Dry ice is the most popular refrigerating agent used during transportation.

Hazardous risks: **CO_2 generated from the dry ice used as the refrigerating agent during transportation may result in cases of poisoning or oxygen deficiencies.**

⇒ **Measuring CO_2 concentrations to prevent poisoning**
Measuring oxygen concentrations to prevent oxygen deficiencies

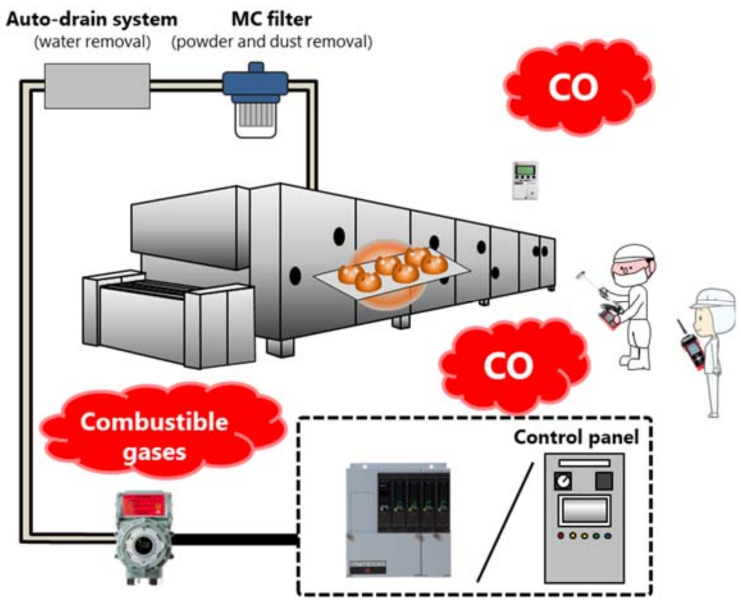


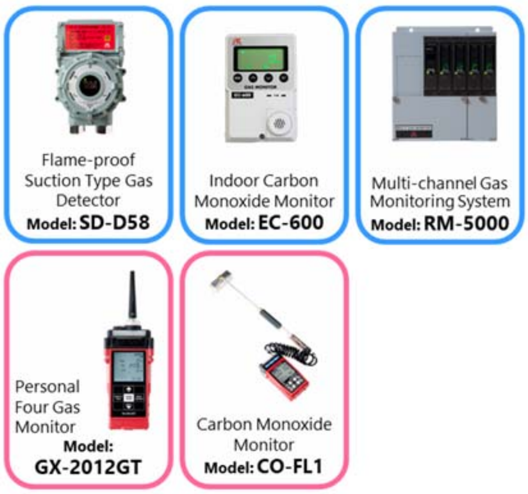
2-7: Other processes ① Bread baking

Description: Baking in a bread factory requires fuel.

Hazardous risks: **Fuel for the baking machine may leak.**
Baking may cause fire.
The carbon monoxide (CO) generated by incomplete combustion during baking may result in cases of poisoning.

⇒ **Preventing explosions involving combustible gases**
⇒ **Detecting fire to prevent the spread of fire**
⇒ **Detecting CO to prevent poisoning**

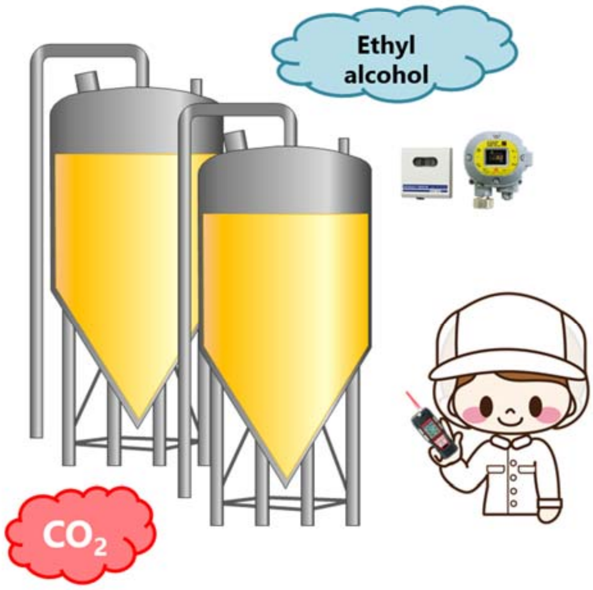




2-7: Other processes ② Beer production

Description: During the beer fermentation process, yeast coverts most of the sugar in the wort into alcohol (ethyl alcohol) and carbon dioxide.

Hazardous risks: **Alcohol and carbon dioxide (CO_2) generated during beer fermentation may cause poisoning.** ⇒ **Measuring concentrations of ethyl alcohol and CO_2 to prevent poisoning**

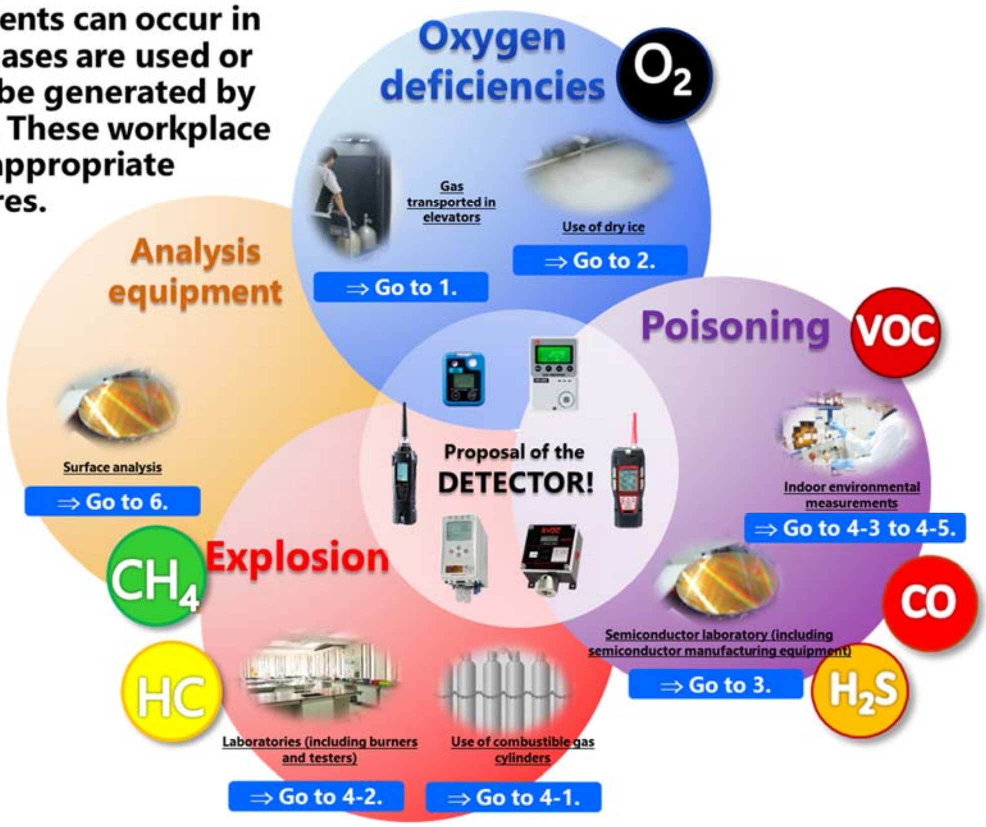


11-6. Applications at Universities and Research Institutions

Hazardous areas hidden in research facilities

Unexpected accidents can occur in any areas where gases are used or where gases may be generated by specific reactions. These workplace hazards demand appropriate protective measures.

Riken Keiki proposes gas detectors and alarms to safeguard against such accidents.



1. Carrying cryogens in elevators

Description:	When carrying cylinders of cryogen (such as liquid nitrogen) on a hand cart, etc., a carrier may use elevators.

Hazardous risks: **Leaks of cryogens (e.g., liquid nitrogen) from the cylinder if the container is overturned may cause oxygen deficiencies in the elevator.** ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**

2. Dry ice used to cool objects in experiments

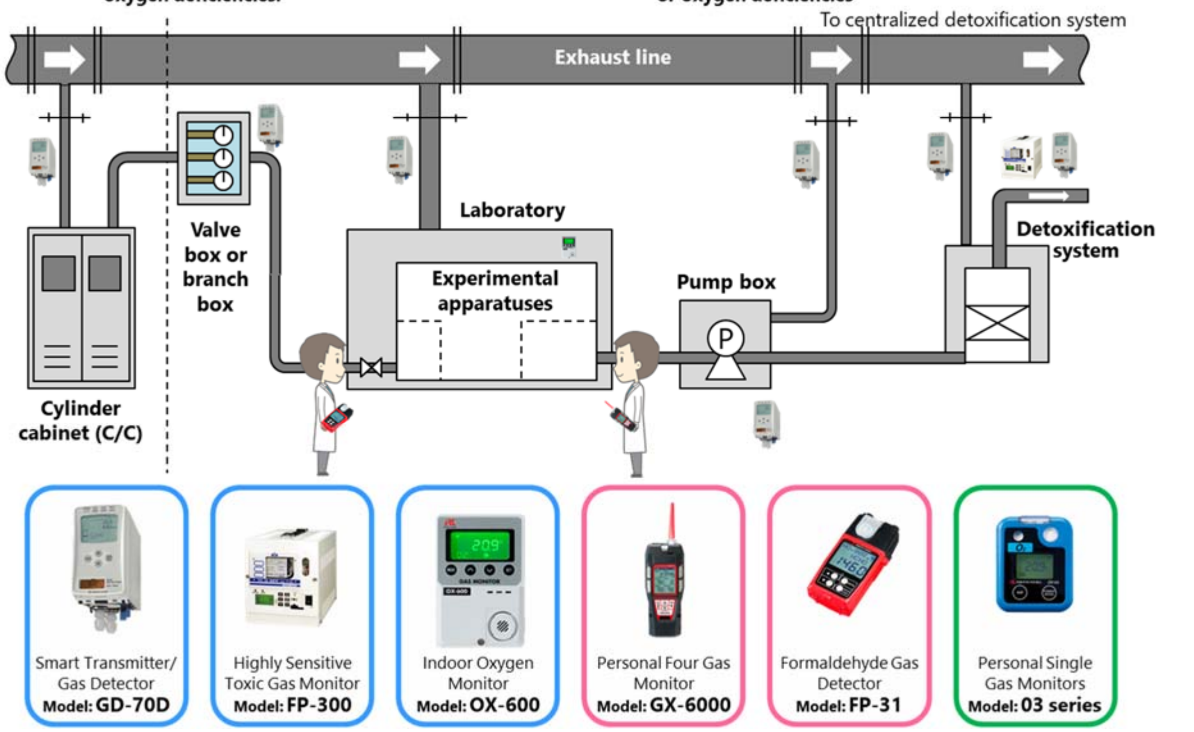
Description: Substances like dry ice (CO_2) are used to cool chemicals used in experiments.

Hazardous risks: **The CO_2 generated by dry ice sublimation may cause CO_2 poisoning or oxygen deficiencies.** ⇒ **Detecting CO_2 to prevent poisoning Measuring oxygen concentrations to prevent oxygen deficiencies**

3. Semiconductor laboratory

Description: In semiconductor laboratories, researchers seek to improve semiconductor products in processes that involve the use of semiconductor material gases.

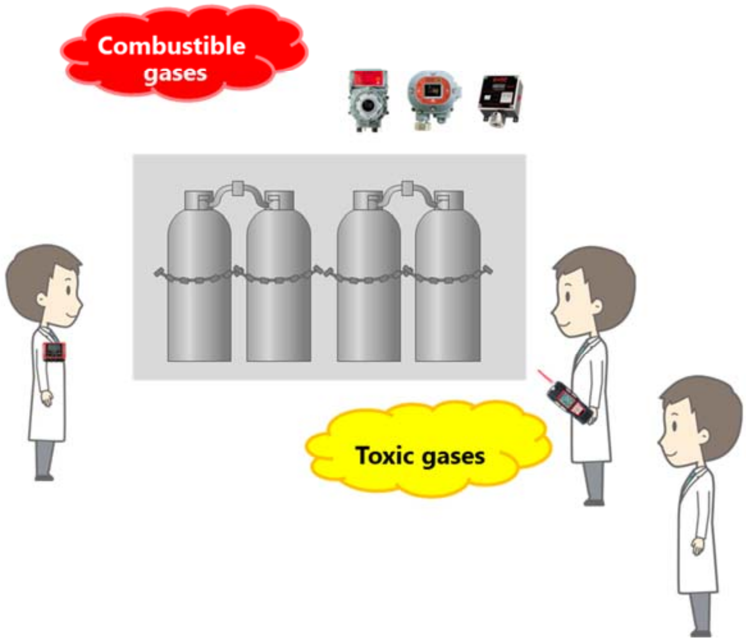
Hazardous risks: **Semiconductor material gases may cause poisoning or oxygen deficiencies.** ⇒ **Detecting semiconductor material gases to prevent poisoning or oxygen deficiencies**



4-1: Use of gas cylinders

Description: Some laboratories are equipped with cylinders of combustible or toxic gases required for experiments.

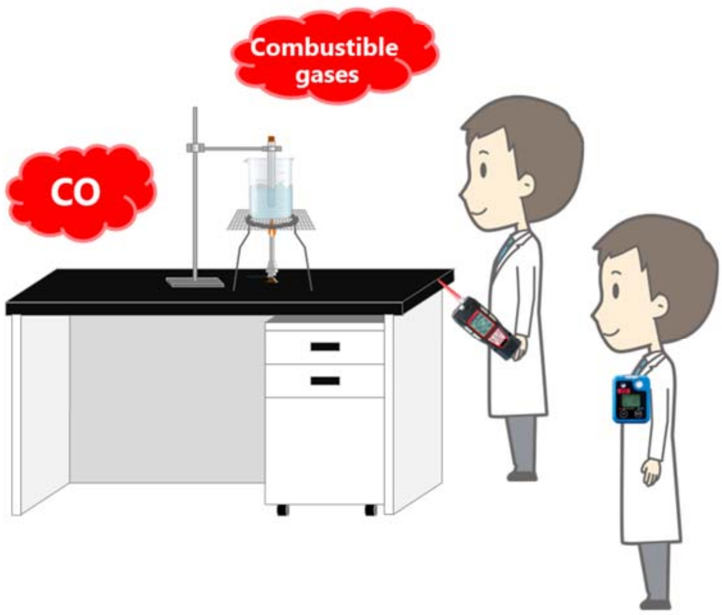
Hazardous risks: **Gas leaks from combustible or toxic gas cylinders may cause explosions or poisoning.** ⇒ **Detecting combustible gases to prevent explosions**
Detecting toxic gases to prevent poisoning



4-2: Use of burners in heating test

Description: Burners fueled by town gas, propane gas, and other combustible gases may be used in heating tests.

Hazardous risks: **Leaks of town gas, propane gas, and other combustible gases from burners may cause explosions.**
Incomplete combustion of burner fuel may cause CO poisoning. ⇒ **Detecting town gas, propane gas, and other combustible gases to prevent explosions**
Detecting CO to prevent poisoning

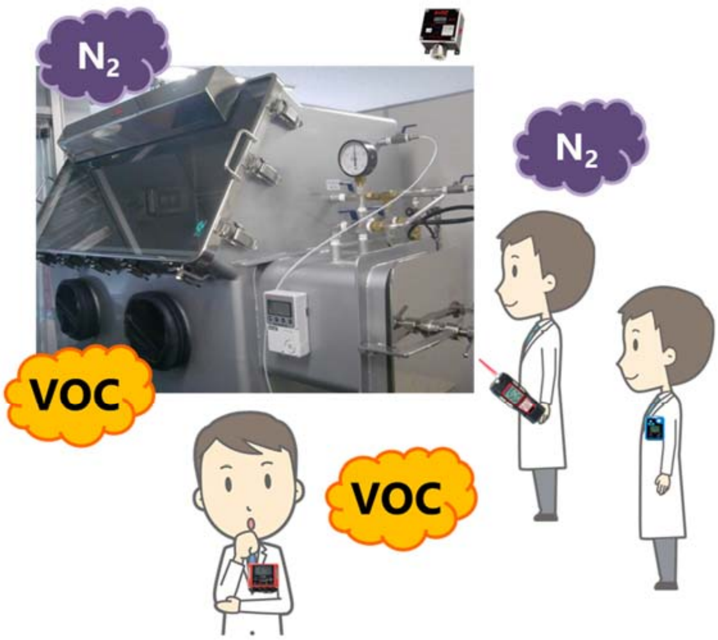


4-3: Experiments involving use of glove box

Description: A glove box is used to handle substances unstable in air via gloves by filling the inside of the box with N_2 or other inert gas of high purity.

Hazardous risks: **N_2 leaks from the glove box may cause oxygen deficiencies. Volatile organic compounds (VOCs) evaporating from organic solvents handled in the glove box may result in cases of poisoning.**

⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**
Detecting VOCs to prevent poisoning

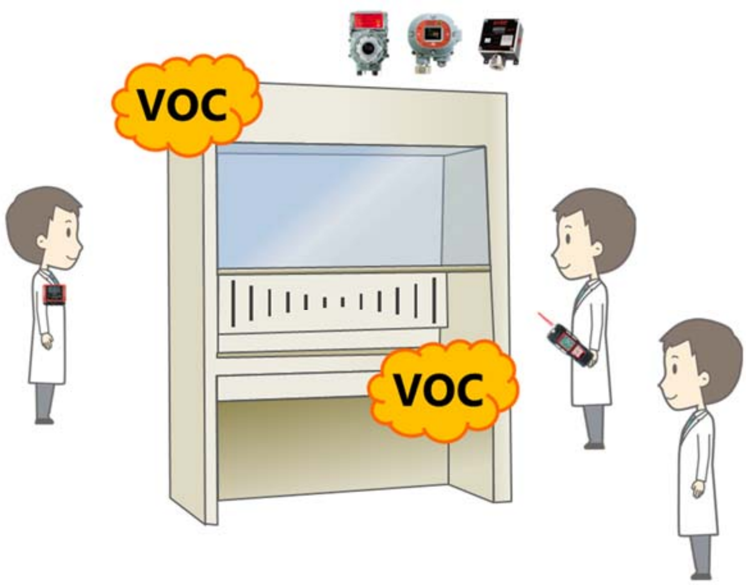


4-4: Tests using draft chamber

Description: A draft chamber is local ventilation equipment that ensures the safety of workers (such as researchers) by discharging toxic gases generated when using organic solvents in the draft chamber from the room.

