Gas book

Honeywell

Perfectly placed^H to deliver innovation in gas detection

1. Honeywell Analytics

Honeywell Analytics is the World’s leading manufacturer of flammable, toxic and oxygen detection systems, bringing together nearly 200 years of collective experience in the design and creation of some of the most innovative products in gas detection. Suitable for industrial, commercial and domestic applications where people can be exposed to flammable, toxic or oxygen deficiency gas hazards, Honeywell Analytics’ gas detection solutions are available in a variety of fixed and portable ranges.

The company’s core competencies lie in the design, development and manufacture of electrochemical, catalytic, paper tape and infrared sensors. With a high commitment to research and engineering, the company offers solutions to increasingly difficult gas detection and monitoring applications.

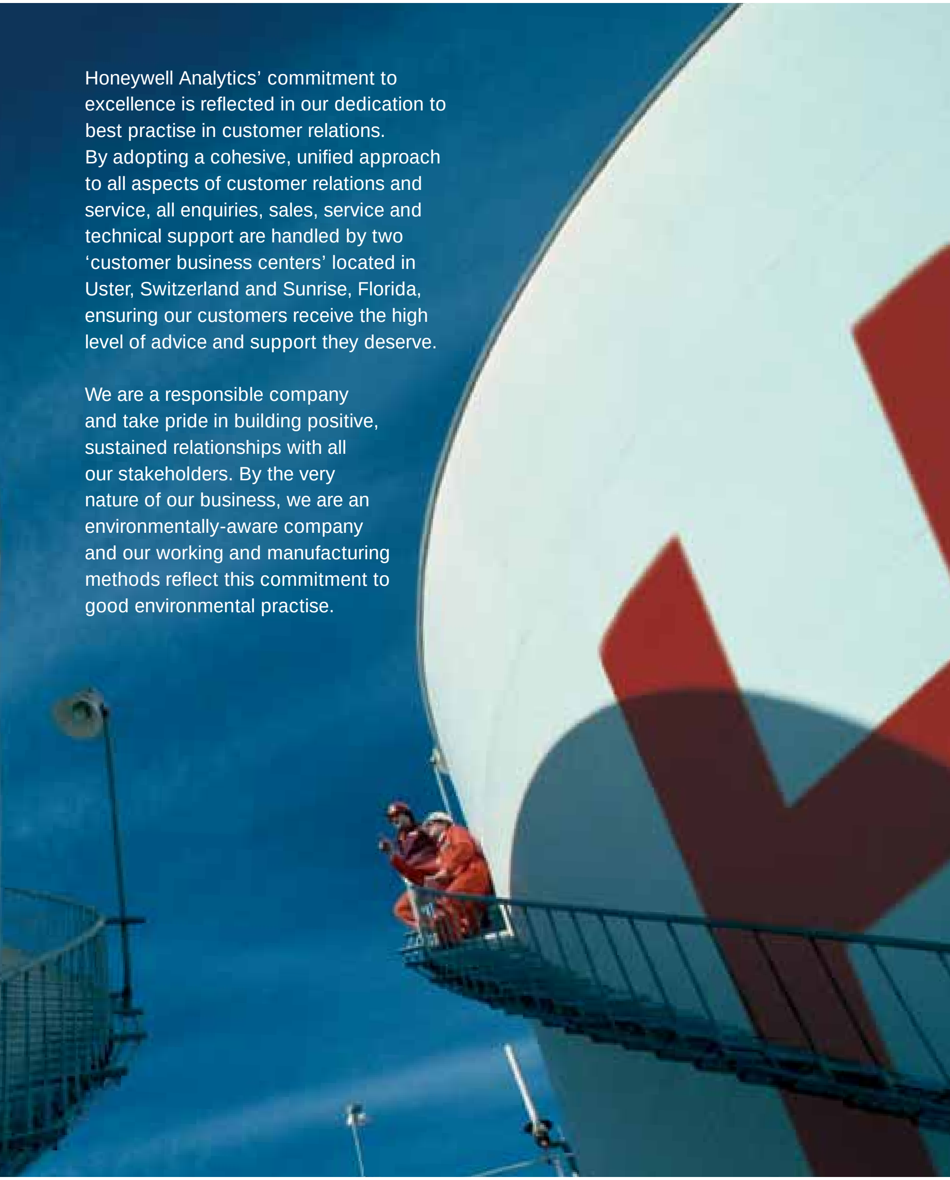
Lumidor and Neotronics are the company’s portable ranges that include instruments with disposable multi-gas cartridges and automated calibration facilities; Sieger fixed, robust detectors are crucial for gas monitoring in extreme conditions such as the marine and offshore industry; MDA Scientific is the leading fixed solution for the semiconductor industry, monitoring low levels of highly toxic gases and Zareba, Honeywell Analytics’ newest family of detectors, makes compliance with health and safety regulations in commercial and industrial sites, simple, convenient and cost-effective.

The success and influence of these brands is evident in them having become as much associated with industry-standard processes as with the products they represent - for example, ‘MDA rooms’ are commonly found in the semiconductor manufacturing facilities, while Sieger is used so commonly on offshore oil platforms it has become effectively a shorthand term to describe gas detection technology.

Honeywell Analytics’ success is built on a legacy of innovation in and the development of gas detection technology. Responsible for a number of industry ‘firsts’ that has defined and transformed the theory, practise and language of the gas detection industry, notable innovations include the original Siegistor catalytic bead, development of optical point and open path infrared gas detection technology, the Chemcasette® paper tape cartridge and the world’s first automated electrochemical cell manufacturing facility.

Honeywell Analytics' commitment to excellence is reflected in our dedication to best practise in customer relations.
By adopting a cohesive, unified approach to all aspects of customer relations and service, all enquiries, sales, service and technical support are handled by two 'customer business centers' located in Uster, Switzerland and Sunrise, Florida, ensuring our customers receive the high level of advice and support they deserve.

We are a responsible company and take pride in building positive, sustained relationships with all our stakeholders. By the very nature of our business, we are an environmentally-aware company and our working and manufacturing methods reflect this commitment to good environmental practise.



2 Introduction

Industrial processes increasingly involve the use and manufacture of highly dangerous substances, particularly flammable, toxic and oxygen gases. Inevitably, occasional escapes of gas occur, which create a potential hazard to the industrial plant, its employees and people living nearby. Worldwide incidents, involving asphyxiation, explosions and loss of life, are a constant reminder of this problem.

In most industries, one of the key parts of any safety plan for reducing risks to personnel and plant is the use of early-warning devices such as gas detectors. These can help to provide more time in which to take remedial or protective action. They can also be used as part of a total, integrated monitoring and safety system for an industrial plant.

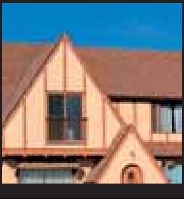
This handbook is intended to offer a simple guide to anyone considering the use of such gas detection equipment. It provides an explanation of both the principles involved and the instrumentation needed for satisfactory protection of personnel, plant and environment. The aim has been to answer as many as possible of the most commonly asked questions about the selection and use of industrial gas detection equipment.

Contents

3 What is gas?

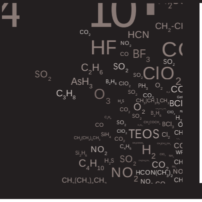
The name gas comes from the word chaos. Gas is a swarm of molecules moving randomly and chaotically, constantly colliding with each other and anything else around it. Gases fill any available volume and due to the very high speed at which they move will mix rapidly into any atmosphere in which they are released.

Different gases are all around us in everyday life. The air we breathe is made up of several different gases including Oxygen and Nitrogen.



Natural Gas (Methane) is used in many homes for heating and cooking.

Vehicle engines combust fuel and oxygen and produce exhaust gases that include Nitrogen Oxides, Carbon Monoxide and Carbon Dioxide.



Gases can be lighter, heavier or about the same density as air. Gases can have an odour or be odourless. Gases can have colour or be colourless. If you can't see it, smell it or touch it, it doesn't mean that it is not there.

Air Composition

Name	Symbol	Percent by Volume
Nitrogen	N_2	78.084%
Oxygen	O_2	20.9476%
Argon	Ar	0.934%
Carbon Dioxide	CO_2	0.0314%
Neon	Ne	0.001818%
Methane	CH_4	0.0002%
Helium	He	0.000524%
Krypton	Kr	0.000114%
Hydrogen	H_2	0.00005%
Xeron	Xe	0.0000087%

The table gives the sea-level composition of air (in percent by volume at the temperature of 15°C and the pressure of 101325 Pa).