Hazardous risks: **During the treatment of waste organic solvents, spills or evaporated volatile organic compounds (VOCs) may cause explosions, poisoning, or oxygen deficiencies.**

⇒ **Detecting VOCs to prevent explosions or poisoning**

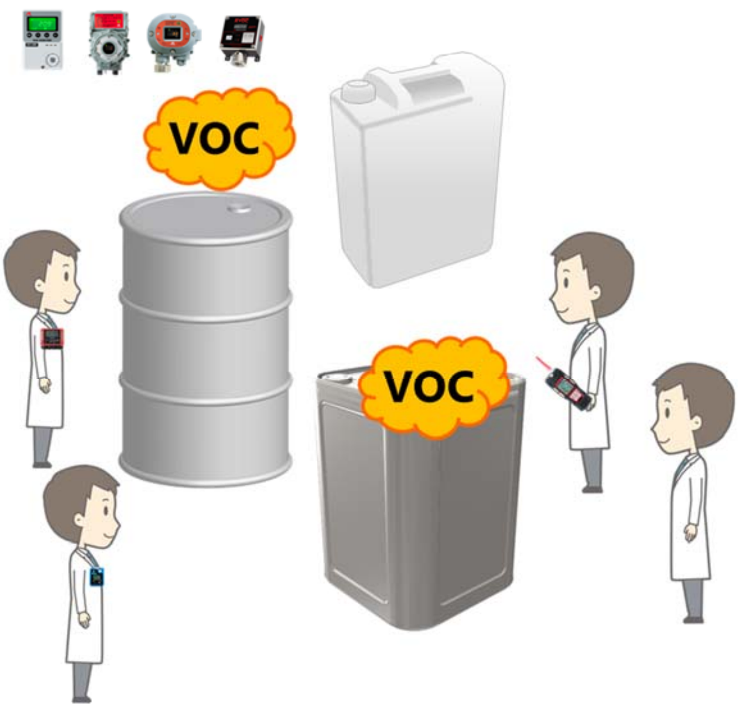


4-5: Risks around waste liquid storage area

Description: In the waste liquid storage area, plastic containers and drums containing various waste organic solvents are stored until treatment or disposal.

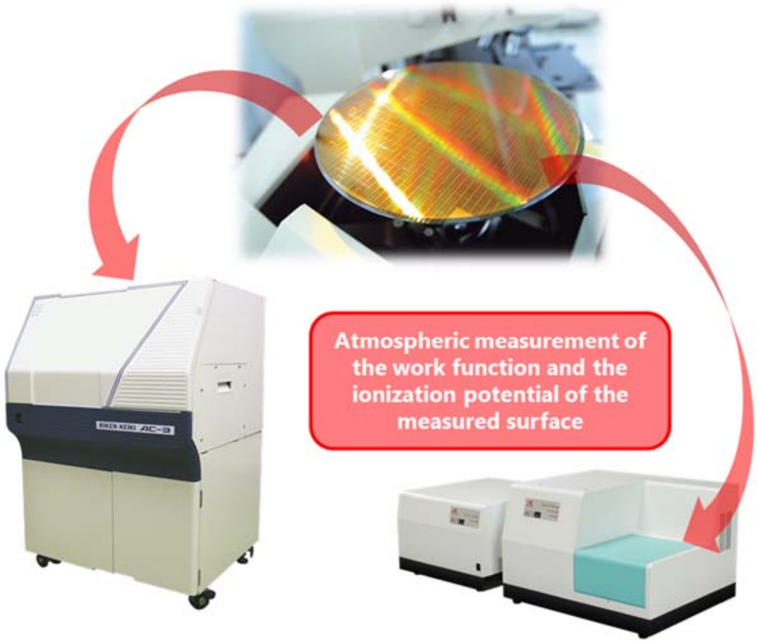
Hazardous risks: **During the treatment of waste organic solvents, spills or evaporated volatile organic compounds (VOCs) may cause explosions, poisoning, or oxygen deficiencies.**

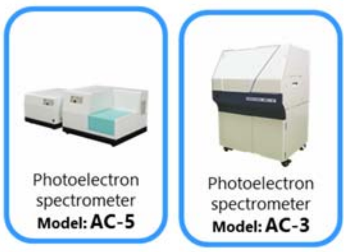
⇒ **Detecting VOCs to prevent explosions, poisoning, or oxygen deficiencies**



5. Analysis equipment for research

Description: To select and manage the materials for charge transfer devices, including organic solar cells, organic EL, organic transistors, and drums for copying machines, the energy level of the highest occupied molecular orbital (HOMO) of the material is important, creating a need to measure HOMO levels. Additionally, glass plates on which transparent conductive oxide (such as ITO, FTO, and SnO_2) films are formed are used as electrodes for displays and solar cells. The extent of the contamination of the surface of the glass plate can be checked by assessing changes in work function.



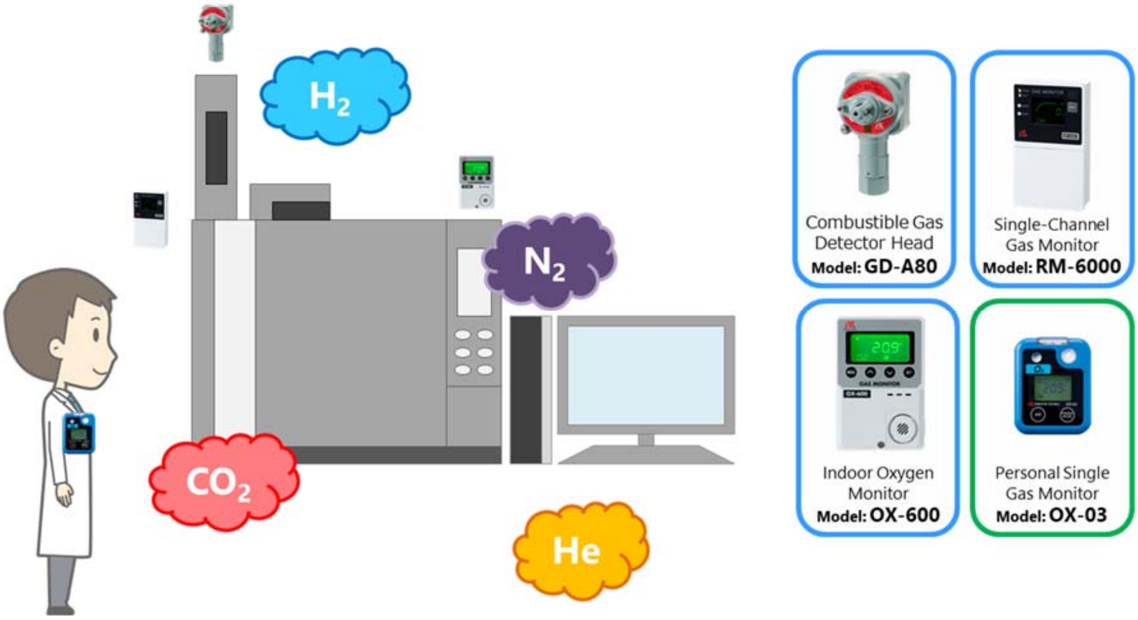


6. Gases used in analysis equipment

Description: Experiments using analysis equipment (such as gas chromatography) may use substances such as dry ice, nitrogen (including liquid nitrogen), helium, and H_2.

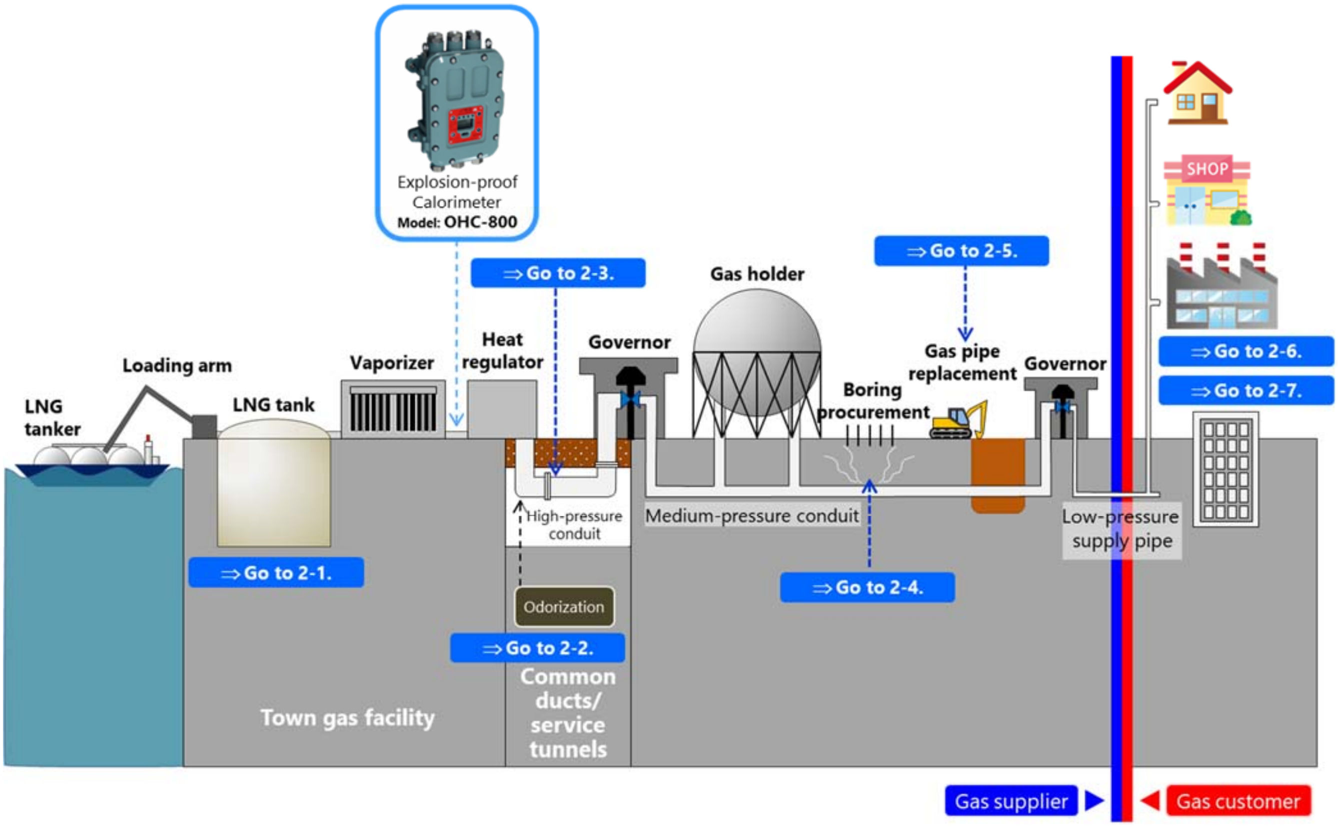
Hazardous risks: **The accumulation of gases generated from dry ice, nitrogen (including liquid nitrogen), and helium may cause oxygen deficiencies.** ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**

Combustible gases (such as H_2) used as carrier gas may cause explosions. ⇒ **Explosion monitoring of combustible gases to prevent explosions**



11-7. Applications in Gas Market

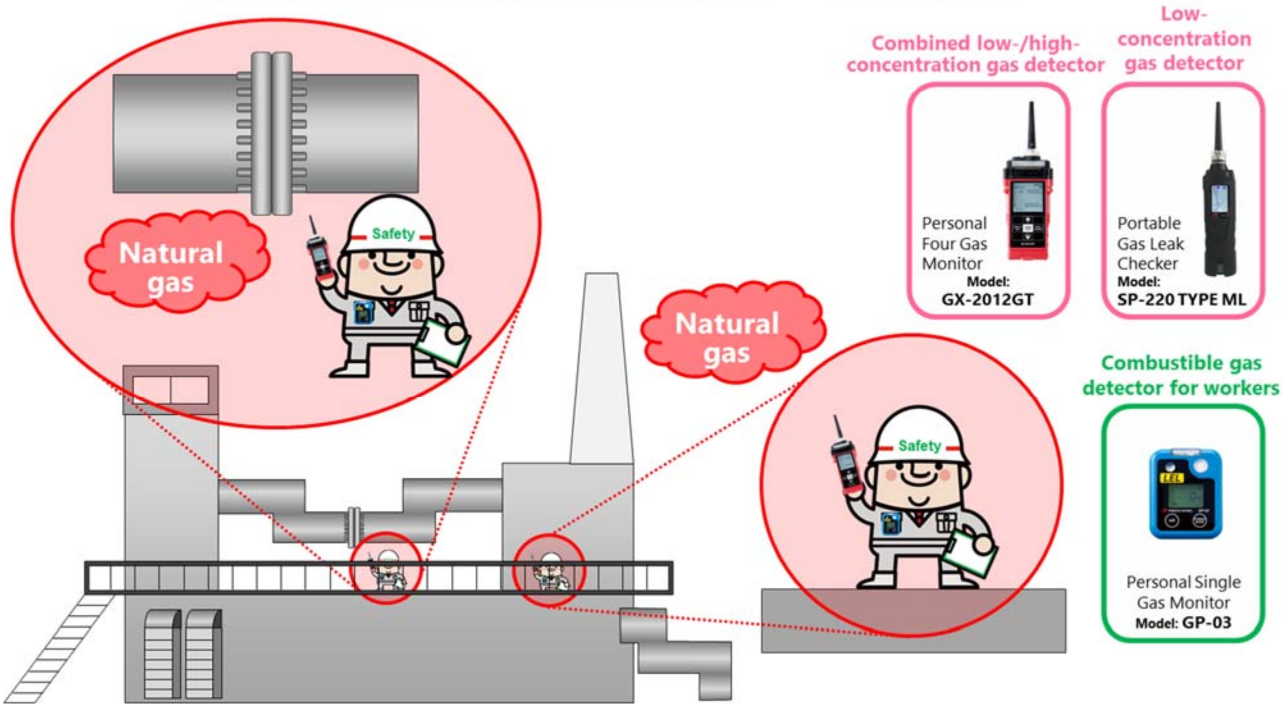
1. Overview of processes in gas market



2-1: Detecting leaks from pipe joints and related facilities

Description: Town gas plants typically have vaporizer facilities that spray seawater over containers of liquefied natural gas (LNG) to heat and return the LNG to a gaseous state. Since LNG liquefies at the ultralow temperature of -162°C, it's readily vaporized by spraying seawater.

Hazardous risks: **Natural gas leaking from joints within town gas plants—for example, at LNG tanks or vaporizers—poses explosion risk.** ⇒ **Detecting natural gas to prevent explosions**

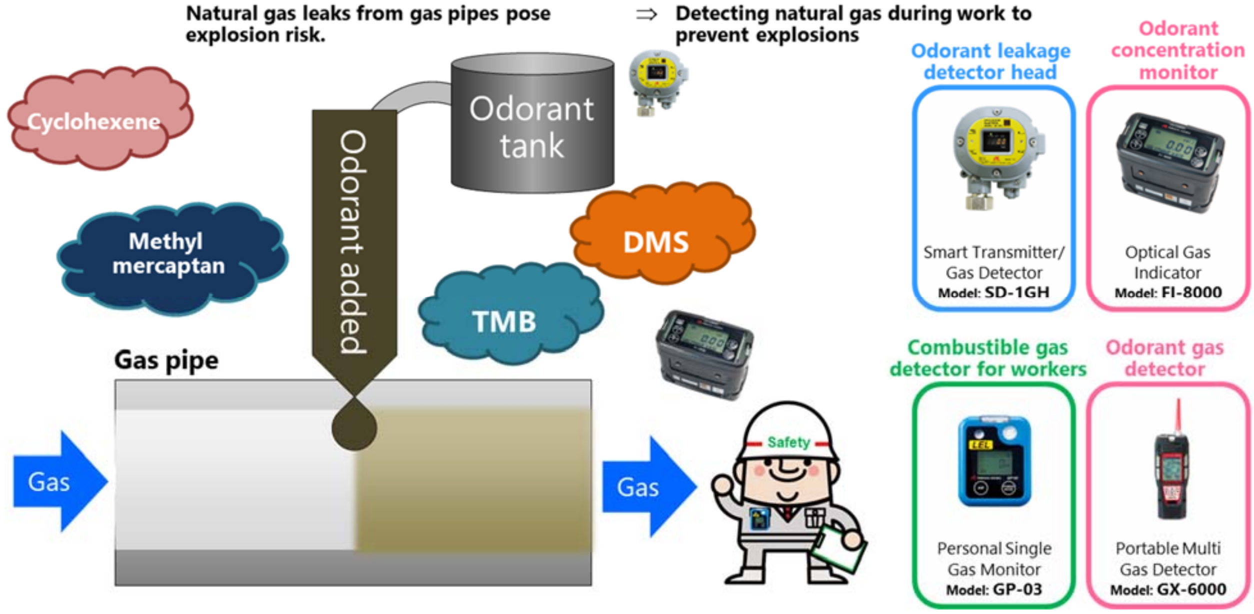


2-2: Detecting and measuring odorant leaks

Description: The process of liquefying natural gas into LNG removes sulfur, moisture, and dust and produces a colorless, transparent, odorless liquid. Since LNG remains odorless when it reverts to gas, an odorant is added to help detect gas leaks.

Hazardous risks:

- **Leaks from odorant tank pose risk of poisoning.** ⇒ **Detecting cyclohexene (C_6H_{10}), TBM ($C_4H_{10}S$), DMS (C_2H_6S), and methyl mercaptan (CH_3SH) in odorant to prevent poisoning**
- **Inadequate purging of odorant facilities during maintenance may lead to excessive odorant consumption.** ⇒ **Measuring odorant constituents to make odorant use more efficient**
- **Natural gas leaks from gas pipes pose explosion risk.** ⇒ **Detecting natural gas during work to prevent explosions**

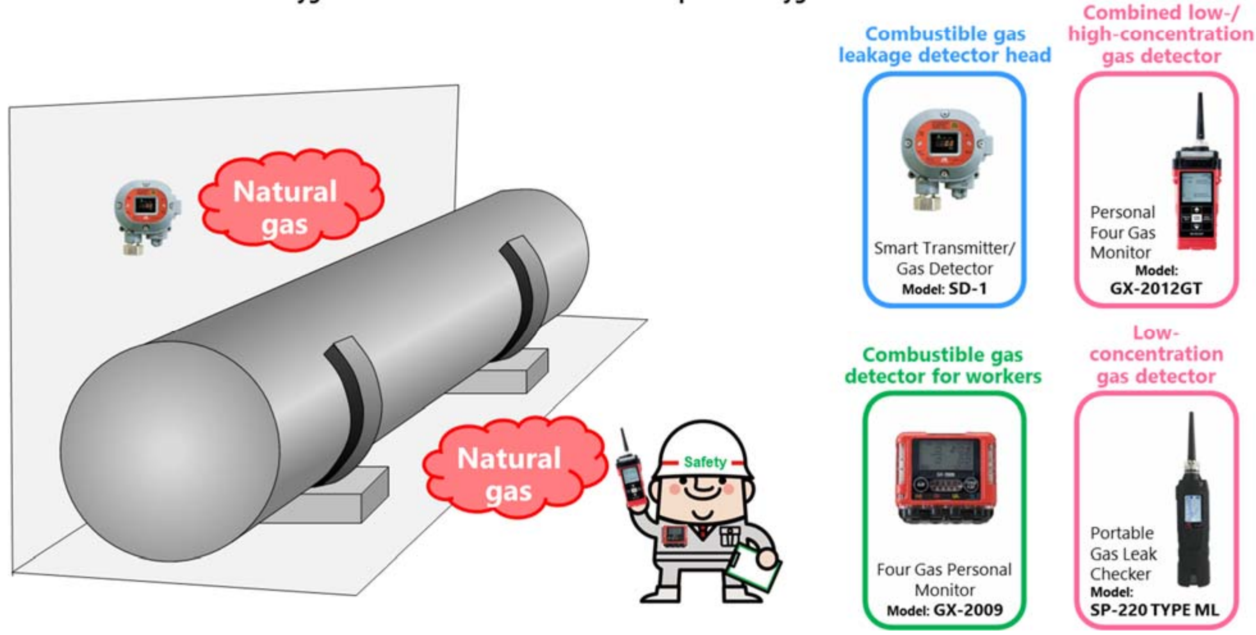


2-3: Facility inspections and maintenance work

Description: The space provided around underground high-pressure conduits allows workers to perform maintenance, repairs, and inspections.

Hazardous risks:

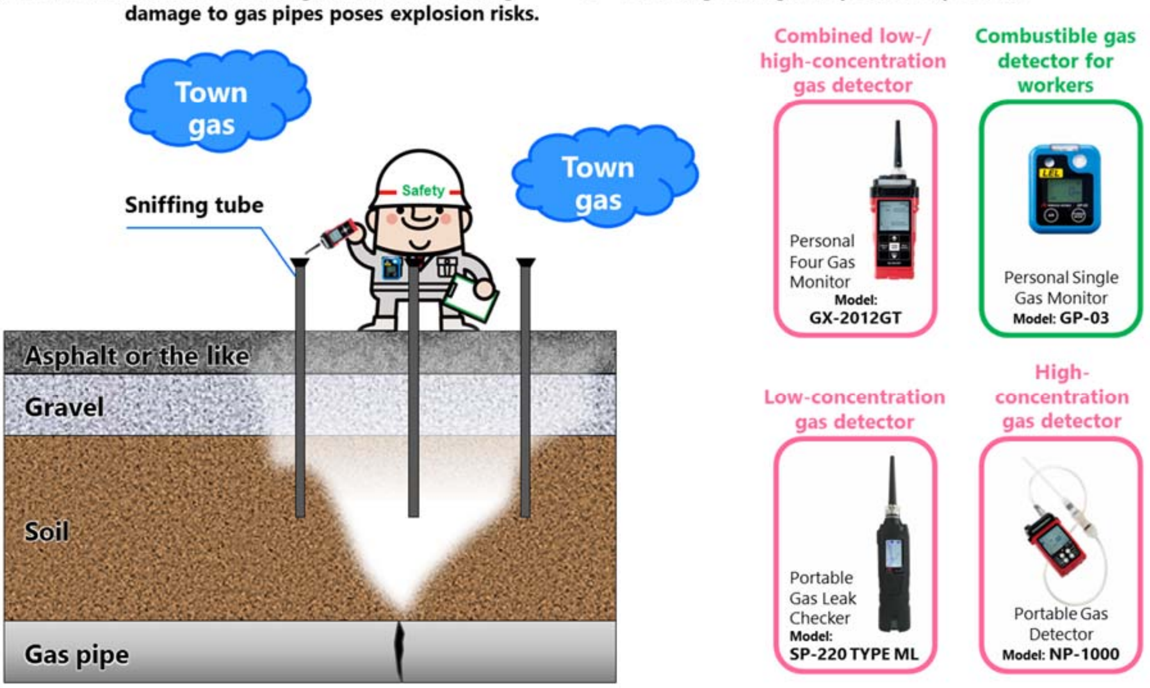
- **Natural gas leaks from high-pressure conduits pose explosion risk.** ⇒ **Detecting natural gas to prevent explosions**
- **Insufficient ventilation within the duct may result in oxygen deficiencies.** ⇒ **Measuring oxygen concentrations to prevent oxygen deficiencies**



2-4: Leakage inspections using boring

Description: Damage to underground gas pipes can cause town gas to diffuse into the soil above the pipes.

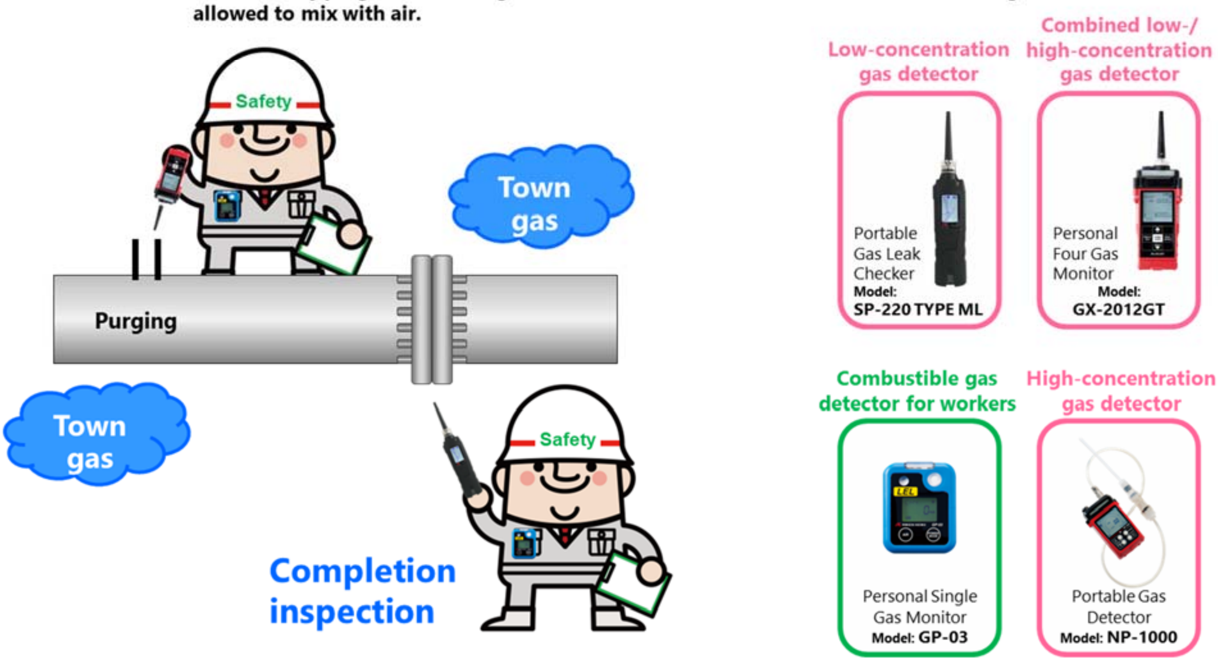
Hazardous risks: **Diffusion of town gas into soil following damage to gas pipes poses explosion risks.** ⇒ **Detecting town gas to prevent explosions**



2-5: Gas engineering work

Description: Purging must be performed (i.e., gas flushed from inside the equipment) before carrying out tasks related to inspections, cleaning, or removal at gas installations.

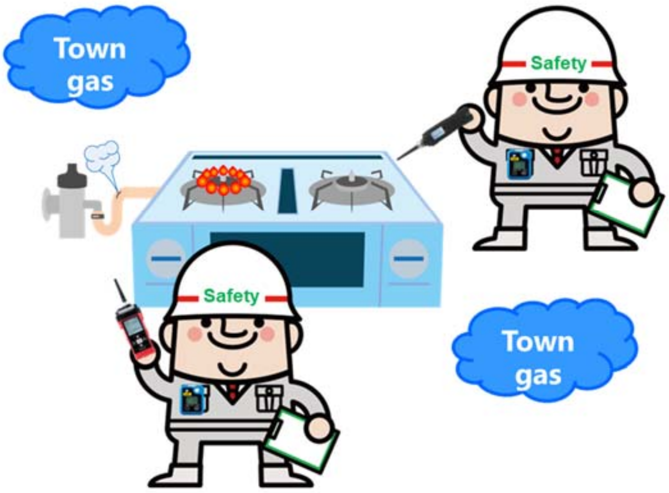
Hazardous risks: **There is a risk of explosion in the presence of an ignition source if a gas pipe is insufficiently purged and town gas is allowed to mix with air.** ⇒ **Detecting town gas to prevent explosions Measuring combustible gas and oxygen concentrations to confirm flushing rate**



2-6: Interior pipe and gas equipment installation and valve opening

Description: Pipes and gas equipment must be installed and valves opened inside gas customers' homes, stores, and factories before gas can be used.

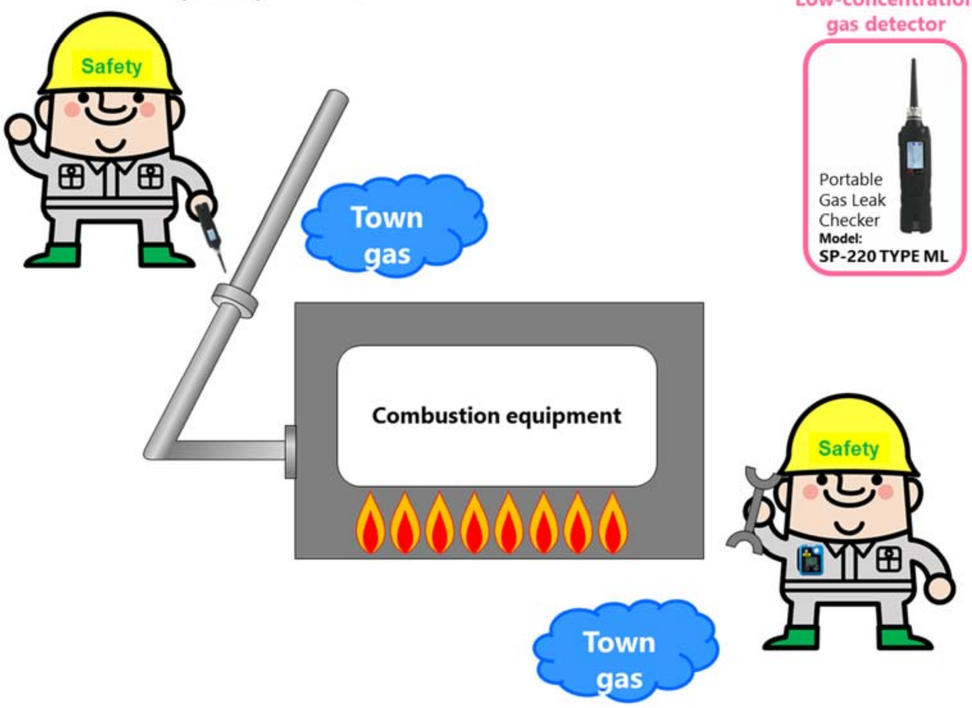
Hazardous risks: **Gas leaks during the process of installing interior pipe and gas equipment pose explosion risks.** ⇒ **Detecting town gas leaks to prevent explosions**



2-7: Gas engineering work inside large-scale customer gas facilities

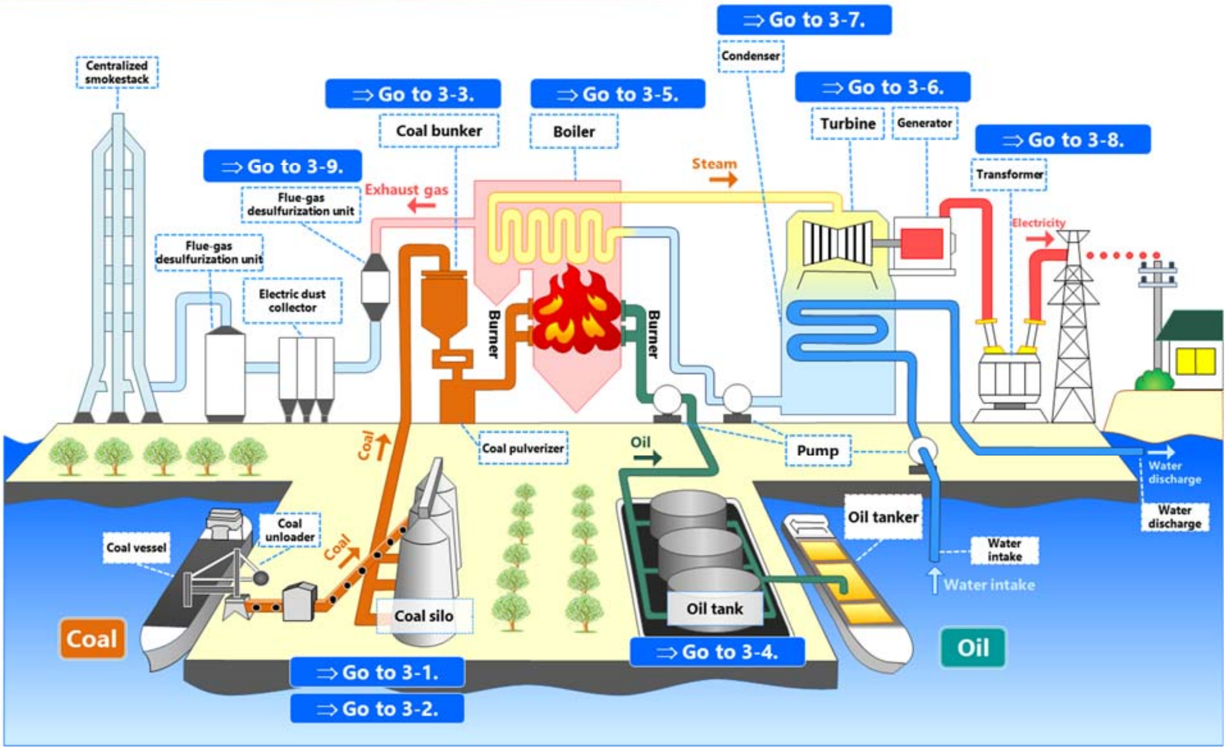
Description: Combustion equipment installed in large-scale customer gas facilities must be adjusted periodically.

Hazardous risks: **Town gas leaks from pipes occurring while workers adjust combustion equipment pose explosion risk.** ⇒ **Measuring town gas to prevent explosions**

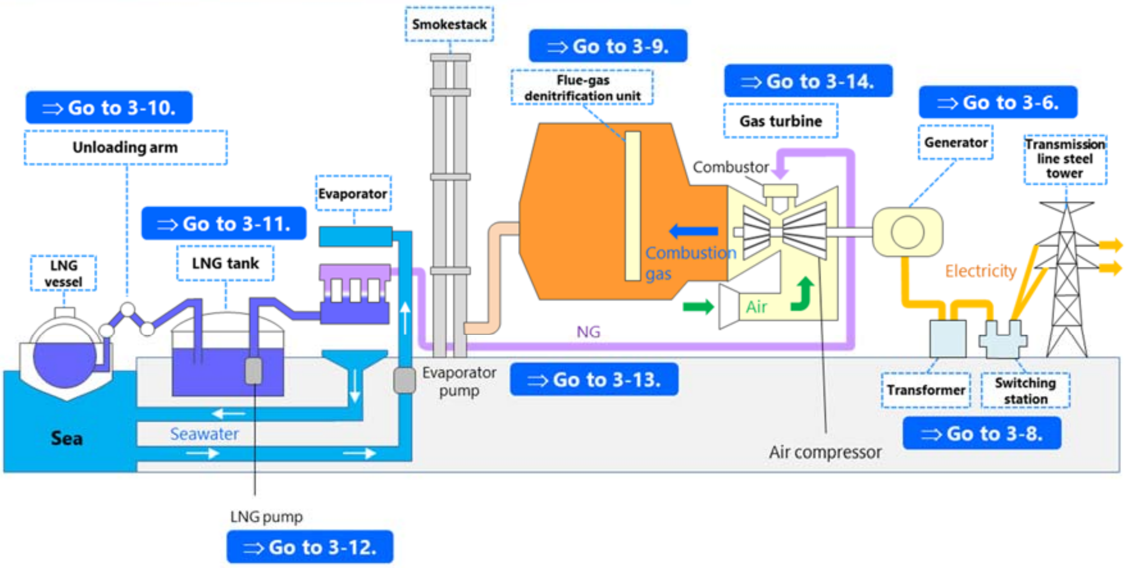


11-8. Applications in Electric Power Market

1. Overview of processes at thermal power stations (coal-fired/oil-fired steam power generation)



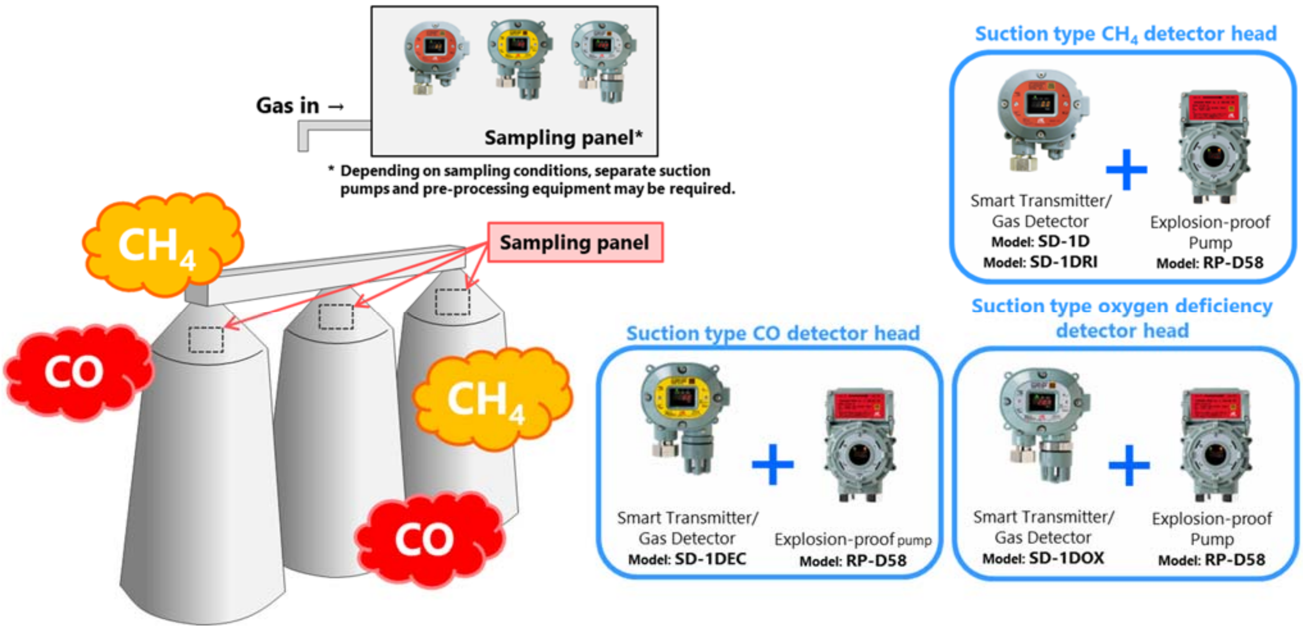
2. Overview of processes at thermal power stations (natural-gas-fired GTCC power generation)



3-1: Coal silo

Description: Coal unloaded from the coal vessel is transferred via a belt conveyor to the coal silo for temporary storage.