4 Gas Hazards

There are three main types of gas hazard:

Flammable

RISK OF FIRE AND OR EXPLOSION

e.g.
Methane,
Butane, Propane

Toxic

RISK OF POISONING

e.g.
Carbon Monoxide,
Hydrogen Carbon
Dioxide, Chlorine

Asphyxiant

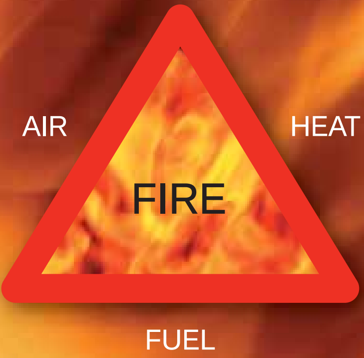
RISK OF SUFFOCATION

e.g.
Oxygen deficiency.
Oxygen can be
consumed or displaced
by another gas

5 Flammable Gas Hazards

Combustion is a fairly simple chemical reaction in which oxygen is combined rapidly with another substance resulting in the release of energy. This energy appears mainly as heat – sometimes in the form of flames. The igniting substance is normally, but not always, a Hydrocarbon compound and can be solid, liquid, vapor or gas. However, only gases and vapors are considered in this publication.

(N.B. The terms 'flammable', 'explosive', and 'combustible' are, for the purpose of this publication, interchangeable).



The process of combustion can be represented by the well known fire triangle.

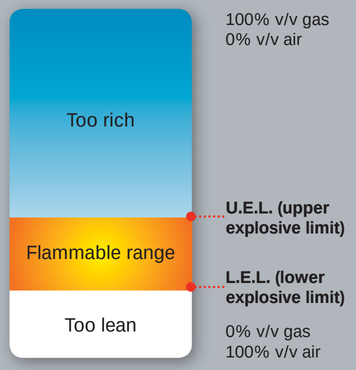
Three factors are always needed to cause combustion:

1. **A source of ignition**
2. **Oxygen**
3. **Fuel in the form of a gas or vapor**

In any fire protection system, therefore, the aim is to always remove at least one of these three potentially hazardous items.

Flammable Limit

There is only a limited band of gas/air concentration which will produce a combustible mixture. This band is specific for each gas and vapor and is bounded by an upper level, known as the Upper Explosive Limit (or the UEL) and a lower level, called the Lower Explosive Limit (LEL).



At levels below the LEL, there is insufficient gas to produce an explosion (i.e. the mixture is too 'lean'), whilst above the UEL, the mixture has insufficient oxygen (i.e. the mixture is too 'rich'). The flammable range therefore falls between the limits of the LEL and UEL for each individual gas or mixture of gases. Outside these limits, the mixture is not capable of combustion. The Flammable Gases Data in section 2.4 indicates the limiting values for some of the better-known combustible gases and compounds. The data is given for gases and vapors at normal conditions of pressure and temperature. An increase in pressure, temperature or oxygen content will generally broaden the flammability range.

In the average industrial plant, there would normally be no gases leaking into the surrounding area or, at worst, only a low background level of gas present. Therefore the detecting and early warning system will only be required to detect levels from zero percent of gas up to the lower explosive limit. By the time this concentration is reached, shut-down procedures or site clearance should have been put into operation. In fact this will typically take place at a concentration of less than 50 percent of the LEL value, so that an adequate safety margin is provided.

However, it should always be remembered that in enclosed or unventilated areas, a concentration in excess of the UEL can sometimes occur. At times of inspection, therefore, special care needs to be taken when operating hatches or doors, since the ingress of air from outside can dilute the gases to a hazardous, combustible mixture.

(N.B LEL/LFL and UEL/UFL are for the purpose of this publication, interchangeable).

Ignition Temperature

Flammable gases also have a temperature where ignition will take place, even without an external ignition source such as a spark or flame. This temperature is called the Ignition Temperature. Apparatus for use in a hazardous area must not have a surface temperature that exceeds the ignition temperature. Apparatus is therefore marked with a maximum surface temperature or T rating.

Flash Point (F.P. °C)

The flash point of a flammable liquid is the lowest temperature at which the surface of the liquid emits sufficient vapor to be ignited by a small flame.

Don’t confuse with Ignition Temperature as the two can be very different:

Gas / Vapor	Flash Point °C	Ignition Temp. °C
Methane	<-20	595
Kerosene	38	210
Bitumen	270	310

To convert a Celsius temperature into degrees Fahrenheit:
Tf = ((9/5)*Tc)+32
E.g. to convert -20 Celsius into degrees Fahrenheit, first multiply the Celsius temperature reading by nine-fifths to get -36. Then add 32 to get -4°F.

Vapor Density

Helps determine sensor placement
The density of a gas / vapor is compared with air when air = 1.0
Vapor density < 1.0 will rise
Vapor density > 1.0 will fall

Gas / Vapor	Vapor density
Methane	0.55
Carbon Monoxide	0.97
Hydrogen Sulfide	1.19
Petrol Vapor	3.0 approx

Flammable Gases Data

Common Name	CAS Number	Formula	Mol. Wt.	B.P. °C
Acetaldehyde	75-07-0	CH_3CHO	44.05	20
Acetic acid	64-19-7	CH_3COOH	60.05	118
Acetic anhydride	108-24-7	$(CH_3CO)_2O$	102.09	140
Acetone	67-64-1	$(CH_3)_2CO$	58.08	56
Acetonitrile	75-05-8	CH_3CN	41.05	82
Acetyl chloride	75-36-5	CH_3COCl	78.5	51
Acetylene	74-86-2	$CH=CH$	26	-84
Acetyl fluoride	557-99-3	CH_3COF	62.04	20
Acrylaldehyde	107-02-8	$CH_2=CHCHO$	56.06	53
Acrylic acid	79-10-7	$CH_2=CHCOOH$	72.06	139
Acrylonitrile	107-13-1	$CH_2=CHCN$	53.1	77
Acryloyl chloride	814-68-6	$CH_2CHCOCl$	90.51	72
Allyl acetate	591-87-7	$CH_2=CHCH_2OOCCH_3$	100.12	103
Allyl alcohol	107-18-6	$CH_2=CHCH_2CH$	58.08	96
Allyl chloride	107-05-1	$CH_2=CHCH_2Cl$	76.52	45
Ammonia	7664-41-7	NH_3	17	-33
Aniline	62-53-3	$C_6H_6NH_2$	93.1	184
Benzaldehyde	100-52-7	C_6H_5CHO	106.12	179
Benzene	71-43-2	C_6H_6	78.1	80
1-Bromobutane	109-65-9	$CH_3(CH_2)_2CH_2Br$	137.02	102
Bromoethane	74-96-4	CH_3CH_2Br	108.97	38
Buta-1,3-diene	106-99-0	$CH_2=CHCH=CH_2$	54.09	-4.5
Butane	106-97-8	C_4H_{10}	58.1	-1
Isobutane	75-28-5	$(CH_3)_2CHCH_3$	58.12	-12
Butan-1-ol	71-36-3	$CH_3(CH_2)_2CH_2OH$	74.12	116
Butanone	78-93-3	$CH_3CH_2COCH_3$	72.1	80
But-1-ene	106-98-9	$CH_2=CHCH_2CH_3$	56.11	-6.3
But-2-ene (isomer not stated)	107-01-7	$CH_3CH=CHCH_3$	56.11	1
Butyl acetate	123-86-4	$CH_3COOCH_2(CH_2)_2CH_3$	116.2	127
n-Butyl acrylate	141-32-2	$CH_2=CHCOOC_4H_9$	128.17	145
Butylamine	109-73-9	$CH_3(CH_2)_3NH_2$	73.14	78
Isobutylamine	78-81-9	$(CH_3)_2CHCH_2NH_2$	73.14	64
Isobutylisobutyrate	97-85-8	$(CH_3)_2CHCOOCH_2CH(CH_3)_2$	144.21	145
Butylmethacrylate	97-88-1	$CH_2=C(CH_3)COO(CH_2)_3CH_3$	142.2	160
Tert-butyl methyl ether	1634-04-4	$CH_3OC(CH_3)_2$	88.15	55
n-Butylpropionate	590-01-2	$C_2H_5COOC_4H_9$	130.18	145
Butyraldehyde	123-72-8	$CH_3CH_2CH_2CHO$	72.1	75
Isobutyraldehyde	78-84-2	$(CH_3)_2CHCHO$	72.11	63
Carbon disulphide	75-15-0	CS_2	76.1	46
Carbon monoxide	630-08-0	CO	28	-191
Carbonyl sulphide	463-58-1	COS	60.08	-50
Chlorobenzene	108-90-7	$C6H_5Cl$	112.6	132
1-Chlorobutane	109-69-3	$CH_3(CH_2)_2CH_2Cl$	92.57	78
2-Chlorobutane	78-86-4	$CH_3CHClC_2H_5$	92.57	68
1-Chloro-2,3-epoxypropane	106-89-8	OCH_2CHCH_2Cl	92.52	115
Chloroethane	75-00-3	CH_3CH_2Cl	64.5	12
2-Chloroethanol	107-07-3	CH_2ClCH_2OH	80.51	129
Chloroethylene	75-01-4	$CH_2=CHCl$	62.3	-15
Chloromethane	74-87-3	CH_3Cl	50.5	-24
1-Chloro-2-methylpropane	513-36-0	$(CH_3)_2CHCH_2Cl$	92.57	68
3-Chloro-2-methylprop-1-ene	563-47-3	$CH_2=C(CH_3)CH_2Cl$	90.55	71
5-Chloropentan-2-one	5891-21-4	$CH_3CO(CH_2)_3Cl$	120.58	71
1-Chloropropane	540-54-5	$CH_3CH_2CH_2Cl$	78.54	37
2-Chloropropane	75-29-6	$(CH_3)_2CHCl$	78.54	47
Chlorotrifluoroethyl-ene	79-38-9	$CF_2=CFCl$	116.47	-28.4
[illegible]-Chlorotoluene	100-44-7	$C_6H_5CH_2Cl$	126.58	

Data may change by country
and date, always refer to local
up to date regulations.