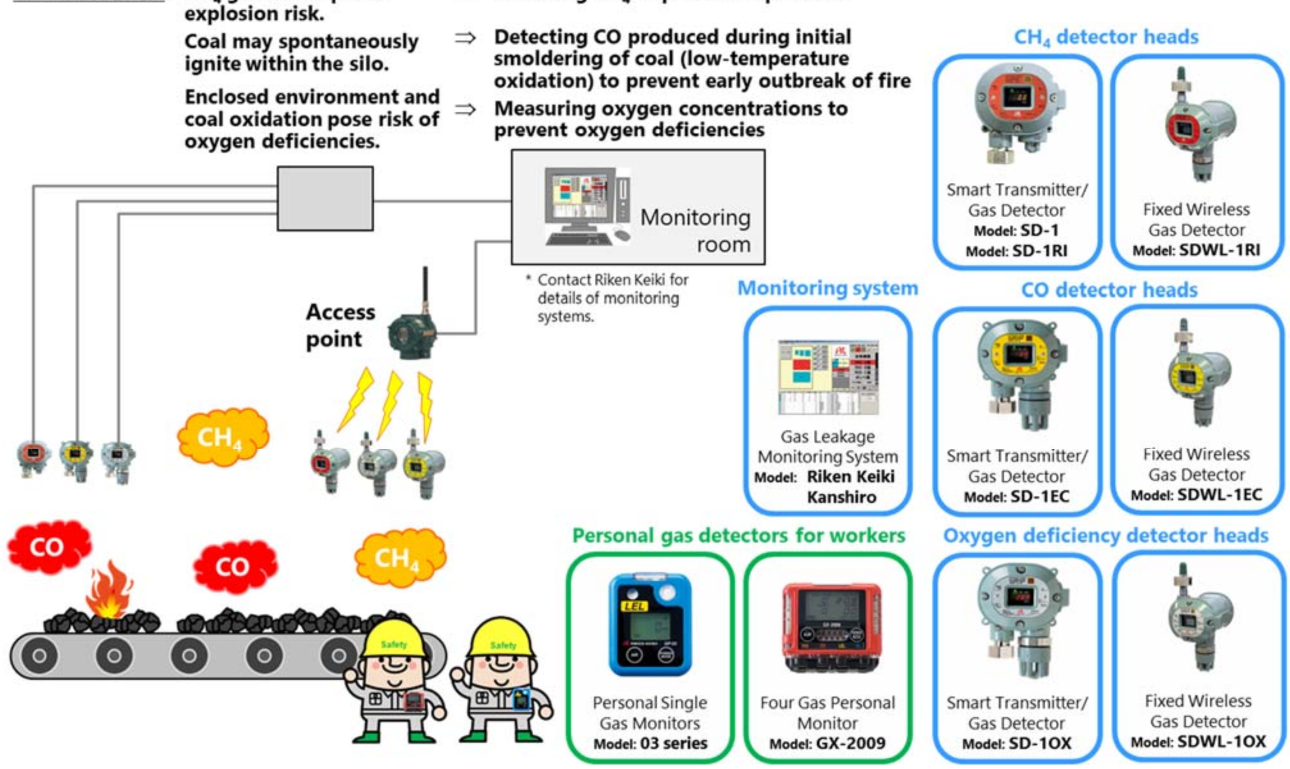
Hazardous risks:
- CH_4 generated from coal poses explosion risk. ⇒ Detecting CH_4 to prevent explosions
- Coal can spontaneously ignite within the silo. ⇒ Detecting CO produced during initial coal smoldering (low-temperature oxidation) to prevent early outbreak of fire
- Enclosed environment and coal oxidation pose risk of oxygen deficiencies. ⇒ Measuring oxygen concentrations to prevent oxygen deficiencies



3-2: Coal silo discharge conveyor

Description: Coal stored in the coal silo is transferred via a belt conveyor to the coal bunker in accordance with power station operating requirements.

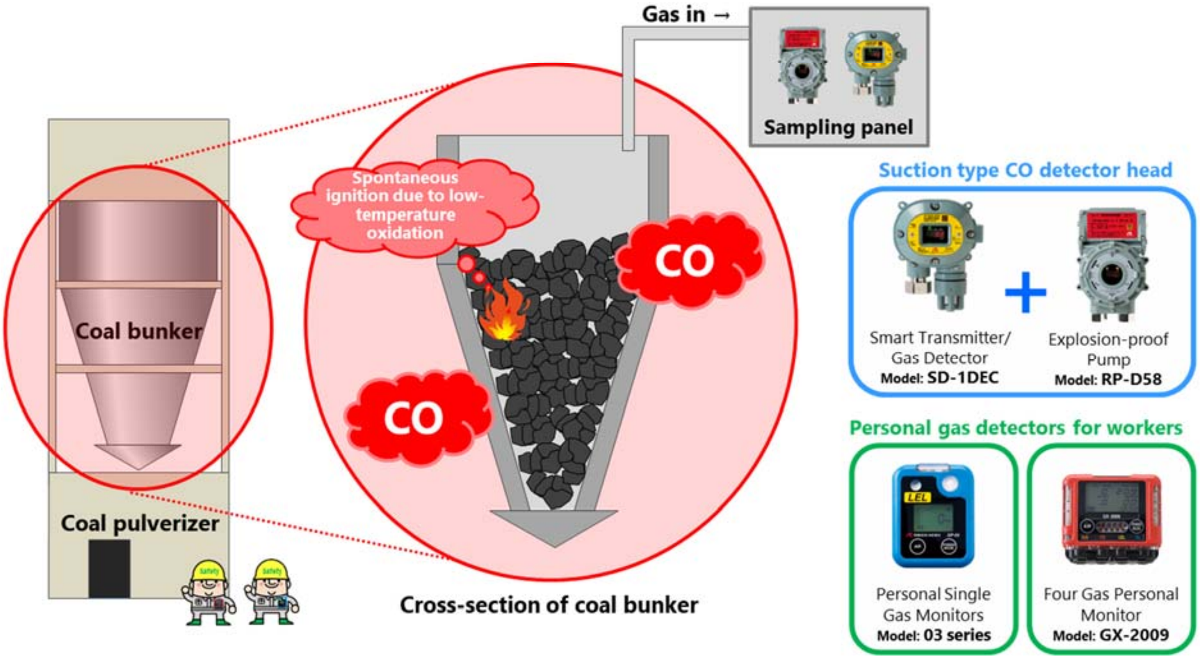
Hazardous risks:
- CH_4 generated poses explosion risk. ⇒ Detecting CH_4 to prevent explosions
- Coal may spontaneously ignite within the silo. ⇒ Detecting CO produced during initial smoldering of coal (low-temperature oxidation) to prevent early outbreak of fire
- Enclosed environment and coal oxidation pose risk of oxygen deficiencies. ⇒ Measuring oxygen concentrations to prevent oxygen deficiencies



3-3: Coal bunker

Description: Coal transferred via a belt conveyor is stored in the coal bunker to be supplied to the coal pulverizer.

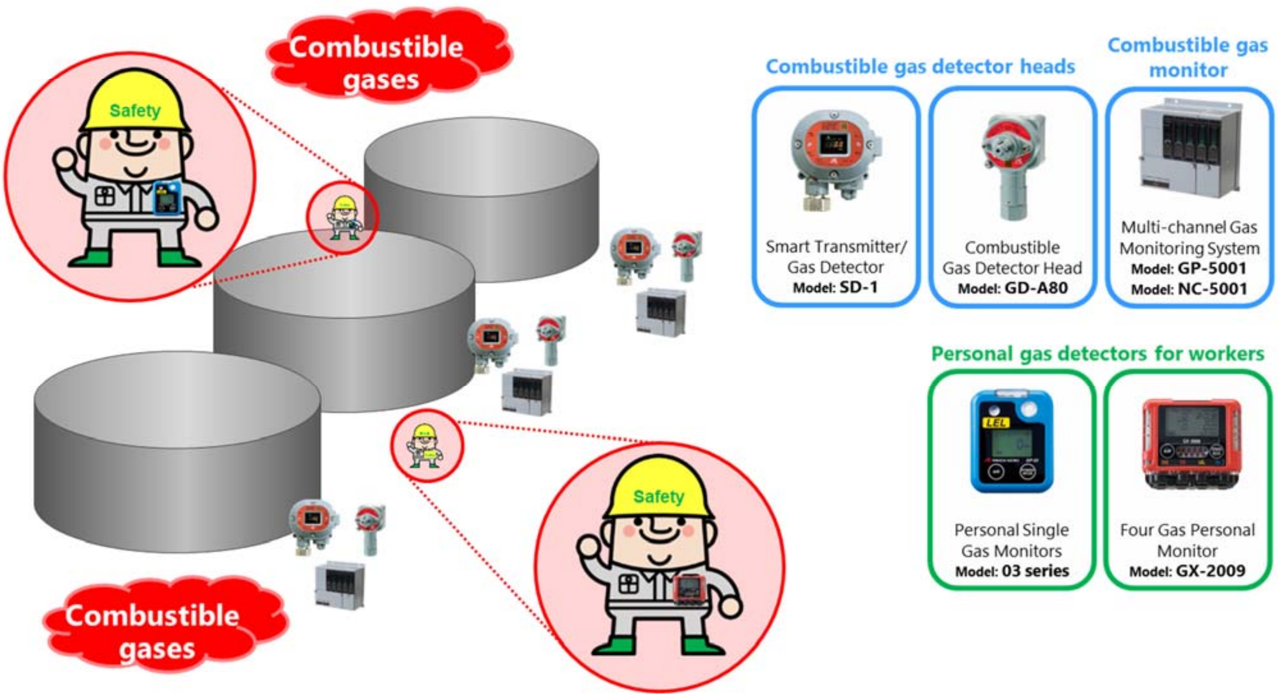
Hazardous risks: **Coal may spontaneously ignite within the coal bunker.** ⇒ **Detecting CO produced during initial smoldering of coal (low-temperature oxidation) to prevent early outbreak of fire**



3-4: Oil tank

Description: Oil unloaded from an oil tanker is transferred to the oil tank via a pipeline for temporary storage.

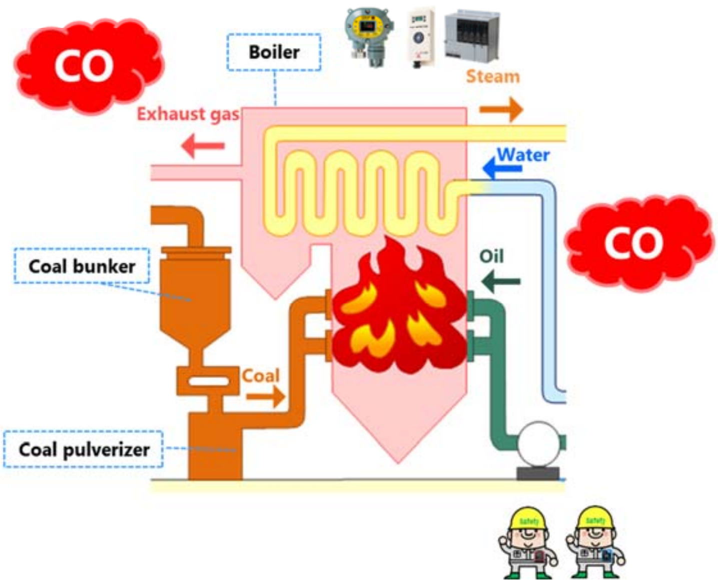
Hazardous risks: **Hydrocarbons (combustible gases) vaporizing from the oil pose explosion risk.** ⇒ **Detecting combustible gases to prevent explosions**



3-5: Boiler

Description: Pulverized coal and oil is burned in the boiler to produce high-temperature, high-pressure steam, which is then sent to the turbine.

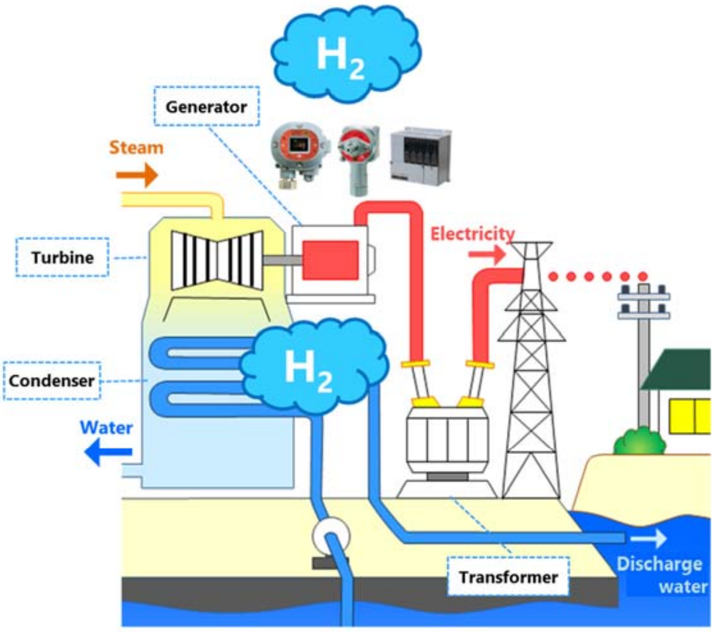
Hazardous risks: **CO generated by incomplete combustion in the boiler poses poisoning risk.** ⇒ **Detecting CO to prevent poisoning**



3-6: Turbine generator

Description: Steam sent from the boiler drives the turbine rotors to generate electricity in a generator coupled to the turbine. The steam generated within the generator is cooled using coolant such as hydrogen gas.

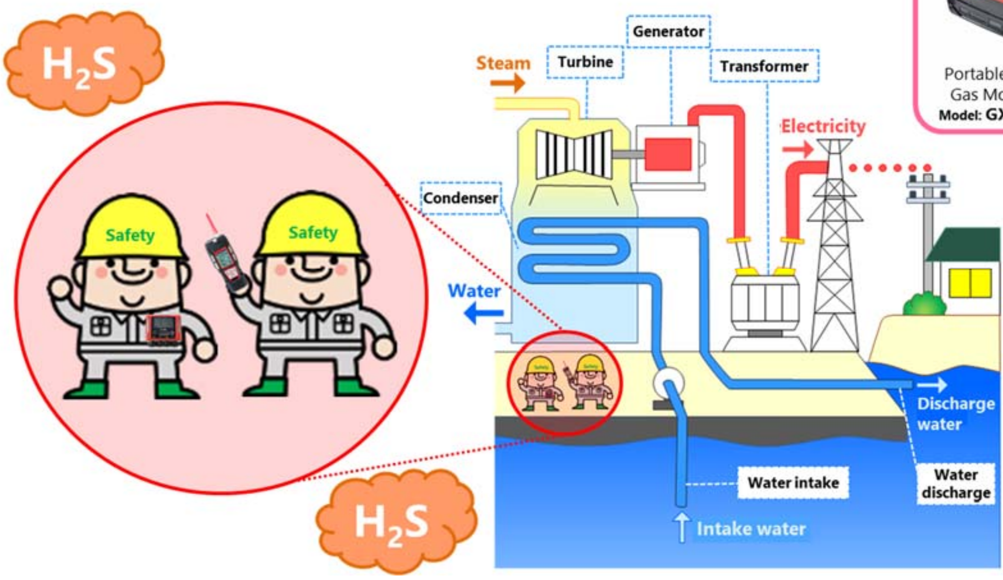
Hazardous risks: **Leaks of hydrogen gas used as coolant inside the generator pose explosion risk.** ⇒ **Detecting hydrogen gas to prevent explosions**



3-7: Condenser

Description: The steam used to operate the turbine is cooled in the condenser, where it condenses back to water. This is returned to the boiler, where it becomes steam once again. The process is continually repeated. The condenser uses a large volume of seawater to cool the steam.

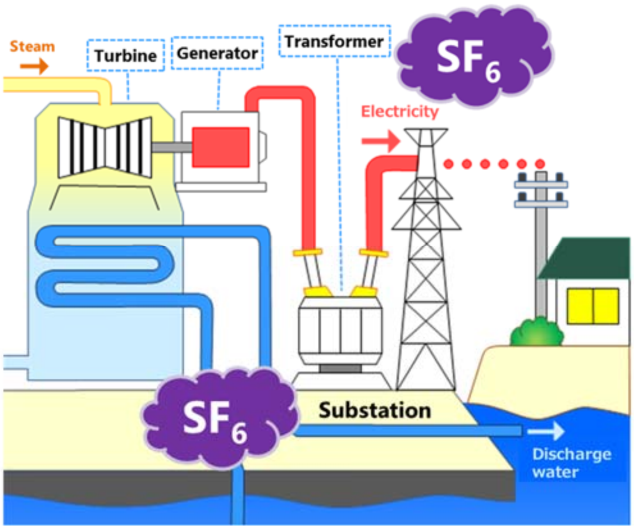
Hazardous risks: **Decaying shellfish inside the condenser seawater intake pipe poses risk of hydrogen sulfide poisoning and oxygen deficiencies.** ⇒ **Detecting hydrogen sulfide to prevent poisoning and detecting oxygen to prevent oxygen deficiencies**



3-8: Substation

Description: The substation includes a transformer to control the voltage of the electricity supplied from the generator and a circuit-breaker to shut off the power in the event of problems. These facilities use sulfur hexafluoride (SF_6) as an insulating gas.