References: BS EN 61779-1:2000 Electrical apparatus for the detection and measurement of flammable gases-Part 1: General requirements and test methods. NIST Chemistry Web Book June 2005 release. Aldrich Handbook of Fine Chemicals and Laboratory Equipment 2003-2004.

		Flammable Limits				
Rel. Vap. Dens.	**F.P. °C**	**LFL % v/v**	**UFL % v/v**	**LFL mg/L**	**UFL mg/L**	**I.T. °C**
1.52	–38	4.00	60.00	74	1108	204
2.07	40	4.00	17.00	100	428	464
3.52	49	2.00	10.00	85	428	334
2.00	<–20	2.50	13.00	80	316	535
1.42	2	3.00	16.00	51	275	523
2.70	–4	5.00	19.00	157	620	390
0.90		2.30	100.00	24	1092	305
2.14	<–17	5.60	19.90	142	505	434
1.93	–18	2.85	31.80	65	728	217
2.48	56	2.90		85		406
1.83	–5	2.80	28.00	64	620	480
3.12	–8	2.68	18.00	220	662	463
3.45	13	1.70	9.30	69	3 800	348
2.00	21	2.50	18.00	61	438	378
2.64	–32	2.90	11.20	92	357	390
0.59		15.00	33.60	107	240	630
3.22	75	1.20	11.00	47	425	630
3.66	64	1.40		62		192
2.70	–11	1.20	8.60	39	280	560
4.72	13	2.50	6.60	143	380	265
3.75	<–20	6.70	11.30	306	517	511
1.87	-76	1.40	16.30	31	365	430
2.05		1.40	9.30	33	225	372
2.00	gas	1.30	9.80	31	236	460
2.55	29	1.70	12.00	52	372	359
2.48	–9	1.80	10.00	50	302	404
1.95		1.60	10.00	38	235	440
1.94	gas	1.60	10.00	40	228	325
4.01	22	1.30	7.50	64	390	370
4.41	38	1.20	8.00	63	425	268
2.52	–12	1.70	9.80	49	286	312
2.52	–20	1.47	10.80	44	330	374
4.93	34	0.80		47		424
4.90	53	1.00	6.80	58	395	289
3.03	–27	1.50	8.40	54	310	385
4.48	40	1.10	7.70	58	409	389
2.48	–16	1.80	12.50	54	378	191
2.48	–22	1.60	11.00	47	320	176
2.64	–30	0.60	60.00	19	1 900	95
0.97		10.90	74.00	126	870	805
2.07		6.50	28.50	180	700	209
3.88	28	1.40	11.00	66	520	637
3.20	–12	1.80	10.00	69	386	250
3.19	<–18	2.20	8.80	82	339	368
3.30	28	2.30	34.40	86	1 325	385
2.22		3.60	15.40	95	413	510
2.78	55	5.00	16.00	160	540	425
2.15	–78 gas	3.60	33.00	94	610	415
1.78	–24 gas	7.60	19.00	160	410	625
3.19	<–14	2.00	8.60	75	340	416
3.12	–16	2.10		77		478
4.16	61	2.00		98		440
2.70	–32	2.40	11.10	78	365	520
2.70	<–20	2.80	10.70	92	350	590
4.01	gas	4.60	84.30	220	3 117	607
4.36	60	1.20		63		585

Flammable Gases Data (continued)

Common Name	CAS Number	Formula	Mol. Wt.	B.P. °C
Cresols (mixed isomers)	1319-77-3	$CH_3C_5H_4OH$	108.14	191
Crotonaldehyde	123-73-9	$CH_3CH{=}CHCHO$	70.09	102
Cumene	98-82-8	$C_6H_5CH(CH_3)_2$	120.19	152
Cyclobutane	287-23-0	$CH_2(CH_2)_2CH_2$	56.1	13
Cycloheptane	291-64-5	$CH_2(CH_2)_5CH_2$	98.19	118.5
Cyclohexane	110-82-7	$CH_2(CH_2)_4CH_2$	84.2	81
Cyclohexanol	108-93-0	$CH_2(CH_2)_4CHOH$	100.16	161
Cyclohexanone	108-94-1	$CH_2(CH_2)_4CO$	98.1	156
Cyclohexene	110-83-8	$CH_2(CH_2)_3CH{=}CH$	82.14	83
Cyclohexylamine	108-91-8	$CH_2(CH_2)_4CHNH_2$	99.17	134
Cyclopentane	287-92-3	$CH_2(CH_2)_3CH_2$	70.13	50
Cyclopentene	142-29-0	$CH{=}CHCH_2CH_2CH$	68.12	44
Cyclopropane	75-19-4	$CH_2CH_2CH_2$	42.1	-33
Cyclopropyl methyl ketone	765-43-5	$CH_3COCHCH_2CH_2$	84.12	114
p-Cymene	99-87-6	$CH_3CH_6H_4CH(CH_3)_2$	134.22	176
Decahydro-naphthalene trans	493-02-7	$CH_2(CH_2)_3CHCH(CH_2)_3CH_2$	138.25	185
Decane (mixed isomers)	124-18-5	$C_{10}H_{22}$	142.28	173
Dibutyl ether	142-96-1	$(CH_3(CH_2)_3)_2O$	130.2	141
Dichlorobenzenes (isomer not stated)	106-46-7	$C_6H_4Cl_2$	147	179
Dichlorodiethyl-silane	1719-53-5	$(C_2H_5)SiCl_2$	157.11	128
1,1-Dichloroethane	75-34-3	CH_3CHCl_2	99	57
1,2-Dichloroethane	107-06-2	CH_2ClCH_2Cl	99	84
Dichloroethylene	540-59-0	$ClCH{=}CHCl$	96.94	37
1,2-Dichloro-propane	78-87-5	$CH_3CHClCH_2Cl$	113	96
Dicyclopentadiene	77-73-6	$C_{10}H_{12}$	132.2	170
Diethylamine	109-89-7	$(C_2H_5)_2NH$	73.14	55
Diethylcarbonate	105-58-8	$(CH_3CH_2O)_2CO$	118.13	126
Diethyl ether	60-29-7	$(CH_3CH_5)_2O$	74.1	34
1,1-Difluoro-ethylene	75-38-7	$CH_2{=}CF_2$	64.03	-83
Diisobutylamine	110-96-3	$((CH_3)_2CHCH_2)_2NH$	129.24	137
Diisobutyl carbinol	108-82-7	$((CH_3)_2CHCH_2)_2CHOH$	144.25	178
Diisopentyl ether	544-01-4	$(CH_3)_2CH(CH_2)_2O(CH_2)_2CH(CH_3)_2$	158.28	170
Diisopropylamine	108-18-9	$((CH_3)_2CH)_2NH$	101.19	84
Diisopropyl ether	108-20-3	$((CH_3)_2CH)_2O$	102.17	69
Dimethylamine	124-40-3	$(CH_3)_2NH$	45.08	7
Dimethoxymethane	109-87-5	$CH_2(OCH)_3)_2$	76.09	41
3-(Dimethylamino)propiononitrile	1738-25-6	$(CH_3)_2NHCH_2CH_2CN$	98.15	171
Dimethyl ether	115-10-6	$(CH_3)_2O$	46.1	-25
N,N-Dimethylformamide	68-12-2	$HCON(CH_3)_2$	73.1	152
3,4-Dimethyl hexane	583-48-2	$CH_3CH_2CH(CH_3)CH(CH_3)CH_2CH_3$	114.23	119
N,N-Dimethyl hydrazine	57-14-7	$(CH_3)_2NNH_2$	60.1	62
1,4-Dioxane	123-91-1	$OCH_2CH_2OCH_2CH_2$	88.1	101
1,3-Dioxolane	646-06-0	$OCH_2CH_2OCH_2$	74.08	74
Dipropylamine	142-84-7	$(CH_3CH_2CH_2)_2NH$	101.19	105
Ethane	74-84-0	CH_3CH_3	30.1	-87
Ethanethiol	75-08-1	CH_3CH_2SH	62.1	35
Ethanol	64-17-5	CH_3CH_2OH	46.1	78
2-Ethoxyethanol	110-80-5	$CH_3CH_2OCH_2CH_2OH$	90.12	135
2-Ethoxyethyl acetate	111-15-9	$CH_3COOCH_2CH_2OCH_2CH_3$	132.16	156
Ethyl acetate	141-78-6	$CH_3COOCH_2CH_3$	88.1	77
Ethyl acetoacetate	141-97-9	$CH_3COCH_2COOCH_2CH_3$	130.14	181
Ethyl acrylate	140-88-5	$CH_2{=}CHCOOCH_2CH_3$	100.1	100
Ethylamine	75-04-7	$C_2H_5NH_2$	45.08	16.6
Ethylbenzene	100-41-4	$CH_2CH_3C_6H_5$	106.2	135
Ethyl butyrate	105-54-4	$CH_3CH_2CH_2COOC_2H_5$	116.16	120
Ethylcyclobutane	4806-61-5	$CH_3CH_2CHCH_2CH_2CH_2$	84.16	
Ethylcyclohexane	1678-91-7	$CH_3CH_2CH(CH_2)_4CH_2$	112.2	131
Ethylcyclopentane	1640-89-7	$CH_3CH_2CH(CH_2)_3CH_2$	98.2	103
Ethylene	74-85-1	$CH_2{=}CH_2$	28.1	-104

		Flammable Limits				
Rel. Vap. Dens.	F.P. °C	LFL % v/v	UFL % v/v	LFL mg/L	UFL mg/L	I.T. °C
3.73	81	1.10		50		555
2.41	13	2.10	16.00	82	470	280
4.13	31	0.80	6.50	40	328	424
1.93		1.80		42		
3.39	<10	1.10	6.70	44	275	
2.90	–18	1.20	8.30	40	290	259
3.45	61	1.20	11.10	50	460	300
3.38	43	1.00	9.40	42	386	419
2.83	–17	1.20		41		244
3.42	32	1.60	9.40	63	372	293
2.40	–37	1.40		41		320
2.30	<–22	1.48		41		309
1.45		2.40	10.40	42	183	498
2.90	15	1.70		58		452
4.62	47	0.70	6.50	39	366	436
4.76	54	0.70	4.90	40	284	288
4.90	46	0.70	5.60	41	433	201
4.48	25	0.90	8.50	48	460	198
5.07	86	2.20	9.20	134	564	648
	24	3.40		223		
3.42	–10	5.60	16.00	230	660	440
3.42	13	6.20	16.00	255	654	438
3.55	–10	9.70	12.80	391	516	440
3.90	15	3.40	14.50	160	682	557
4.55	36	0.80		43		455
2.53	–23	1.70	10.00	50	306	312
4.07	24	1.40	11.70	69	570	450
2.55	–45	1.70	36.00	60	1 118	160
2.21		3.90	25.10	102	665	380
4.45	26	0.80	3.60	42	190	256
4.97	75	0.70	6.10	42	370	290
5.45	44	1.27		104		185
3.48	–20	1.20	8.30	49	260	285
3.52	–28	1.00	21.00	45	900	405
1.55	–18 gas	2.80	14.40	53	272	400
2.60	–21	3.00	16.90	93	535	247
3.38	50	1.57		62		317
1.59	–42 gas	2.70	32.00	51	610	240
2.51	58	1.80	16.00	55	500	440
3.87	2	0.80	8.50	38	310	305
2.07	–18	2.40	20	60	490	240
3.03	11	1.90	22.50	74	813	379
2.55	–5	2.30	30.50	70	935	245
3.48	4	1.60	9.10	66	376	280
1.04		2.50	15.50	31	194	515
2.11	<–20	2.80	18.00	73	466	295
1.59	12	3.10	19.00	59	359	363
3.10	40	1.80	15.70	68	593	235
4.72	47	1.20	12.70	65	642	380
3.04	–4	2.20	11.00	81	406	460
4.50	65	1.00	9.50	54	519	350
3.45	9	1.40	14.00	59	588	350
1.50	<–20	2.68	14.00	49	260	425
3.66	23	1.00	7.80	44	340	431
4.00	21	1.40		66		435
2.90	<–16	1.20	7.70	42	272	212
3.87	<24	0.90	6.60	42	310	238
3.40	<5	1.05	6.80	42	280	262
0.97		2.30	36.00	26	423	425

Flammable Gases Data (continued)

Common Name	CAS Number	Formula	Mol. Wt.	B.P. °C
Ethylenediamine	107-15-3	$NH_2CH_2CH_2NH_2$	60.1	118
Ethylene oxide	75-21-8	CH_2CH_2O	44	11
Ethyl formate	109-94-4	$HCOOCH_2CH_3$	74.08	52
Ethyl isobutyrate	97-62-1	$(CH_3)_2CHCOOC_2H_5$	116.16	112
Ethyl methacrylate	97-63-2	$CH_2=CCH_3COOCH_2CH_3$	114.14	118
Ethyl methyl ether	540-67-0	$CH_3OCH_2CH_3$	60.1	8
Ethyl nitrite	109-95-5	CH_3CH_2ONO	75.07	
Formaldehyde	50-00-0	$HCHO$	30	-19
Formic acid	64-18-6	$HCOOH$	46.03	101
2-Furaldehyde	98-01-1	$OCH=CHCH=CHCHO$	96.08	162
Furan	110-00-9	$CH=CHCH=CHO$	68.07	32
Furfuryl alcohol	98-00-0	$OC(CH_2OH)CHCHCH$	98.1	170
1,2,3-Trimethyl-benzene	526-73-8	$CHCHCHC(CH_3)C(CH_3)C(CH_3)$	120.19	175
Heptane (mixed isomers)	142-82-5	C_7H_{16}	100.2	98
Hexane (mixed isomers)	110-54-3	$CH_3(CH_2)_4CH_3$	86.2	69
1-Hexanol	111-27-3	$C_6H_{13}OH$	102.17	156
Hexan-2-one	591-78-6	$CH_3CO(CH_2)_3CH_3$	100.16	127
Hydrogen	1333-74-0	H_2	2	-253
Hydrogen cyanide	74-90-8	HCN	27	26
Hydrogen sulfide	7783-06-4	H_2S	34.1	-60
4-Hydroxy-4-methyl-penta-2-one	123-42-2	$CH_3COCH_2C(CH_3)_2OH$	116.16	166
Kerosene	8008-20-6			150
1,3,5-Trimethylbenzene	108-67-8	$CHC(CH_3)CHC(CH_3)CHC(CH_3)$	120.19	163
Methacryloyl chloride	920-46-7	CH_2CCH_3COCl	104.53	95
Methane (firedamp)	74-82-8	CH_4	16	-161
Methanol	67-56-1	CH_3OH	32	65
Methanethiol	74-93-1	CH_3SH	48.11	6
2-Methoxyethanol	109-86-4	$CH_3OCH_2CH_2OH$	76.1	124
Methyl acetate	79-20-9	CH_3COOCH_3	74.1	57
Methyl acetoacetate	105-45-3	$CH_3COOCH_2COCH_3$	116.12	169
Methyl acrylate	96-33-3	$CH_2=CHCOOCH_3$	86.1	80
Methylamine	74-89-5	CH_3NH_2	31.1	-6
2-Methylbutane	78-78-4	$(CH_3)_2CHCH_2CH_3$	72.15	30
2-Methylbutan-2-ol	75-85-4	$CH_3CH_2C(OH)(CH_3)_2$	88.15	102
3-Methylbutan-1-ol	123-51-3	$(CH_3)_2CH(CH_2)_2OH$	88.15	130
2-Methylbut-2-ene	513-35-9	$(CH_3)_2C=CHCH_3$	70.13	35
Methyl chloro-formate	79-22-1	CH_3OOCC	94.5	70
Methylcyclohexane	108-87-2	$CH_3CH(CH_2)_4CH_2$	98.2	101
Methylcyclo-pentadienes (isomer not stated)	26519-91-5	C_6H_6	80.13	
Methylcyclopentane	96-37-7	$CH_3CH(CH_2)_3CH_2$	84.16	72
Methylenecyclo-butane	1120-56-5	$C(=CH_2)CH_2CH_2CH_2$	68.12	
2-Methyl-1-buten-3-yne	78-80-8	$HC=CC(CH_3)CH_2$	66.1	32
Methyl formate	107-31-3	$HCOOCH_3$	60.05	32
2-Methylfuran	534-22-5	$OC(CH_3)CHCHCH$	82.1	63
Methylisocyanate	624-83-9	CH_3NCO	57.05	37
Methyl methacrylate	80-62-6	$CH_3=CCH_3COOCH_3$	100.12	100
4-Methylpentan-2-ol	108-11-2	$(CH_3)_2CHCH_2CHOHCH_3$	102.17	132
4-Methylpentan-2-one	108-10-1	$(CH_3)_2CHCH_2COCH_3$	100.16	117
2-Methylpent-2-enal	623-36-9	$CH_3CH_2CHC(CH_3)COH$	98.14	137
4-Methylpent-3-en-2-one	141-79-7	$(CH_3)_2(CCHCOCH)_3$	98.14	129
2-Methylpropan-1-ol	78-83-1	$(CH_3)_2CHCH_2OH$	74.12	108
2-Methylprop-1-ene	115-11-7	$(CH_3)_2C=CH_2$	56.11	-6.9
2-Methylpyridine	109-06-8	$NCH(CH_3)CHCHCHCH$	93.13	128
3-Methylpyridine	108-99-6	$NCHCH(CH_3)CHCHCH$	93.13	144
4-Methylpyridine	108-89-4	$NCHCHCH(CH_3)CHCH$	93.13	145
α-Methyl styrene	98-83-9	$C_6H_5C(CH_3)=CH_2$	118.18	165
Methyl tert-pentyl ether	994-05-8	$(CH_3)_2C(OCH_3)CH_2CH_3$	102.17	85
2-Methylthiophene	554-14-3	$SC(CH_3)CHCHCH$	98.17	113
Morpholine	110-91-8	$OCH_2CH_2NHCH_2CH_2$	87.12	129