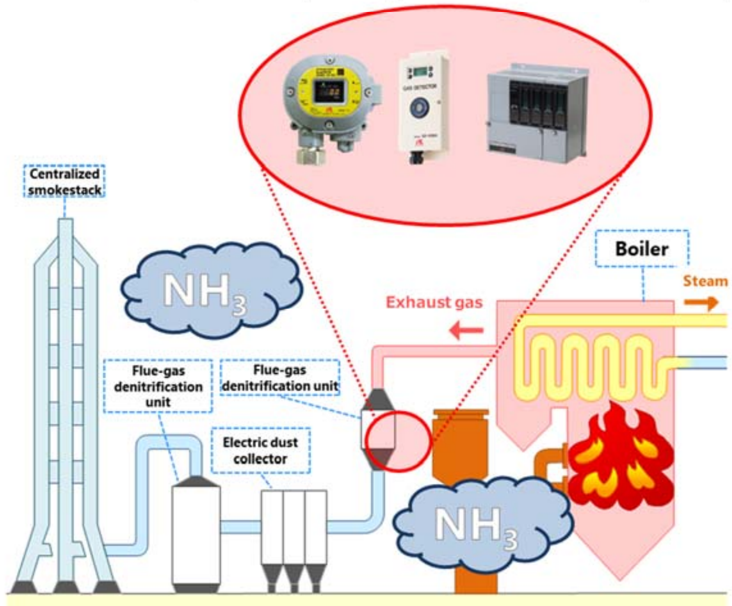
Hazardous risks: **SF_6 leaks occurring during maintenance to the transformer and circuit-breaker equipment may damage the environment if released.** ⇒ **Measuring SF_6 to minimize environmental effects**



3-9: Flue-gas denitrification unit

Description: Combustion of coal, oil, and LNG in the boiler results in oxidation of the nitrogen contained in these fuels, producing NOx, atmospheric pollutants. Flue gases containing NOx are sprayed with ammonia (NH_3) in the flue-gas denitrification unit situated at a postprocessing stage, which decomposes NOx into nitrogen and water to remove the NOx.

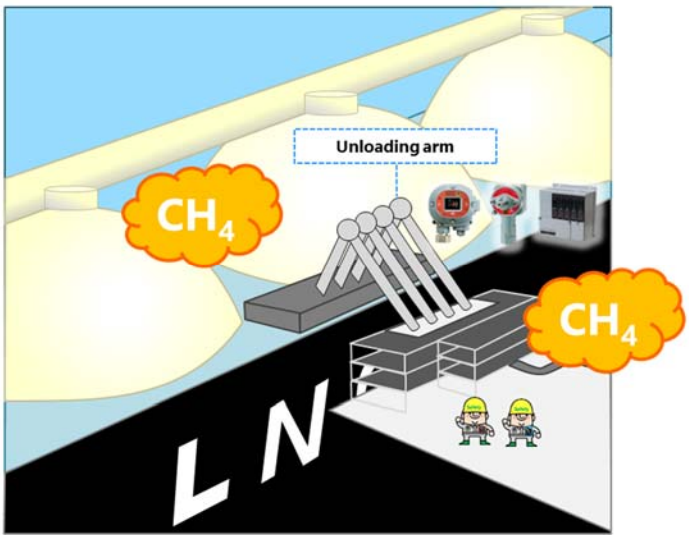
Hazardous risks: **NH_3 leaks from the flue-gas denitrification unit pose risk of poisoning.** ⇒ **Detecting NH_3 to prevent poisoning**



3-10: LNG loading arm

Description: LNG transported by LNG tanker is transferred to the LNG tank by a loading arm.

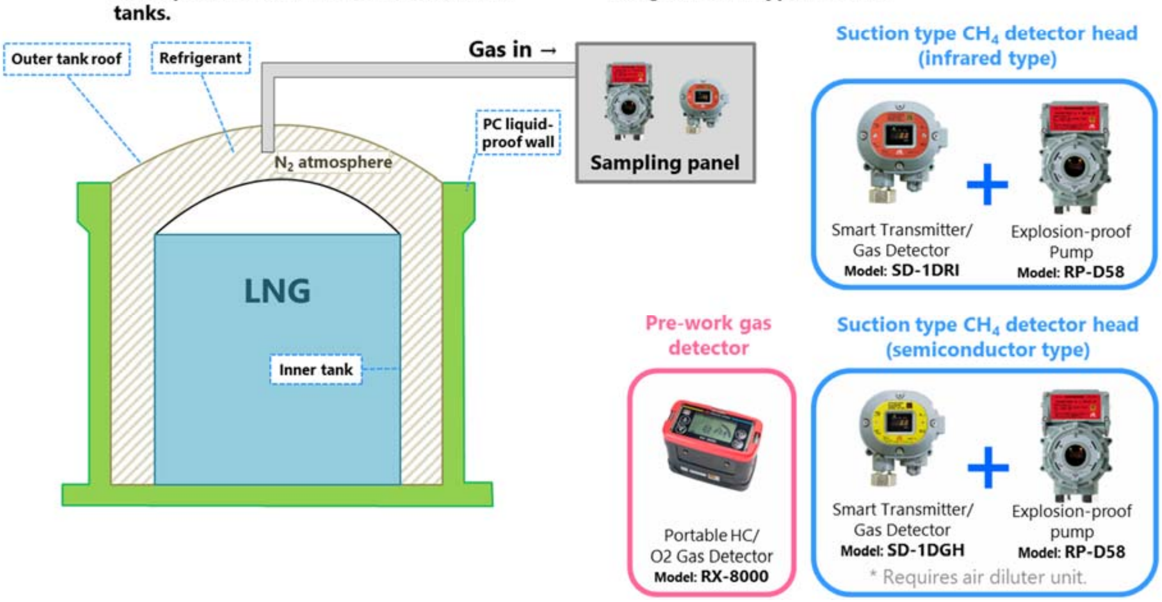
Hazardous risks: **Leaking CH_4 (the main constituent of LNG) during transfer via the loading arm poses explosion risk.** ⇒ **Detecting CH_4 within N_2 to prevent explosions (infrared detection)**



3-11: LNG tank

Description: The LNG tank contains a refrigerant between the inner tank and outer tank to prevent external heating of the tank and to minimize evaporation of the LNG. Nitrogen (N_2) is also contained to prevent a reduction in the insulating properties due to moisture absorption by the refrigerant.

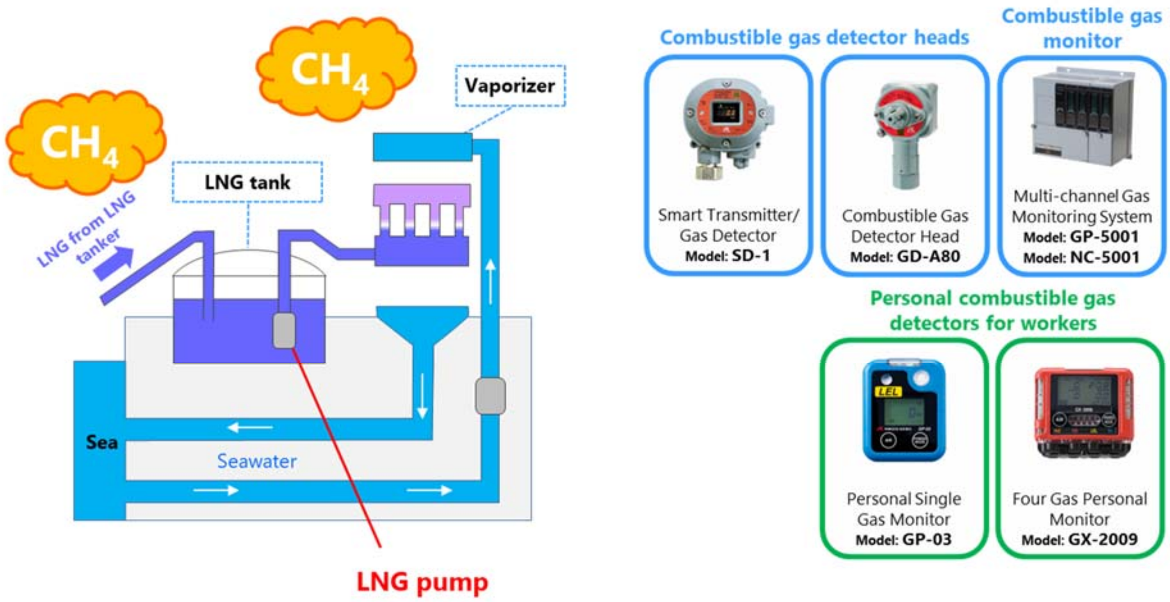
Hazardous risks: **There is a risk of LNG leakage into the N_2 atmosphere between the inner and outer tanks.** ⇒ **Monitoring combustible gas within N_2 using a suction type detector**



3-12: LNG pump and peripheral equipment

Description: The LNG tank includes an LNG pump for transferring the LNG inside the tank to the turbine and other peripheral equipment.

Hazardous risks: **CH_4 leaks from the LNG pump or peripheral equipment pose explosion risk.** ⇒ **Detecting CH_4 to prevent explosions**

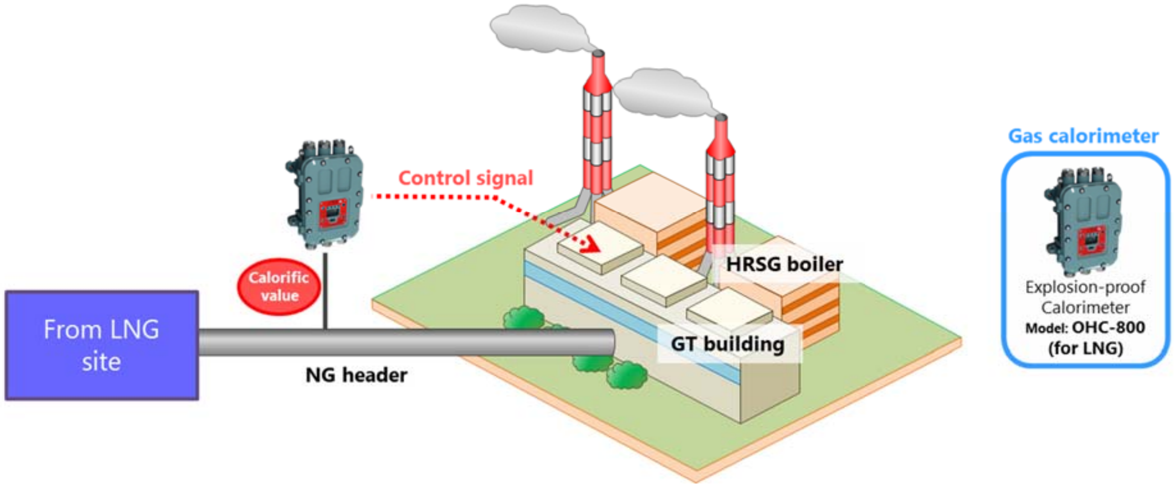


3-13: NG header and gas turbine

Description: LNG is vaporized in the vaporizer to become natural gas (NG). NG is then supplied to the turbine via the NG header.

Hazardous risks: **Gas turbine operations may be affected by variations in the calorific value of the gas caused by diversification of LNG import sources, an increase in BOG* processing, and adoption of shale gas.** ⇒ **Measuring calorific value online using a gas calorimeter and sending control signals to the gas turbine**

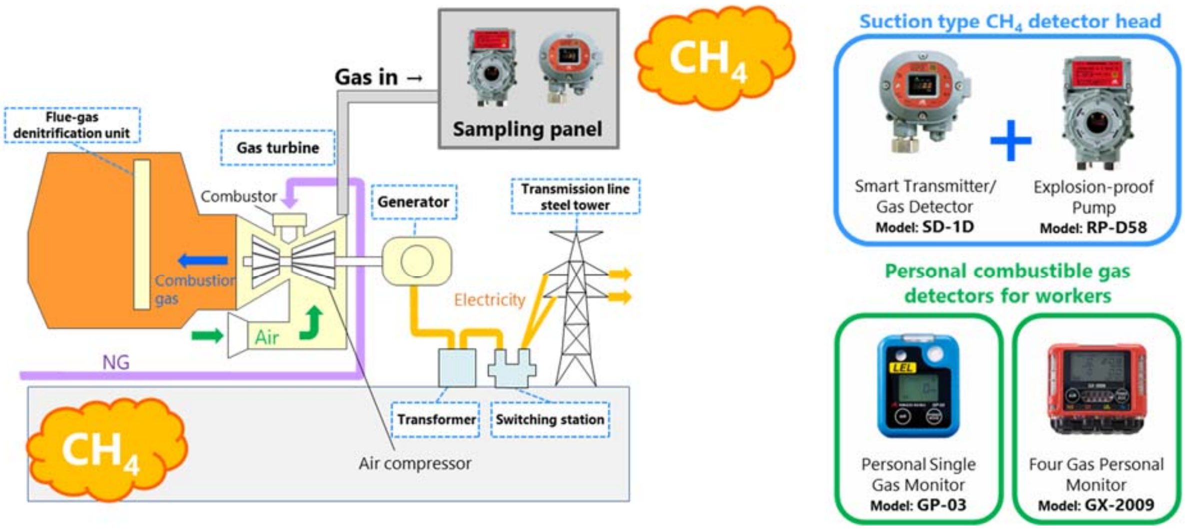
*** BOG (boil off gas): Gas formed by vaporization of part of LNG stored in a tank**



3-14: Gas turbine enclosure

Description: The gas turbine enclosure is a building that houses the main components of the gas turbine generator to protect them. This structure also reduces noise.

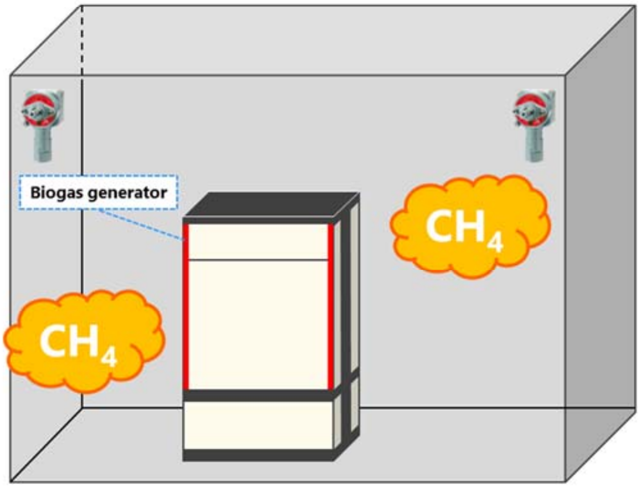
Hazardous risks: **CH_4 leaks inside the gas turbine enclosure pose explosion risk.** ⇒ **Detecting CH_4 to prevent explosions**



4. Biogas power generation

Description: Biogas power generation systems extract combustible biogas (methane) from fermented organic waste material (e.g., cattle manure, waste food material, sewage); this biogas drives gas engines or gas turbines to generate electricity.

Hazardous risks: **CH_4 leaks inside the biogas generator chamber pose explosion risk.** ⇒ **Detecting CH_4 to prevent explosions**



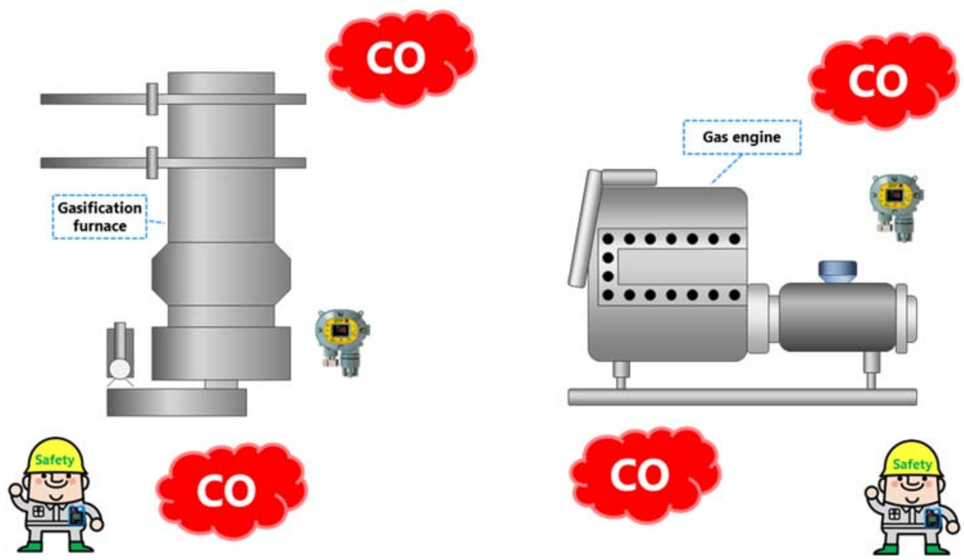
Biogas generator chamber

CH_4 detector head

5. Wood biomass gasification power generation

Description: Wood biomass gasification power generation generates electricity by converting wood chips and similar materials into gas at high temperature, and then burning this gas in a gas engine or gas turbine.

Hazardous risks: **CO leaks inside the wood biomass gasification furnace, gas engine, or gas turbine enclosure pose poisoning risk.** ⇒ **Detecting CO to prevent poisoning**



CO detector head

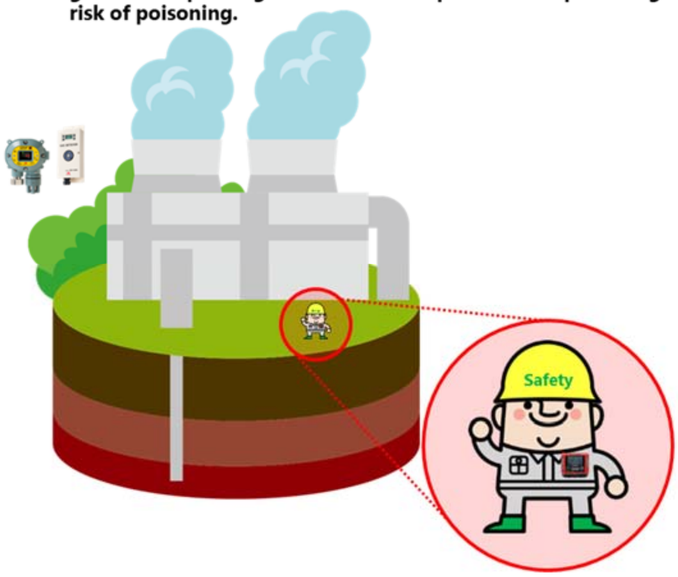
Personal CO gas detector for workers

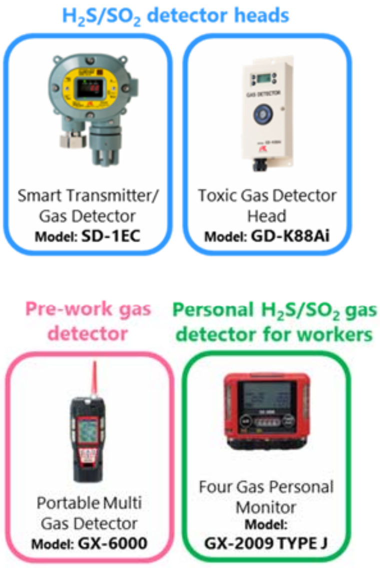
6. Geothermal power generation

Description: Geothermal power generation generates electricity by extracting geothermal fluid from geothermal reservoirs*, vaporizing the geothermal fluid in a separator (moisture separator), and using the geothermal fluid to vaporize a secondary medium to generate steam. The steam thus generated then rotates a turbine to generate electricity. Geothermal fluid contains various substances, including carbon dioxide (CO_2), hydrogen sulfide (H_2S), ammonia (NH_3), methane (CH_4), and sulfur dioxide (SO_2), a volcanic gas.