		Flammable Limits				
Rel. Vap. Dens.	**F.P. °C**	**LFL % v/v**	**UFL % v/v**	**LFL mg/L**	**UFL mg/L**	**I.T. °C**
2.07	34	2.70	16.50	64	396	403
1.52	<–18	2.60	100.00	47	1 848	435
2.65	–20	2.70	16.50	87	497	440
4.00	10	1.60		75		438
3.90	(20)	1.50		70		
2.10		2.00	10.10	50	255	190
2.60	–35	3.00	50.00	94	1 555	95
1.03		7.00	73.00	88	920	424
1.60	42	10.00	57.00	190	1 049	520
3.30	60	2.10	19.30	85	768	316
2.30	<–20	2.30	14.30	66	408	390
3.38	61	1.80	16.30	70	670	370
4.15	51	0.80	7.00			470
3.46	–4	1.10	6.70	46	281	215
2.97	–21	1.00	8.40	35	290	233
3.50	63	1.20		51		293
3.46	23	1.20	8.00	50	336	533
0.07		4.00	77.00	3,4	63	560
0.90	<–20	5.40	46.00	60	520	538
1.19		4.00	45.50	57	650	270
4.00	58	1.80	6.90	88	336	680
	38	0.70	5.00			210
4.15	44	0.80	7.30	40	365	499
3.60	17	2.50		108		510
0.55		4.40	17.00	29	113	537
1.11	11	5.50	38.00	73	484	386
1.60		4.10	21.00	80	420	340
2.63	39	2.40	20.60	76	650	285
2.56	–10	3.20	16.00	99	475	502
4.00	62	1.30	14.20	62	685	280
3.00	–3	2.40	25.00	85	903	415
1.00	–18 gas	4.20	20.70	55	270	430
2.50	<–51	1.30	8.00	38	242	420
3.03	16	1.40	10.20	50	374	392
3.03	42	1.30	10.50	47	385	339
2.40	–53	1.30	6.60	37	189	290
3.30	10	7.50	26	293	1 020	475
3.38	–4	1.16	6.70	47	275	258
2.76	<–18	1.30	7.60	43	249	432
2.90	<–10	1.00	8.40	35	296	258
2.35	<0	1.25	8.60	35	239	352
2.28	–54	1.40		38		272
2.07	–20	5.00	23.00	125	580	450
2.83	<–16	1.40	9.70	47	325	318
1.98	–7	5.30	26.00	123	605	517
3.45	10	1.70	12.50	71	520	430
3.50	37	1.14	5.50	47	235	334
3.45	16	1.20	8.00	50	336	475
3.78	30	1.46		58		206
3.78	24	1.60	7.20	64	289	306
2.55	28	1.70	9.80	52	305	408
1.93	gas	1.60	10	37	235	483
3.21	27	1.20		45		533
3.21	43	1.40	8.10	53	308	537
3.21	43	1.10	7.80	42	296	534
4.08	40	0.90	6.60	44	330	445
3.50	<–14	1.50		62		345
3.40	–1	1.30	6.50	52	261	433
3.00	31	1.80	15.20	65	550	230

Flammable Gases Data (continued)

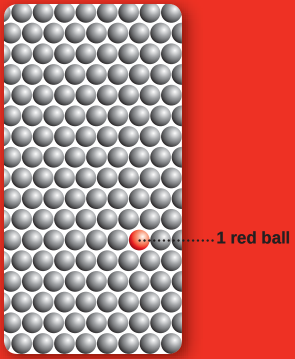
Common Name	CAS Number	Formula	Mol. Wt.	B.P. °C
Naphtha				35
Naphthalene	91-20-3	$C_{10}H_8$	128.17	218
Nitrobenzene	98-95-3	$CH_3CH_2NO_2$	123.1	211
Nitroethane	79-24-3	$C_2H_5NO_2$	75.07	114
Nitromethane	75-52-5	CH_3NO_2	61.04	102.2
1-Nitropropane	108-03-2	$CH_3CH_2CH_2NO_2$	89.09	131
Nonane	111-84-2	$CH_3(CH_2)_7CH_2$	128.3	151
Octane	111-65-9	$CH_3(CH_2)_3CH_3$	114.2	126
1-Octanol	111-87-5	$CH_3(CH_2)_6CH_2OH$	130.23	196
Penta-1,3-diene	504-60-9	$CH_2=CH-CH=CH-CH_3$	68.12	42
Pentanes (mixed isomers)	109-66-0	C_5H_{12}	72.2	36
Pentane-2,4-dione	123-54-6	$CH_3COCH_2COCH_3$	100.1	140
Pentan-1-ol	71-41-0	$CH_3(CH_2)_3CH_2OH$	88.15	136
Pentan-3-one	96-22-0	$(CH_3CH_2)_2CO$	86.13	101.5
Pentyl acetate	628-63-7	$CH_3COO-(CH_2)_4-CH_3$	130.18	147
Petroleum				
Phenol	108-95-2	C_6H_5OH	94.11	182
Propane	74-98-6	$CH_3CH_2CH_3$	44.1	-42
Propan-1-ol	71-23-8	$CH_3CH_2CH_2OH$	60.1	97
Propan-2-ol	67-63-0	$(CH_3)_2CHOH$	60.1	83
Propene	115-07-1	$CH_2=CHCH_3$	42.1	-48
Propionic acid	79-09-4	CH_3CH_2COOH	74.08	141
Propionic aldehyde	123-38-6	C_2H_5CHO	58.08	46
Propyl acetate	109-60-4	$CH_3COOCH_2CH_2CH_3$	102.13	102
Isopropyl acetate	108-21-4	$CH_3COOCH(CH_3)_2$	102.13	85
Propylamine	107-10-8	$CH_3(CH_2)_2NH_2$	59.11	48
Isopropylamine	75-31-0	$(CH_3)_2CHNH_2$	59.11	33
Isopropylchloro-acetate	105-48-6	$ClCH_2COOCH(CH_3)_2$	136.58	149
2-Isopropyl-5-methylhex-2-enal	35158-25-9	$(CH_3)_2CH-C(CHO)CHCH_2CH(CH_3)_2$	154.25	189
Isopropyl nitrate	1712-64-7	$(CH_3)_2CHONO_2$	105.09	101
Propyne	74-99-7	$CH_3C=CH$	40.06	-23.2
Prop-2-yn-1-ol	107-19-7	$HC=CCH_2OH$	56.06	114
Pyridine	110-86-1	C_5H_5N	79.1	115
Styrene	100-42-5	$C_6H_5CH=CH_2$	104.2	145
Tetrafluoroethylene	116-14-3	$CF_2=CF_2$	100.02	
2,2,3,3-Tetrafluoro-propylacrylate	7383-71-3	$CH_2=CHCOOCH_2CF_2CF_2H$	186.1	132
2,2,3,3-Tetrafluoro-propyl methacrylate	45102-52-1	$CH_2=C(CH_2)COOCH_2CF_2CF_2H$	200.13	124
Tetrahydrofuran	109-99-9	$CH_2(CH_2)_2CH_2O$	72.1	64
Tetrahydrofurfuryl alcohol	97-99-4	$OCH_2CH_2CH_2CHCH_2OH$	102.13	178
Tetrahydro-thiophene	110-01-0	$CH_2(CH_2)_2CH_2S$	88.17	119
N,N,N', N'-Tetra-methylmethane-diamine	51-80-9	$(CH_3)_2NCH_2N(CH_3)_2$	102.18	85
Thiophene	110-02-1	$CH=CHCH=CHS$	84.14	84
Toluene	108-88-3	$C_6H_5CH_3$	92.1	111
Triethylamine	121-44-8	$(CH_3CH_2)_3N$	101.2	89
1,1,1-Trifluoro-ethane	420-46-2	CF_3CH_3	84.04	
2,2,2-Trifluoro-ethanol	75-89-8	CF_3CH_2OH	100.04	77
Trifluoroethylene	359-11-5	$CF_2=CFH$	82.02	
3,3,3-Trifluoro-prop-1-ene	677-21-4	$CF_3CH=CH_2$	96.05	-16
Trimethylamine	75-50-3	$(CH_3)_3N$	59.1	3
2,2,4-Trimethyl-pentane	540-84-1	$(CH_3)_2CHCH_2C(CH_3)_3$	114.23	98
2,4,6-Trimethyl-1,3,5-trioxane	123-63-7	$OCH(CH_3)OCH(CH_3)OCH(CH_3)$	132.16	123
1,3,5-Trioxane	110-88-3	$OCH_2OCH_2OCH_2$	90.1	115
Turpentine		$\sim C_{10}H_{16}$		149
Isovaleraldehyde	590-86-3	$(CH_3)_2CHCH_2CHO$	86.13	90
Vinyl acetate	108-05-4	$CH_3COOCH=CH_2$	86.09	72
Vinyl cyclohexenes (isomer not stated)	100-40-3	$CH_2CHC_6H_9$	108.18	126
Vinylidene chloride	75-35-4	$CH_2=CCl_2$	96.94	30
2-Vinylpyridine	100-69-6	$NC(CH_2=CH)CHCHCHCH$	105.14	79
4-Vinylpyridine	100-43-6	$NCHCHC(CH_2=CH)CHCH$	105.14	62
Xylenes	1330-20-7	$C_6H_4(CH_3)_2$	106.2	144