* Layer far below the earth's surface in which rain and snow that seep down are trapped as high-temperature fluid (geothermal fluid)

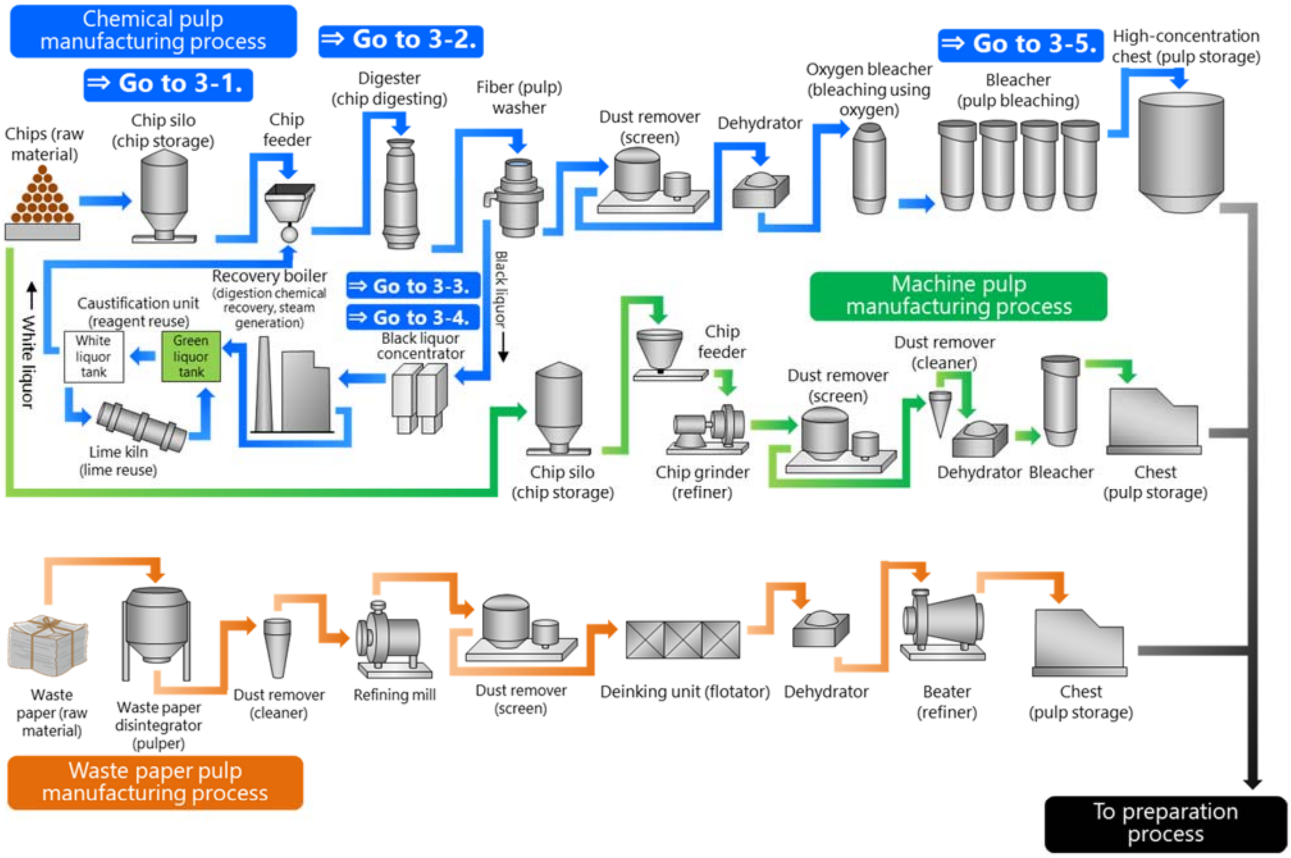
Hazardous risks: **H_2S or SO_2 leaks in the condenser pit, electrical room, culvert, or other areas at the geothermal power generation station pose risk of poisoning.** ⇒ **Detecting H_2S and SO_2 to prevent poisoning**



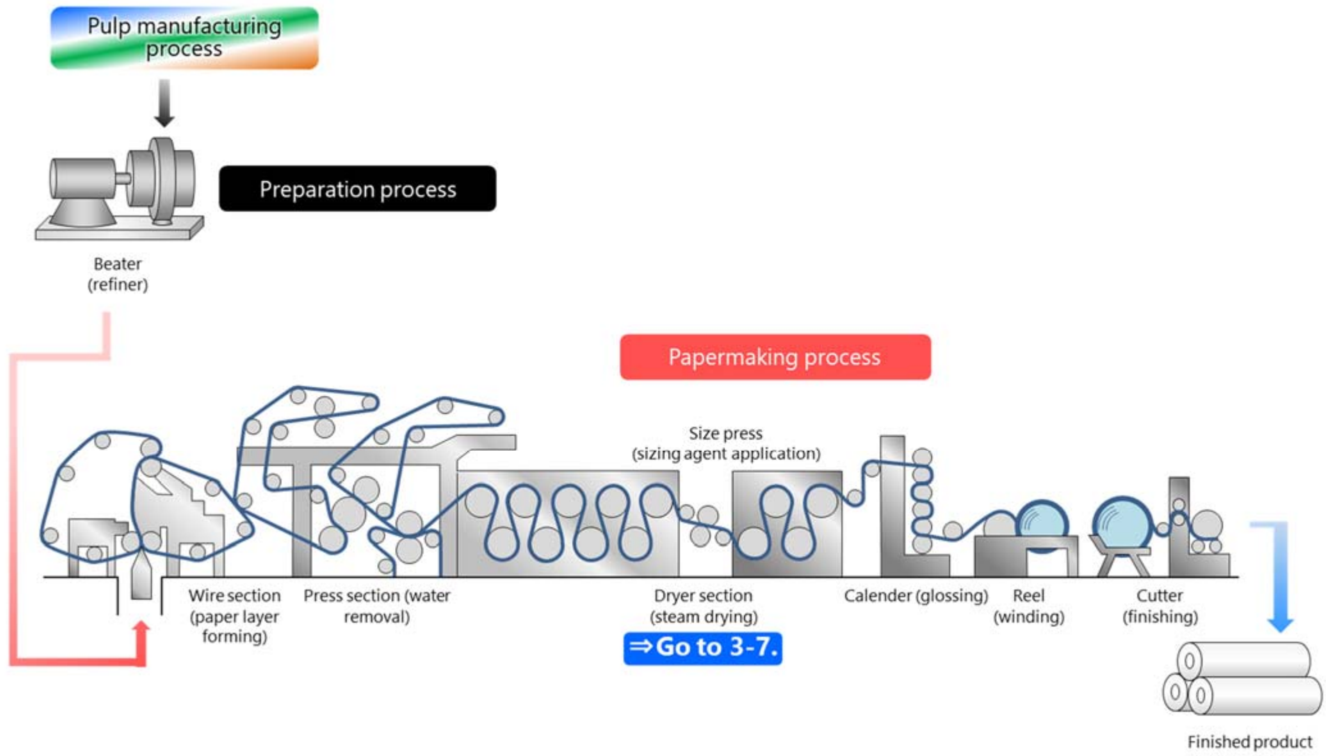


11-9. Applications in Paper Manufacturing Market

1. Overview of processes for the paper manufacturing market (pulp manufacture)



2. Overview of processes for the paper manufacturing market (preparation and papermaking)

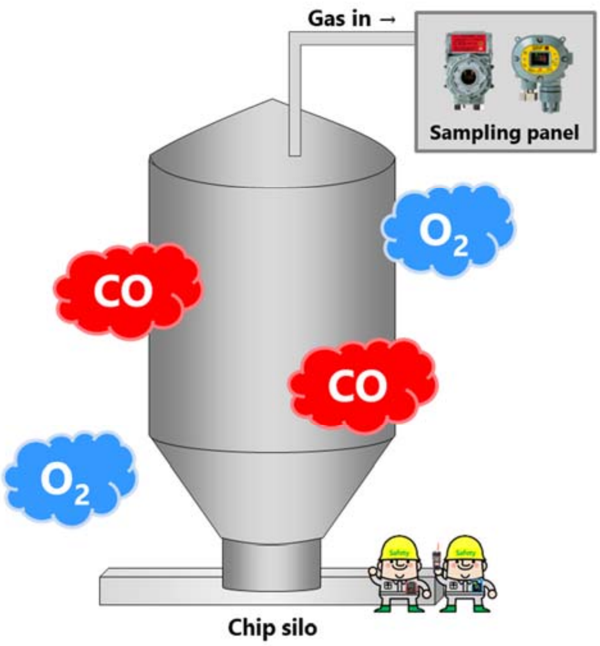


3-1: Chip silo

Description: The wood chips that make up the raw material for the pulp are temporarily stored in the chip silo.

Hazardous risks: Smoldering inside the enclosed chip silo poses oxygen deficiency and fire risks. The carbon monoxide (CO) generated by the smoldering poses poisoning risk.

⇒ **Detecting CO to prevent fire and poisoning**
Measuring oxygen concentrations to prevent oxygen deficiencies

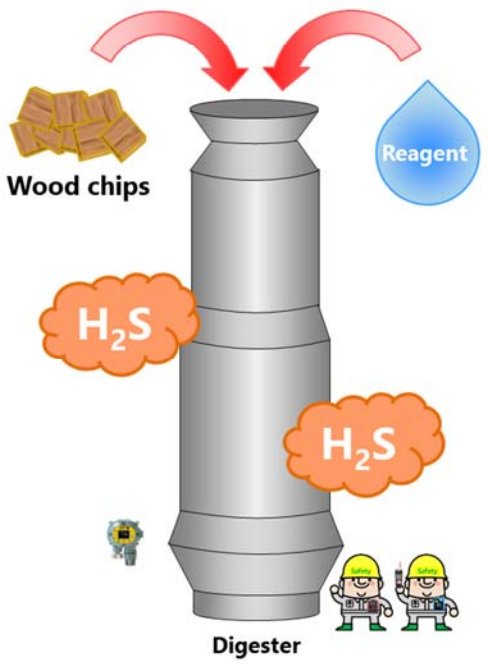


3-2: Digester

Description: Wood chips are supplied with the reagent to the digester and cooked at high temperature and pressure to extract the fibers (pulp). The main components of the reagents are caustic soda and sodium sulfide (Na_2S).

Hazardous risks: The Na_2S used to break down the wood chips poses poisoning risk due to the hydrogen sulfide (H_2S) generated by hydrolysis.

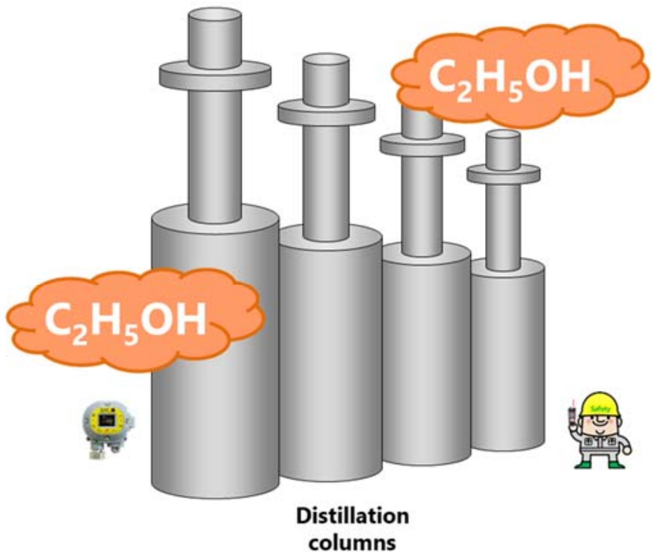
⇒ **Detecting H_2S to prevent poisoning**



3-3: Ethanol manufacture

Description: The fibers (pulp) are washed in the washer, where the waste liquid, known as black liquor, is removed. This black liquor contains dissolved lignin (constituent bonding the wood fibers together) and other components. The biofuel ethanol is manufactured from black liquor.

Hazardous risks: **Ethanol (C_2H_5OH) leaks from ethanol manufacture pose explosion and poisoning risks.** ⇒ **Detecting C_2H_5OH to prevent explosions and poisoning**



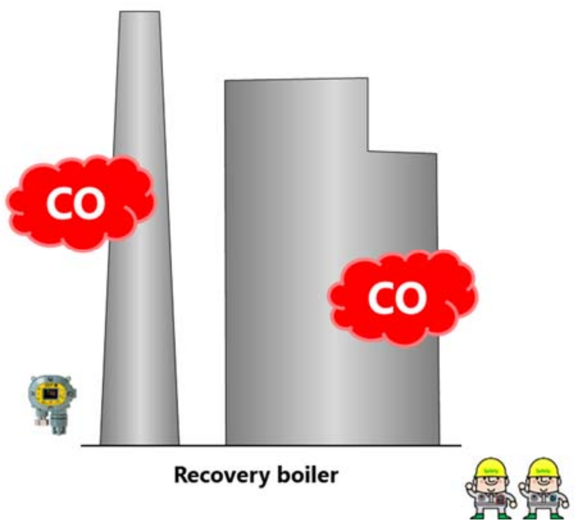
C_2H_5OH detector head

Prework gas detectors

3-4: Recovery boiler

Description: The black liquor produced after washing the fibers is concentrated in the concentrator, and the combustion in the recovery boiler generates steam of high temperature and high pressure.

Hazardous risks: **Incomplete combustion inside the recovery boiler poses poisoning risk due to carbon monoxide (CO).** ⇒ **Detecting CO to prevent poisoning**



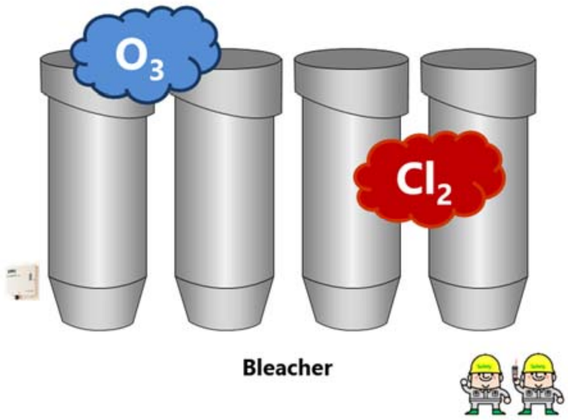
CO detector heads

CO gas detectors for workers

3-5: Bleacher (pulp bleaching)

Description: Foreign matter such as sand and metal fragments are removed from the wood fiber by the dust removers (screen and cleaner) before additional bleaching in the bleacher. Bleaching involves chemicals such as chlorine dioxide (ClO_2), ozone (O_3), and chlorine (Cl_2).

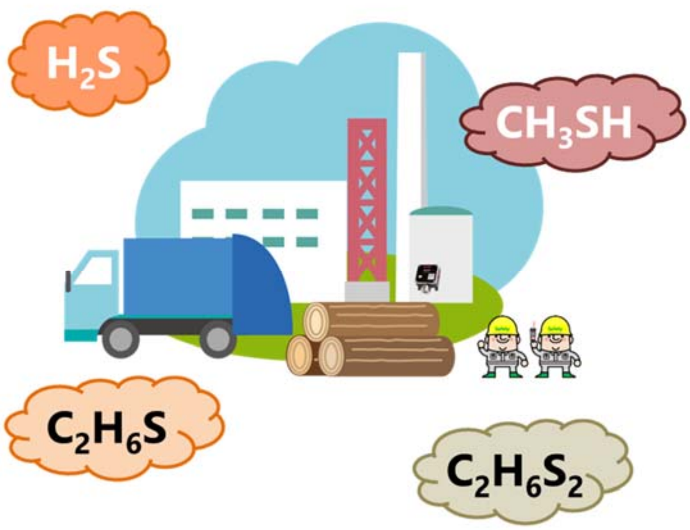
Hazardous risks: **Leaks of O_3 or Cl_2 used as bleaching agents pose poisoning risk.** ⇒ **Detecting O_3 and Cl_2 to prevent poisoning**



3-6: Measurement of environmental parameters during pulp manufacturing process

Description: The pulp manufacturing process generates four differed odorous sulfur compounds: hydrogen sulfide (H_2S), methyl mercaptan (CH_3SH), methyl sulfide (C_2H_6S), and methyl disulfide ($C_2H_6S_2$).

Hazardous risks: **The four sulfur compounds generated during pulp manufacture pose poisoning risk.** ⇒ **Detecting four sulfur compounds to detect odor sources and prevent poisoning**



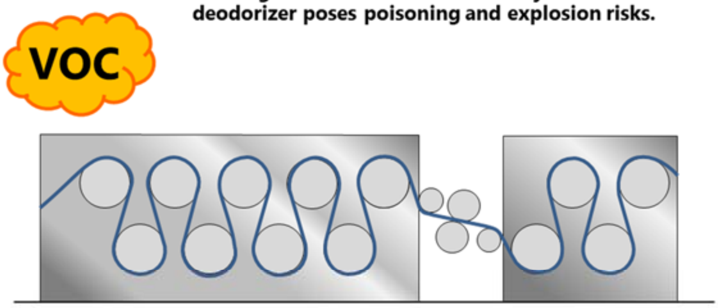
3-7: Dryer section, solvent recovery unit, and deodorizer

Description: In the dryer section (paper-drying process), the paper is brought into contact with steel cylinders heated by steam and dried to achieve the desired water content. This process also involves equipment used to recover solvents generated during the paper manufacturing process and a deodorizer.

Hazardous risks: **The volatile organic compound (VOC) solvent gas generated when drying coated paper poses poisoning and explosion risks.**
Waste gas from the solvent recovery unit and deodorizer poses poisoning and explosion risks.

⇒ **Measuring VOC to prevent poisoning and explosions**

⇒ **Preventing poisoning and explosions due to VOC and measuring source gas concentrations to improve efficiency**



Dryer section

Prework VOC detectors

VOC detector heads

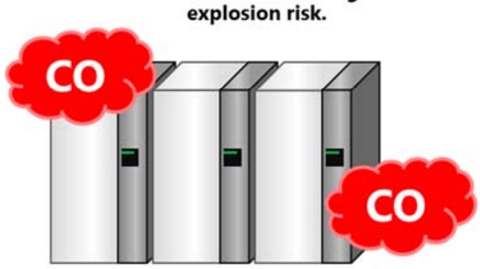
3-8: Natural gas and LPG fueled boiler facility

Description: Paper manufacturing plants may include a boiler facility fueled by natural gas or LPG.

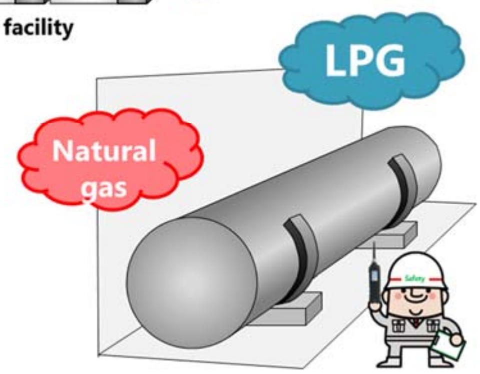
Hazardous risks: **The carbon monoxide (CO) generated by incomplete combustion inside the boiler facility poses poisoning risk.**
Leaks of natural gas or LPG from fuel pipes pose explosion risk.

⇒ **Detecting CO to prevent poisoning**

⇒ **Detecting LPG leaks to prevent explosions**



Boiler facility



Fuel pipe

CO detector heads

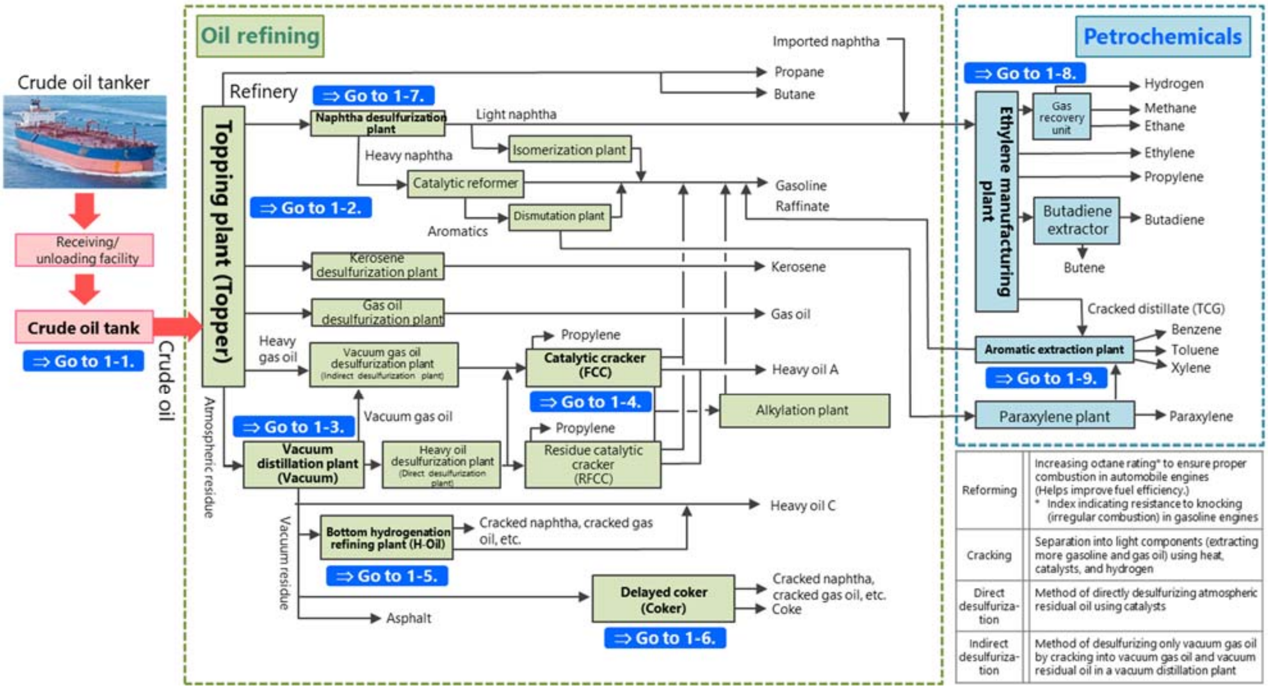
Natural gas/LPG leak detector

CO gas detectors for workers

11-10. Applications in Oil and Fossil Fuel Market

1. Crude oil-derived processes

The typical manufacturing processes used to derive products from crude oil are shown below. Gas detectors and alarms are used in each of these processes. The subsequent pages discuss specific risks associated with leaking combustible and toxic gases produced in each process, alongside examples of the installation of various gas detectors and alarms.

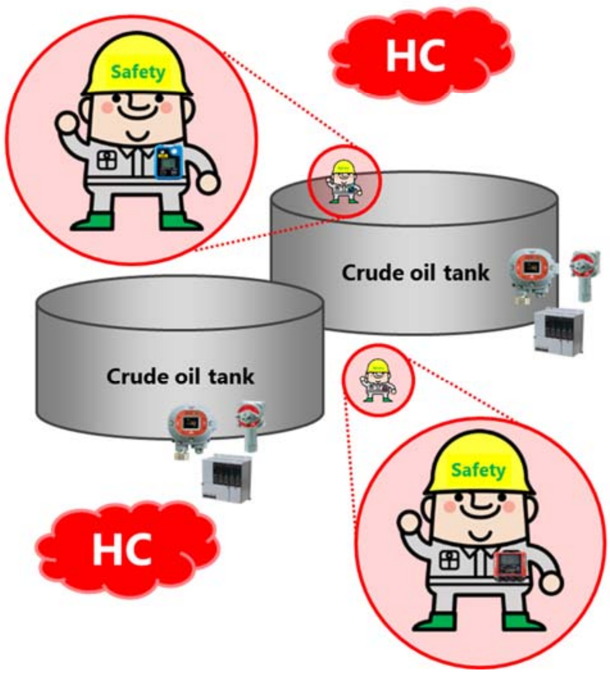


Reforming	Increasing octane rating* to ensure proper combustion in automobile engines (Helps improve fuel efficiency.) * Index indicating resistance to knocking (irregular combustion) in gasoline engines
Cracking	Separation into light components (extracting more gasoline and gas oil) using heat, catalysts, and hydrogen
Direct desulfurization	Method of directly desulfurizing atmospheric residual oil using catalysts
Indirect desulfurization	Method of desulfurizing only vacuum gas oil by cracking into vacuum gas oil and vacuum residual oil in a vacuum distillation plant

1-1: Crude oil tank

Description: Crude oil transported is stored in the crude oil tank.

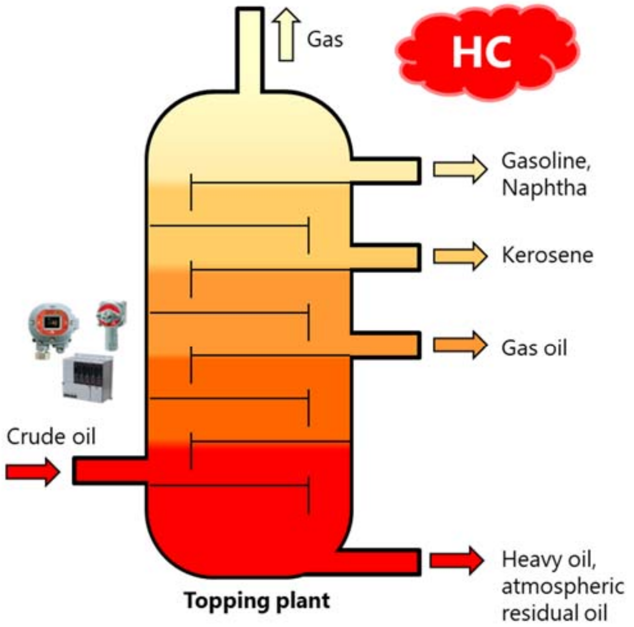
Hazardous risks: **Leaks from the crude oil tank pose explosion risk.** ⇒ **Detecting combustible gas (HC) to prevent explosions**

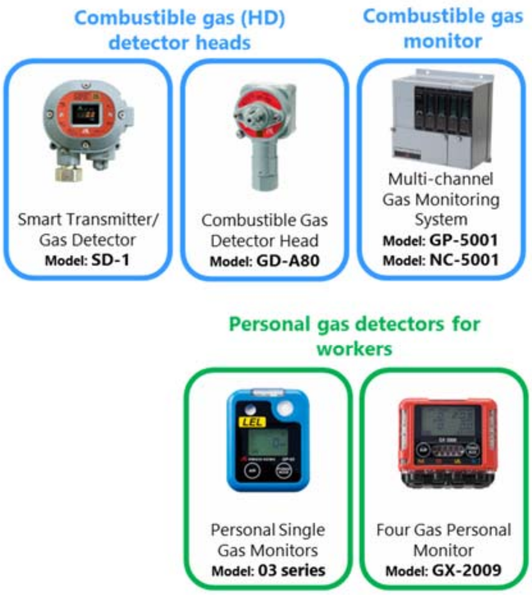


1-2: Topping plant (Topper)

Description: The topping plant leverages the different boiling points of crude oil to separate components into semifinished products such as gasoline, naphtha, kerosene, gas oil, and heavy oil.

Hazardous risks: **Leaks from the topping plant pose explosion risk.** ⇒ **Detecting combustible gas (HC) to prevent explosions**

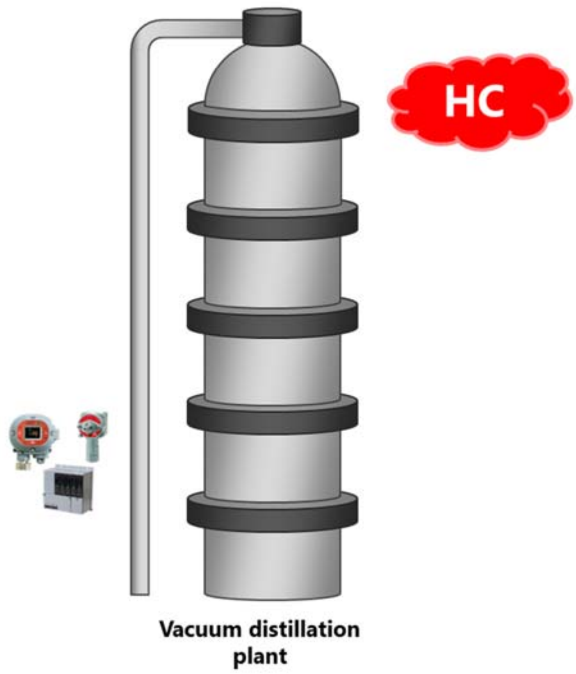




1-3: Vacuum distillation plant (Vacuum)

Description: The vacuum distillation plant distills atmospheric residual oil from the topping plant under reduced pressure to separate it into vacuum residue, heavy oil, gas oil, and other components.

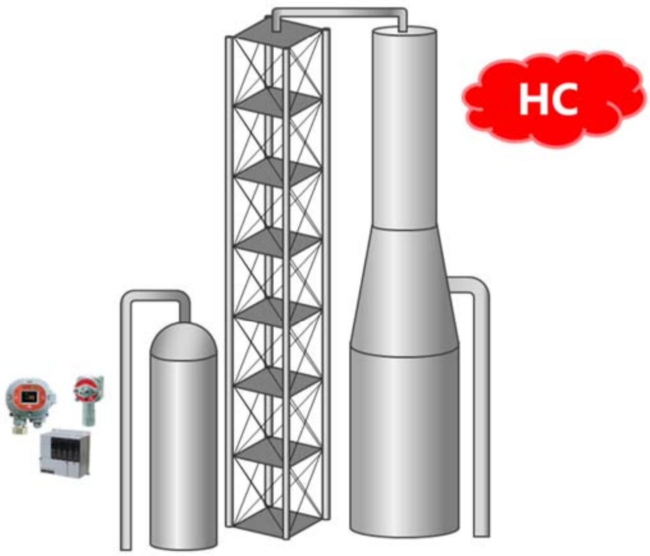
Hazardous risks: **Leaks from the vacuum distillation plant pose explosion risk.** ⇒ **Detecting combustible gas (HC) to prevent explosions**



1-4: Catalytic cracker (FCC)

Description: The catalytic cracker (FCC) cracks residual heavy oil into light residual components using a high-temperature catalyst. This plant increases gasoline extraction rates at oil refineries.

Hazardous risks: **Leaks from the catalytic cracker pose explosion risk.** ⇒ **Detecting combustible gas (HC) to prevent explosions**

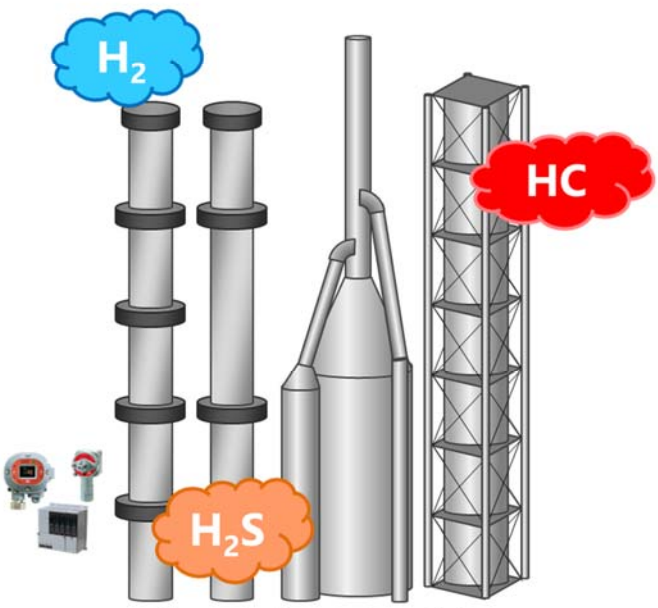


Catalytic cracker

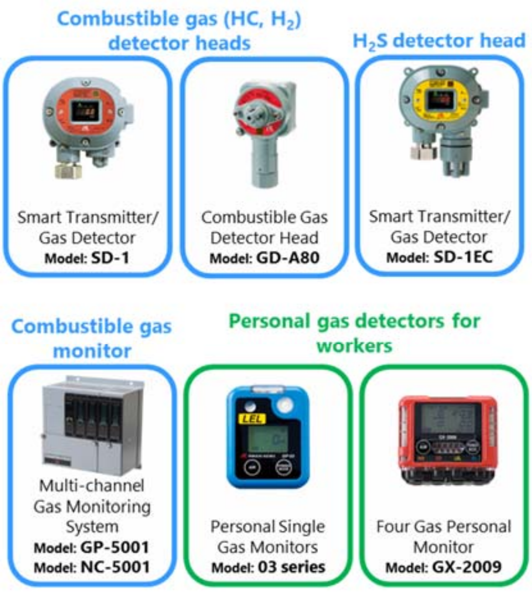
1-5: Bottom hydrogenation refining plant (H-Oil)

Description: The bottom hydrogenation refining plant (H-Oil) produces cracked naphtha and cracked gas oil by removing sulfur within the residual oil by hydrogenation reaction with a catalyst.

Hazardous risks: **Leaks from the bottom hydrogenation refining plant pose explosion risk and poisoning risk.** ⇒ **Detecting combustible gas (HC, H_2) to prevent explosions**
Detecting H_2S to prevent poisoning



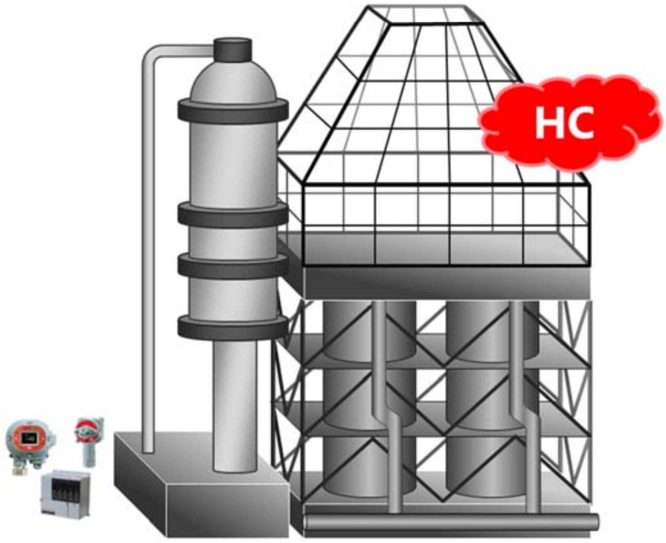
Bottom hydrogenation refining plant



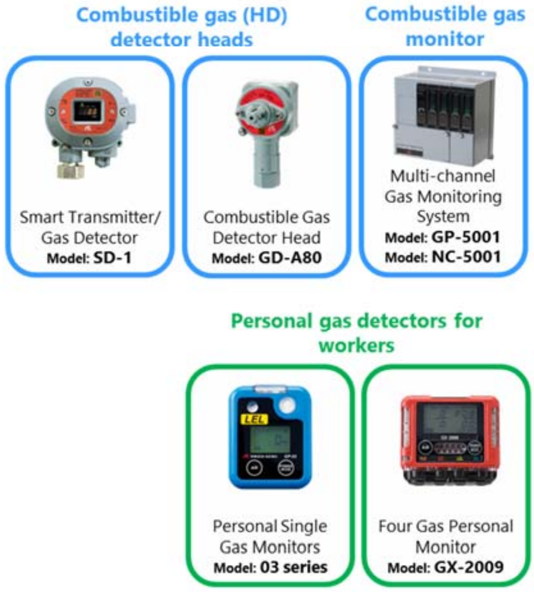
1-6: Delayed coker (Coker)

Description: The delayed coker (coker) produces gasoline and gas oil by thermal cracking of the vacuum residual oil at high temperature, which otherwise only becomes heavy oil C base material or asphalt.