Rel. Vap. Dens.	F.P. °C	Flammable Limits				I.T. °C
		LFL % v/v	UFL % v/v	LFL mg/L	UFL mg/L	
2.50	<–18	0.90	6.00			290
4.42	77	0.90	5.90	48	317	528
4.25	88	1.70	40.00	87	2 067	480
2.58	27	3.40		107		410
2.11	36	7.30	63.00	187	1 613	415
3.10	36	2.20		82		420
4.43	30	0.70	5.60	37	301	205
3.93	13	0.80	6.50	38	311	206
4.50	81	0.90	7.40	49	385	270
2.34	<–31	1.20	9.40	35	261	361
2.48	–40	1.40	7.80	42	236	258
3.50	34	1.70		71		340
3.03	38	1.06	10.50	38	385	298
3.00	12	1.60		58		445
4.48	25	1.00	7.10	55	387	360
2.80	<–20	1.20	8.00			560
3.24	75	1.30	9.50	50	370	595
1.56	–104 gas	1.70	10.90	31	200	470
2.07	22	2.20	17.50	55	353	405
2.07	12	2.00	12.70	50	320	425
1.50		2.00	11.00	35	194	455
2.55	52	2.10	12.00	64	370	435
2.00	<–26	2.00		47		188
3.60	10	1.70	8.00	70	343	430
3.51	4	1.80	8.10	75	340	467
2.04	–37	2.00	10.40	49	258	318
2.03	<–24	2.30	8.60	55	208	340
4.71	42	1.60		89		426
5.31	41	3.05		192		188
	11	2.00	100.00	75	3 738	175
1.38		1.70	16.80	28	280	
1.89	33	2.40		55		346
2.73	17	1.70	12.00	58	398	550
3.60	30	1.10	8.00	48	350	490
3.40		10.00	59.00	420	2 245	255
6.41	45	2.40		182		357
6.90	46	1.90		155		389
2.49	–20	1.50	12.40	46	370	224
3.52	70	1.50	9.70	64	416	280
3.04	13	1.10	12.30	42	450	200
3.50	<–13	1.61		67		180
2.90	–9	1.50	12.50	50	420	395
3.20	4	1.10	7.60	42	300	535
3.50	–7	1.20	8.00	51	339	
2.90		6.80	17.60	234	605	714
3.45	30	8.40	28.80	350	1 195	463
2.83		15.30	27.00	502	904	319
3.31		4.70		184		490
2.04		2.00	12.00	50	297	190
3.90	–12	1.00	6.00	47	284	411
4.56	27	1.30		72		235
3.11	45	3.20	29.00	121	1 096	410
	35	0.80				254
2.97	–12	1.70		60		207
3.00	–8	2.60	13.40	93	478	425
3.72	15	0.80		35		257
3.40	–18	7.30	16.00	294	645	440
3.62	35	1.20		51		482
3.62	43	1.10		47		501
3.66	30	1.00	7.60	44	335	464

6 Toxic Gas Hazards

Some gases are poisonous and can be dangerous to life at very low concentrations. Some toxic gases have strong smells like the distinctive ‘rotten eggs’ smell of H_2S. The measurements most often used for the concentration of toxic gases are parts per million (ppm) and parts per billion (ppb). For example 1ppm would be equivalent to a room filled with a total of 1 million balls and 1 of those balls being red. The red ball would represent 1ppm.

1 MILLION BALLS



100%V/V = 1,000,000ppm
1%V/V = 10,000ppm

EXAMPLE

100%LEL Ammonia = 15%V/V
50%LEL Ammonia = 7.5%V/V
50%LEL Ammonia = 75,000ppm

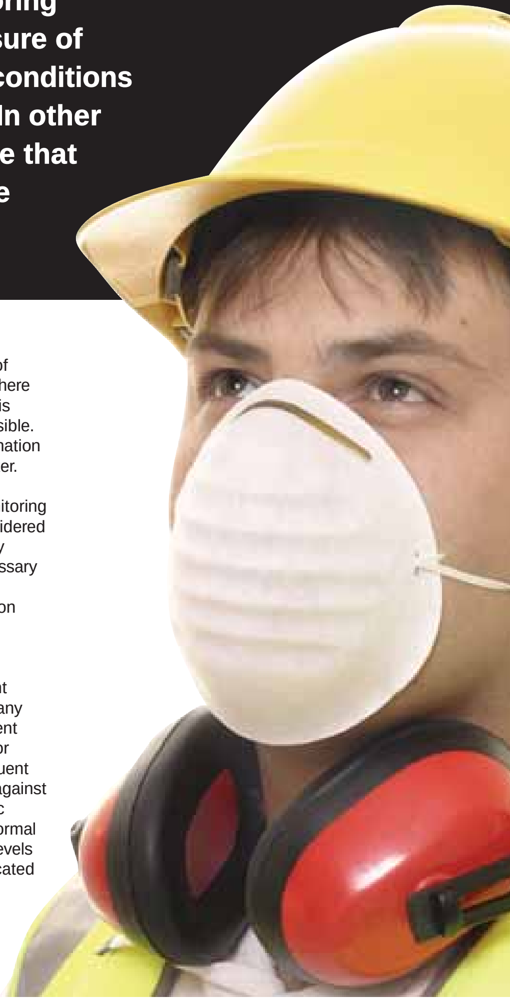
More people die from toxic gas exposure than from explosions caused by the ignition of flammable gas. (It should be noted that there is a large group of gases which are both combustible and toxic, so that even detectors of toxic gases sometimes have to carry hazardous area approval). The main reason for treating flammable and toxic gases separately is that the hazards and regulations involved and the types of sensor required are different.

With toxic substances, (apart from the obvious environmental problems) the main concern is the effect on workers of exposure to even very low concentrations, which could be inhaled, ingested, or absorbed through the skin. Since adverse effects can often result from additive, long-term exposure, it is important not only to measure the concentration of gas, but also the total time of exposure. There are even some known cases of synergism, where substances can interact and produce a far worse effect when together than the separate effect of each on its own.

Concern about concentrations of toxic substances in the workplace focus on both organic and inorganic compounds, including the effects they could have on the health and safety of employees, the possible contamination of a manufactured end-product (or equipment used in its manufacture) and also the subsequent disruption of normal working activities.

Hygiene Monitoring

The term ‘hygiene monitoring’ is generally used to cover the area of industrial health monitoring associated with the exposure of employees to hazardous conditions of gases, dust, noise etc. In other words, the aim is to ensure that levels in the workplace are below the statutory limits.



This subject covers both area surveys (profiling of potential exposures) and personal monitoring, where instruments are worn by a worker and sampling is carried out as near to the breathing zone as possible. This ensures that the measured level of contamination is truly representative of that inhaled by the worker.

It should be emphasised that both personal monitoring and monitoring of the workplace should be considered as important parts of an overall, integrated safety plan. They are only intended to provide the necessary information about conditions as they exist in the atmosphere. This then allows the necessary action to be taken to comply with the relevant industrial regulations and safety requirements.