Hazardous risks: **Leaks from the delayed coker pose explosion risk.** ⇒ **Detecting combustible gas (HC) to prevent explosions**



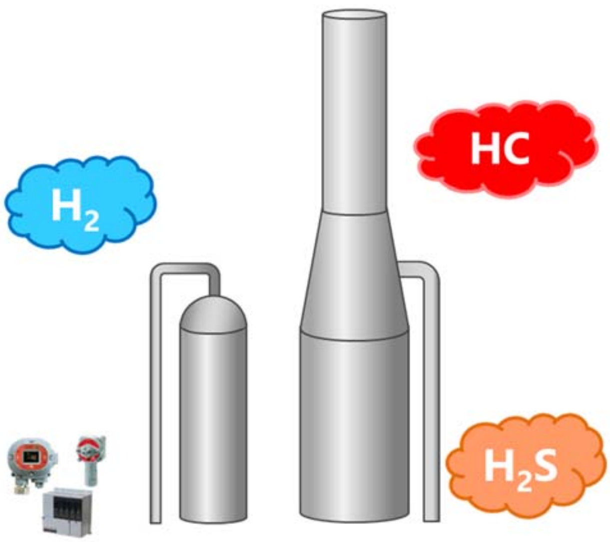
Delayed coker



1-7: Naphtha desulfurization plant

Description: The naphtha desulfurization plant removes sulfur and other impurities from the naphtha fraction to produce raw materials for use in ethylene plants and catalyst reformers.

Hazardous risks: **Leaks from the naphtha desulfurization plant pose explosion risk and poisoning risk.** ⇒ **Detecting combustible gas (HC, H_2) to prevent explosions**
Detecting H_2S to prevent poisoning

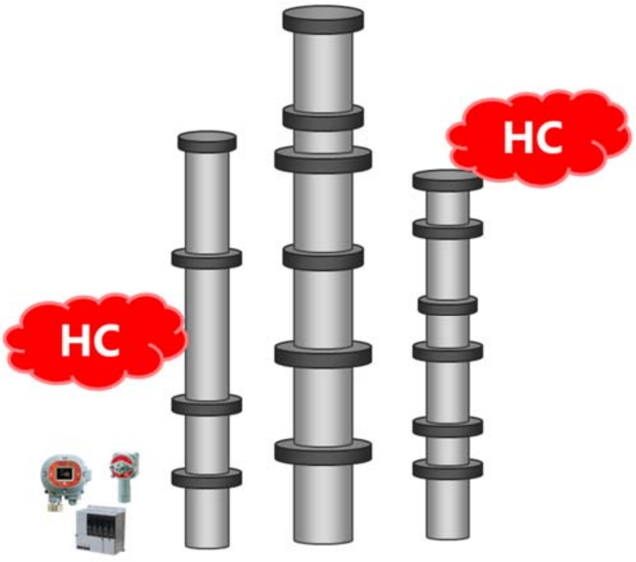


Naphtha desulfurization plant

1-8: Ethylene manufacturing plant

Description: The ethylene manufacturing plant thermally cracks naphtha into hydrocarbons of lower molecular weight containing olefins such as ethylene and propylene and separates them into their respective components.

Hazardous risks: **Leaks from the ethylene manufacturing plant pose explosion risk.** ⇒ **Detecting combustible gas (HC) to prevent explosions**

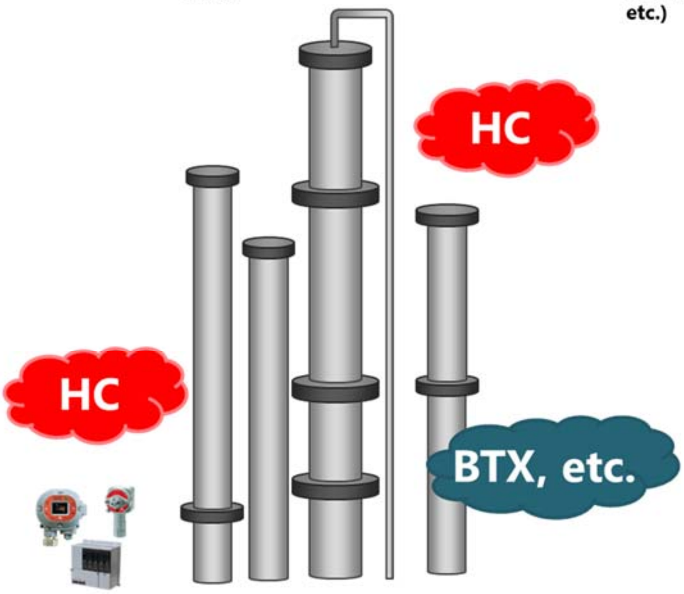


Ethylene manufacturing plant

1-9: Aromatic extraction plant

Description: The aromatic extraction plant extracts benzene, toluene, and xylene from thermal cracking residual oil (oil produced as by-product in ethylene manufacture) and reformed gasoline.

Hazardous risks: **Leaks from the aromatic extraction plant pose poisoning and explosion risks.** ⇒ **Detecting combustible gas (HC) to prevent explosions**
Preventing poisoning due to VOC (BTX, etc.)

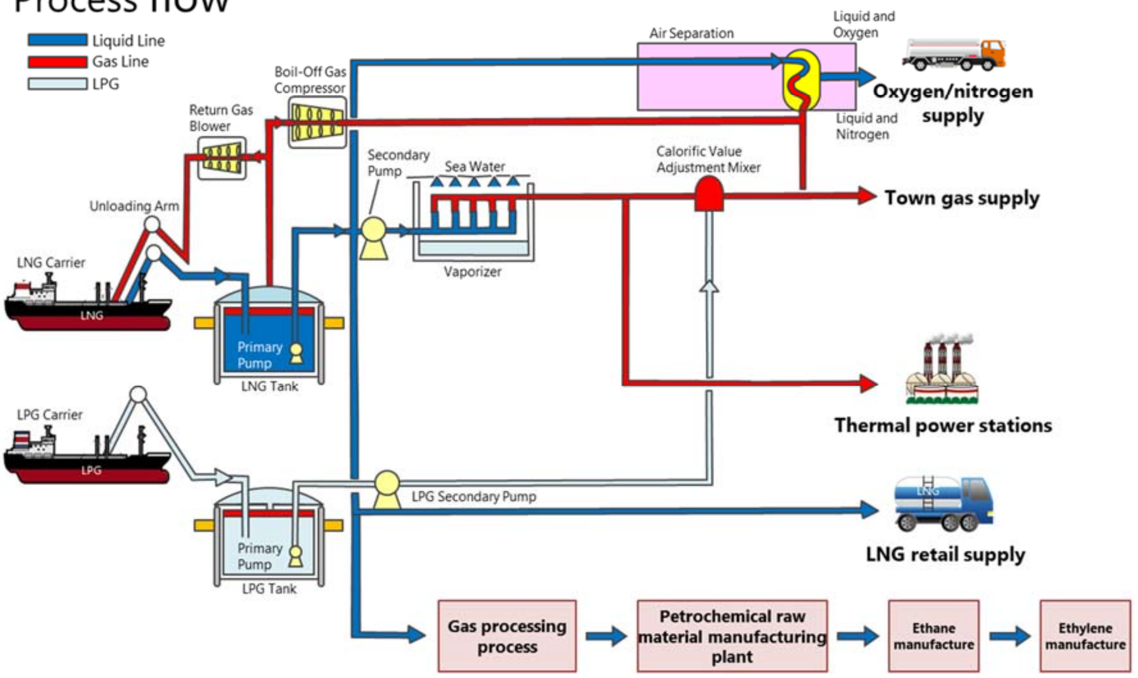


Aromatic extraction plant

2. Shale gas–derived processes

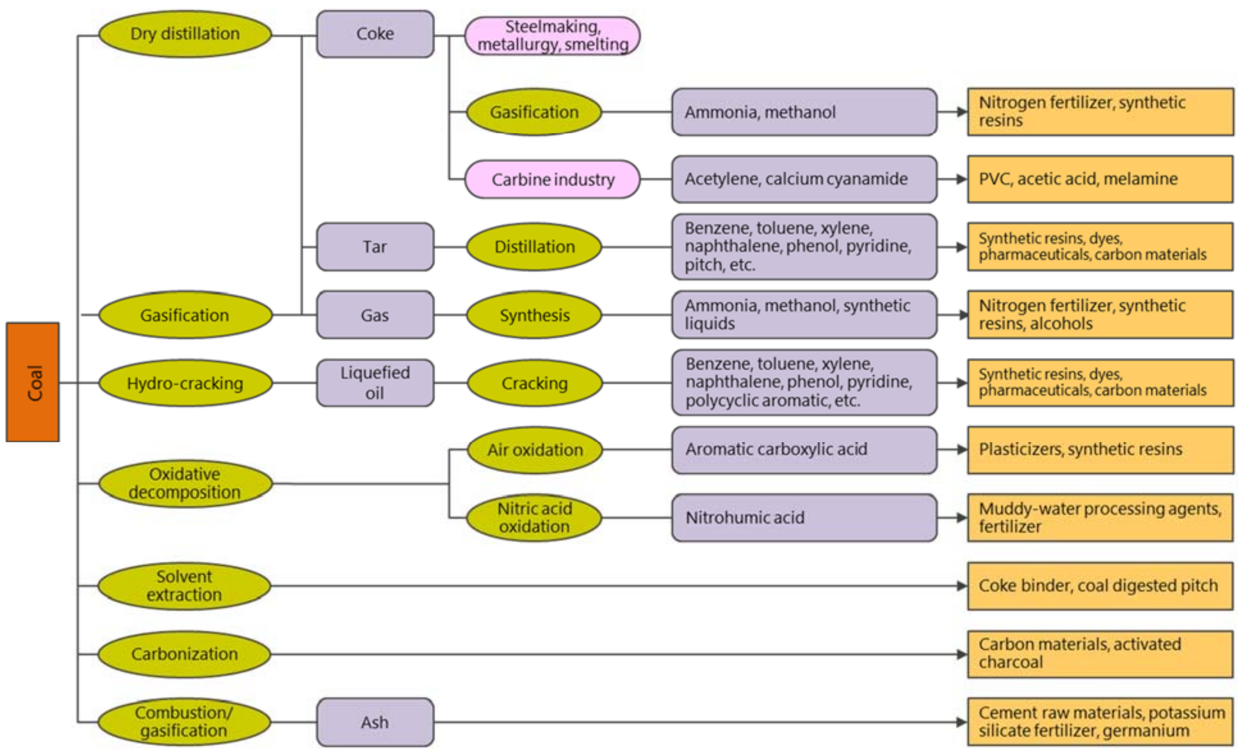
The typical manufacturing processes used to derive products from shale gas are shown below. Gas detectors and alarms are used in each of the processes.

Process flow



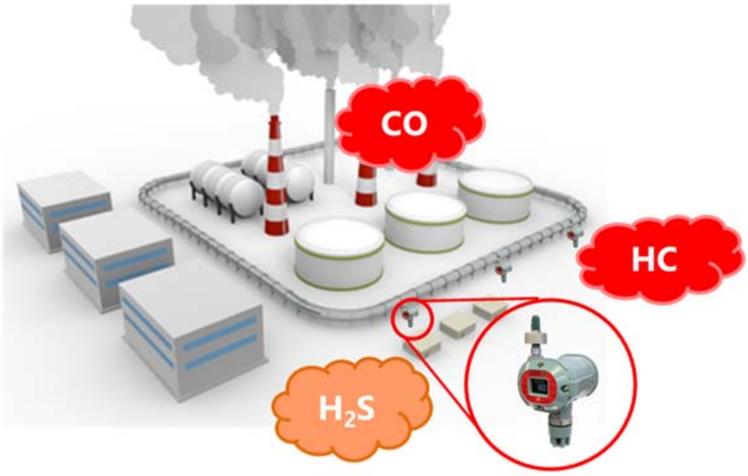
3. Coal-derived processes

The typical manufacturing processes used to derive products from coal are shown below. Gas detectors and alarms are used in each process.



4. Overall plant safety management

- A wide range of boundary monitors are used to manage overall plant safety.
- In addition to serving as boundary monitors, wireless gas detectors can also be used for monitoring wide areas and as temporary gas detectors.



Plant

Gas detector heads that can be used as boundary monitors

12

Standards and Certification

12-1. ATEX

Directive 94/9/EC

Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres

ATEX directive

Compliance with the ATEX directive became compulsory within the EU from July 1, 2013 for equipment used in potentially explosive atmospheres.

■ CE marking and ATEX

The ATEX directive forms part of the CE marking applicability and incorporates previous European explosion-proof standards.

■ Purposes of the ATEX directive

The ATEX directive has the following main purposes:

◎Preventing electrostatic charge

◎Preventing ignition from sparks generated by friction, impact, or wear

◎Preventing ignition due to temperature increases due to the above

◎The manufacturer assumes responsibility.

◎Separate certification by zone and category

■ Zone/category classification

ATEX divides applicability to individual hazardous locations (zones) into different categories.

Zone	Product protection level	Likelihood of presence of explosive atmosphere (zone)
Zone 0	**Category 1**	Continuously or long-term > 1,000 hours/year
Zone 1	**Category 2**	Occasionally 10 to 1,000 hours/year
Zone 2	**Category 3**	Unlikely or short-term < 10 hours/year

12-2. IECEx

IECEx is managed by industry representatives including governing bodies, manufacturers, and end users to ensure compliance with worldwide standards for safety of equipment used in hazardous locations (Ex).

The IECEx Scheme is an international certification scheme covering equipment that meet the r equirements of International Standards; most notably IEC 60079.

EN/IEC 60079-0 General Requirements Marking

Gas Zones			
Gas Zones	Definition	EPL	Required Protection
Methane	Mines with methane and dust. Equipment remains energised in explosive atmosphere	Ma	Two Faults
Methane	Mines with methane and dust. Equipment is de-energized in explosive atmosphere	Mb	Severe Normal
Zone 0	Explosive atmosphere present continuously or for long periods, frequently	Ga	Two Faults
Zone 1	Explosive atmosphere is likely to occur under normal conditions, occasionally	Gb	One Fault
Zone 2	Explosive atmosphere is unlikely to occur under normal conditions, short periods	Gc	Normal

Protection Concept - Electrical - Gas	
Type of Protection (electrical - gas)	Reference
Flameproof - Ex d / da / db / dc	EN/IEC 60079-1
Intrinsic Safety - Ex i / ia / ib / ic	EN/IEC 60079-11

Gas Groups	
Gas Groups	Gases are classified according to the ignitability of the gas/air mixture as defined in EN/IEC 60079-20-1
IIA	Acetic Acid, Acetone, Ammonia, Butane, Cyclohexane, Propane, Gasoline (petrol), Methane (natural gas, non-mining), Toluene, Xylene. Methanol (methyl alcohol), Propane-2-ol (iso-propyl alcohol) etc.
IIB	Group IIA gases plus, Di-ethyl ether, Ethylene, Ethanol Methyl ethyl ketone (MEK), Propane-1-ol (n-propyl alcohol) etc.
IIC	Group IIA and IIB gases plus, Acetylene, Hydrogen etc.

Temperature Class	
Temperature Class	Highest tempera ture achieved under the most adverse equipment rating and heating conditions. (Flashpoint temperature of some gases)
T1: 450℃	Ammonia (630℃), Hydrogen (560℃), Methane (537℃), Propane (470℃)
T2: 300℃	Ethylene (425℃), Butane (372℃), Acetylene (305℃)
T3: 200℃	Cyclohexane (259℃), Kerosene (210℃)
T4: 135℃	Di-ethyl Ether (160℃)
T5: 100℃	—
T6: 85℃	Carbon Disulphate (95℃)

13

Product Ingress Protection Rating

Enclosure ingress protection rating

A coded rating is currently widely used to indicate the level of protection in the case of ingress of liquids and solid matter into the enclosure. This classification also covers the protection of persons if they come into contact with charged or moving parts inside the enclosure. Note that this complements protection ratings for electronic equipment used in hazardous areas. It does not replace these protection ratings.

In Europe, the letters “IP” are used to indicate the protection rating, followed by two digits indicating the level of protection. The first digit indicates the level of protection for persons against contact with internal charged or moving parts. The second digit indicates enclosure protection in the case of water ingress. For example, an enclosure marked IP65 offers full protection (dust protection) against contact with charged and moving parts and protection against water spray or water flow ingress. This is suited to gas detectors such as controllers. Note the need to ensure adequate cooling of the electronic equipment. The two-digit IP code is a shortened form widely used in the UK. The comprehensive international version uses three digits rather than two digits after the IP letters (e.g., IP653). The third digit indicates impact resistance. The following table shows the meaning of the digits:

Third Numeral	Meaning
0	No Protection
1	Impact of 0.225 Joule (150g weight dropped from 15cm)
2	Impact of 0.375 Joule (250g weight dropped from 15cm)
3	Impact of 0.5 Joule (250g weight dropped from 20cm)
4	(No meaning)
5	Impact of 2.0 Joule (500g weight dropped from 40cm)
6	(No meaning)
7	Impact of 6.0 Joule (1.5kg weight dropped from 40cm)
8	(No meaning)
9	Impact of 6.0 Joule (5kg weight dropped from 40cm)

IP codes (IEC / EN 60529)

Protection rating (IP) codes (IEC / EN 60529)

First Numeral		Second Numeral	
Protection against solid bodies	IP		Protection against liquid
No protection	0	0	No Protection
Objects greater than 50mm	1	1	Vertically dripping water
Objects greater than 12mm	2	2	Angled dripping water -75° to 90°
Objects greater than 2.5mm	3	3	Splashed water
Objects greater than 1.0mm	4	4	Sprayed water
Dust protected	5	5	Water jets
Dust tight	6	6	Heavy seas
		7	Effects of immersion(defined in minutes)
		8	Indefinite immersion

Example: IP67 is dust tight and protected against the effects of immersion

In North America, the NEMA system is used to evaluate enclosures. The following table compares the NEMA system to the IP ratings.

NEMA,UL and CSA type rating	Approximate IEC/IP Code	Description
1	IP20	Indoor, from contact with contents
2	IP22	Indoor, limited, falling dirt and water
3	IP55	Outdoor from rain, sleet, windblown dust and ice damage
3R	IP24	Outdoor from rain, sleet and ice damage
4	IP66	Indoor and outdoor, from windblown dust, splashing and hose directed water and ice damage
4X	IP66	Indoor and outdoor, from corrosion, windblown dust, rain, splashing and hose directed water and ice damage
6	IP67	Indoor and outdoor, from hose directed water, water entry during submersion and ice damage
12	IP54	Indoor, from dust, falling dirt and dripping non corrosive liquids
13	IP54	Indoor, from dust, falling dirt and dripping non corrosive liquids

14

Maintenance

Gas detectors and alarms are special devices that require expert knowledge and experience for maintenance, because they vary significantly by type, they must detect target gases at extremely low concentrations or with high chemical activity, and careful handling of hazardous substances is required. Maintenance is particularly important to maintain the reliability of these devices since they are used in diverse and often harsh environments.

Riken Keiki operates a network of sales and maintenance bases worldwide. The service engineers in each country undergo periodic maintenance training and are certified to improve and ensure high-quality maintenance service. We encourage you to contact Riken Keiki for any maintenance needs related to gas detectors and alarms.

The Riken Keiki sales and maintenance network