Whatever method is decided upon, it is important to take into account the nature of the toxicity of any of the gases involved. For instance, any instrument which measures only a time-weighted average, or an instrument which draws a sample for subsequent laboratory analysis, would not protect a worker against a short exposure to a lethal dose of a highly toxic substance. On the other hand, it may be quite normal to briefly exceed the average, long-term (LTEL) levels in some areas of a plant, and it need not be indicated as an alarm situation. Therefore, the optimum instrument system should be capable of monitoring both short and long term exposure levels as well as instantaneous alarm levels.

Toxic Exposure Limits

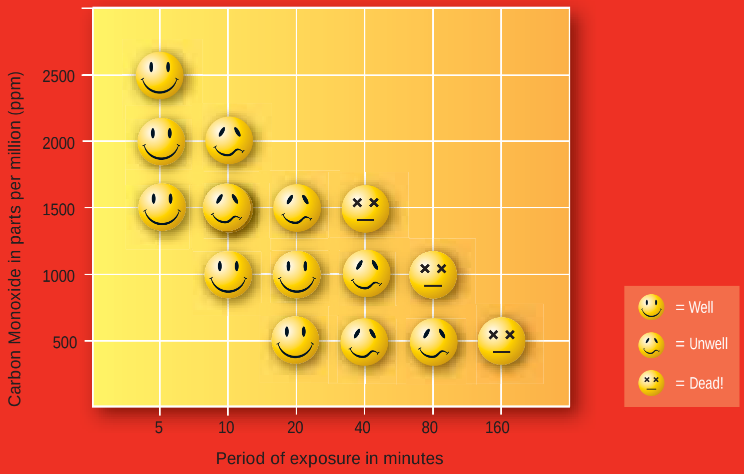
European Occupational Exposure Limits

Occupational Exposure Limit values (OELs) are set by competent national authorities or other relevant national institutions as limits for concentrations of hazardous compounds in workplace air. OELs for hazardous substances represent an important tool for risk assessment and management and valuable information for occupational safety and health activities concerning hazardous substances.

Occupational Exposure Limits can apply both to marketed products and to waste and by products from production processes. The limits protect workers against health effects, but do not address safety issues such as explosive risk. As limits frequently change and can very by country, you should consult your relevant national authorities to ensure that you have the latest information.

Occupational exposure limits in the UK function under the Control of Substances Hazardous to Health Regulations (COSHH). The COSHH regulations require the employer to ensure that the employee's exposure to substances hazardous to health is either prevented or if not practically possible, adequately controlled. As of 6 April 2005, the regulations introduced a new, simpler Occupational Exposure Limit system. The existing requirements to follow good practice were brought together by the introduction of eight principles in the Control of Substances Hazardous to Health (Amendment) Regulations 2004.

Maximum Exposure Limits (MELs) and Occupational Exposure Standards (OESs) were replaced with a single type of limit - the Workplace Exposure Limit (WEL). All the MELs, and most of the OESs, are being transferred into the new system as WELs and will retain their previous numerical values. The OESs for approximately 100



Effects of exposure to Carbon Monoxide

substances were deleted as the substances are now banned, scarcely used or there is evidence to suggest adverse health effects close to the old limit value. The list of exposure limits is known as EH40 and is available from the UK Health and Safety Executive. All legally enforceable WELs in UK are air limit values. The maximum admissible or accepted concentration varies from substance to substance according to its toxicity. The exposure times are averaged for eight hours (8-hour TWA) and 15 minutes (short-term exposure limit STEL). For some substances, a brief exposure is considered so critical that they are set only a STEL, which should not be exceeded even for a shorter time. The potency to penetrate through skin is annotated in the WEL list by remark “Skin”. Carcinogenicity, reproduction toxicity, irritation and sensitation potential are considered when preparing a proposal for an OEL according to the present scientific knowledge.

US Occupational Exposure Limits

The Occupational Safety systems in the United States vary from state to state. Here, Information is given on 3 major providers of the Occupational Exposure Limits in the USA - ACGIH, OSHA, and NIOSH.

The American Conference of Governmental Industrial Hygienists (ACGIH) publishes Maximum Allowable Concentrations (MAC), which were later renamed to “Threshold Limit Values” (TLVs).

Threshold Limit Values are defined as an exposure limit “to which it is believed nearly all workers can be exposed day after day for a working lifetime without ill effect”. The ACGIH is a professional organisation of occupational hygienists from universities or governmental institutions. Occupational hygienists from private industry can join as associate members. Once a year, the different committees propose new threshold limits or best working practice guides. The list of TLVs includes more than 700 chemical substances and physical agents, as well as dozens of Biological Exposure Indices for selected chemicals.

The ACGIH defines different TLV-Types as:

Threshold Limit Value – Time-Weighted Average (TLV-TWA): the time-weighted average concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.

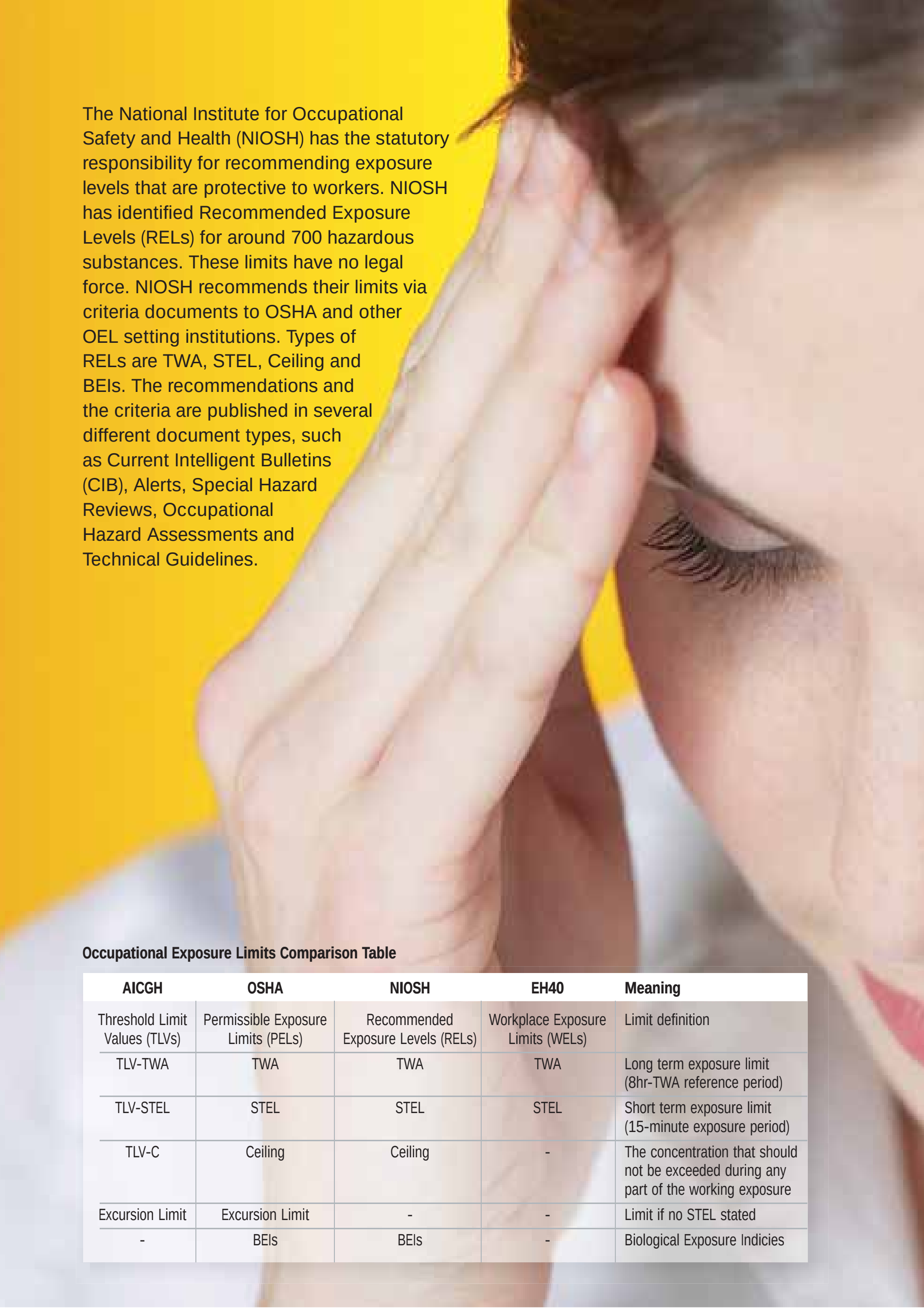
Threshold Limit Value – Short-Term Exposure Limit (TLV-STEL): the concentration to which it is believed that workers can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage, or narcosis. STEL is defined as a 15-minute TWA exposure, which should not be exceeded at any time during a workday.

Threshold Limit Value - Ceiling (TLV-C): the concentration that should not be exceeded during any part of the working exposure.

There is a general excursion limit recommendation that applies to those TLV-TWAs that do not have STELs. Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday, and under no circumstances should they exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded.

ACGIH-TLVs do not have a legal force in the USA, they are only recommendations. OSHA defines regulatory limits. However, ACGIH-TLVs and the criteria documents are a very common base for setting TLVs in the USA and in many other countries. ACGIH exposure limits are in many cases more protective than OSHA’s. Many US companies use the current ACGIH levels or other internal and more protective limits.

The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor publishes Permissible Exposure Limits (PEL). PELs are regulatory limits on the amount or concentration of a substance in the air, and they are enforceable. The initial set of limits from 1971 was based on the ACGIH TLVs. OSHA currently has around 500 PELs for various forms of approximately 300 chemical substances, many of which are widely used in industrial settings. Existing PELs are contained in a document called “29 CFR 1910.1000”, the air contaminants standard. OSHA uses in a similar way as the ACGIH the following types of OELs: TWAs, Action Levels, Ceiling Limits, STELs, Excursion Limits and in some cases Biological Exposure Indices (BEIs).



The National Institute for Occupational Safety and Health (NIOSH) has the statutory responsibility for recommending exposure levels that are protective to workers. NIOSH has identified Recommended Exposure Levels (RELs) for around 700 hazardous substances. These limits have no legal force. NIOSH recommends their limits via criteria documents to OSHA and other OEL setting institutions. Types of RELs are TWA, STEL, Ceiling and BEIs. The recommendations and the criteria are published in several different document types, such as Current Intelligent Bulletins (CIB), Alerts, Special Hazard Reviews, Occupational Hazard Assessments and Technical Guidelines.

Occupational Exposure Limits Comparison Table

AICGH	OSHA	NIOSH	EH40	Meaning
Threshold Limit Values (TLVs)	Permissible Exposure Limits (PELs)	Recommended Exposure Levels (RELs)	Workplace Exposure Limits (WELs)	Limit definition
TLV-TWA	TWA	TWA	TWA	Long term exposure limit (8hr-TWA reference period)
TLV-STEL	STEL	STEL	STEL	Short term exposure limit (15-minute exposure period)
TLV-C	Ceiling	Ceiling	-	The concentration that should not be exceeded during any part of the working exposure
Excursion Limit	Excursion Limit	-	-	Limit if no STEL stated
-	BEIs	BEIs	-	Biological Exposure Indicies

Toxic Gases Data

The toxic gases listed below can be detected using equipment supplied by Honeywell Analytics. Gas data is supplied where known.
As product development is ongoing, contact Honeywell Analytics if the gas you require is not listed.
Data may change by country and date, always refer to local up to date regulations.

Common Name	CAS Number	Formula
Ammonia	7664-41-7	NH_3
Arsine	7784-42-1	AsH_3
Boron Trichloride	10294-34-5	BCl_3
Boron Trifluoride	7637-07-2	BF_3
Bromine	7726-95-6	Br_2
Carbon Monoxide	630-08-0	CO
Chlorine	7782-50-5	Cl_2
Chlorine Dioxide	10049-04-4	ClO_2
1,4 Cyclohexane diisocyanate		CHDI
Diborane	19287-45-7	B_2H_6
Dichlorosilane (DCS)	4109-96-0	H_2Cl_2Si
Dimethyl Amine (DMA)	124-40-3	C_2H_7N
Dimethyl Hydrazine (UDMH)	57-14-7	$C_2H_8N_2$
Disilane	1590-87-0	Si_2H_6
Ethylene Oxide	75-21-8	C_2H_4O
Fluorine	7782-41-4	F_2
Germane	7782-65-2	GeH_4
Hexamethylene Diisocyanate (HDI)	822-06-0	$C_8H_{12}N_2O_2$
Hydrazine	302-01-2	N_2H_4
Hydrogen	1333-74-0	H_2
Hydrogen Bromide	10035-10-6	HBr
Hydrogen Chloride	7647-01-0	HCl
Hydrogen Cyanide	74-90-8	HCN
Hydrogen Fluoride	7664-39-3	HF
Hydrogen Iodide	10034-85-2	HI
Hydrogen Peroxide	7722-84-1	H_2O_2
Hydrogen Selenide	7783-07-5	H_2Se
Hydrogen Sulfide	7783-06-4	H_2S
Hydrogenated Methylene Bisphenyl Isocyanate (HMDI)		
Isocyanatoethylmethacrylate (IEM)		$C_7H_9NO_3$
Isophorone Diisocyanate (IPDI)		$C_{12}H_{18}N_2O_2$
Methyl Fluoride (R41)	593-53-3	CH_3F
Methylene Bisphenyl Isocyanate (MDI)	101-68-8	$C_{15}H_{10}N_2O_2$
Methylene Bisphenyl Isocyanate -2 (MDI-2)	101-68-8	$C_{15}H_{10}N_2O_2$
Methylene Dianiline (MDA)	101-77-9	$C_{13}H_{14}N_2$
Monomethyl Hydrazine (MMH)	60-34-4	CH_6N_2
Naphthalene Diisocyanate (NDI)	3173-72-6	$C_{12}H_6N_2O_2$
Nitric Acid	7697-37-2	HNO_3

Ref: EH40/2005 Workplace exposure limits, OSHA Standard 29 CFR 1910.1000 tables Z-1 and Z-2 and ACGIH Threshold Limit Valves and Biological Exposure Indices Book 2005.

EH40 Workplace Exposure Limit (WEL)				**OSHA Permissible Exposure Limits (PEL)**		**ACGIH Threshold Limit Value (TLV)**
Long-term exposure limit (8-hour TWA reference period)		Short-term exposure limit (15-minute reference period)		Long-term exposure limit (8-hour TWA reference period)		8-hour TWA workday and a 40-hour workweek
ppm	**mg.m^{-3}**	**ppm**	**mg.m^{-3}**	**ppm**	**mg.m^{-3}**	**ppm**
25	18	35	25	50	35	25
0.05	0.16			0.05	0.2	0.05
				1 (ceiling)	3 (ceiling)	1 (ceiling)
0.1	0.66	0.3	2	0.1	0.7	0.1
30	35	200	232	50	55	25
0.5	1.5	1	2.9	1 (ceiling)	3 (ceiling)	0.5
0.1	0.28	0.3	0.84	0.1	0.3	0.1
				0.1	0.1	0.1
2	3.8	6	11	10	18	5
						0.01
5	9.2			1		1
1		1		0.1	0.2	1
0.2	0.62	0.6	1.9			0.2
						0.005
0.02	0.03	0.1	0.13	1	1.3	0.01
						Asphyxiant
		3	10	3	10	2 (ceiling)
1	2	5	8	5 (ceiling)	7 (ceiling)	2 (ceiling)
		10	11	10	11	4.7 (ceiling)
1.8	1.5	3	2.5	3		3 (ceiling)
1	1.4	2	2.8	1	1.4	1
				0.05	0.2	0.05
5	7	10	14	20 (ceiling)		10
						0.005
						0.005
						0.005
0.01	0.08					0.1
						0.01
						0.005
2	5.2	4	10	2	5	2

Toxic Gases Data (continued)

Common Name	CAS Number	Formula
Nitric Oxide	10102-43-9	NO
Nitrogen Dioxide	10102-44-0	NO_2
Nitrogen Trifluoride	7783-54-2	NF_3
n-Butyl Amine (N-BA)	109-73-9	$C_4H_{11}N$
Ozone	10028-15-6	O_3
Phosgene	75-44-5	$COCl_2$
Phosphine	7803-51-2	PH_3
Propylene Oxide	75-56-9	C_3H_6O
p-Phenylene Diamine (PPD)	106-50-3	$C_6H_8N_2$
p-Phenylene Diisocyanate (PPDI)	104-49-4	$C_8H_4N_2O_2$
Silane	7803-62-5	SiH_4
Stibine	7803-52-3	SbH_3
Sulfur Dioxide	7446-09-5	SO_2
Sulfuric Acid	7664-93-9	H_2SO_4
Tertiary Butyl Arsine (TBA)		
Tertiary Butyl Phosphine (TBP)	2501-94-2	$C_4H_{11}P$
Tetraethylorthosilicate (TEOS)	78-10-4	$C_8H_{20}O_4Si$
Tetrakis (Dimethylamino) Titanium (TDMAT)	3275-24-9	$C_8H_{24}N_4Ti$
Tetramethylxylene Diisocyanate (TMXDI)		$C_{14}H_{16}N_2O_2$
Toluene Diamine (TDA)	95-80-7	$C_7H_{10}N_2$
Toluene Diisocyanate (TDI)	584-84-9	$C_9H_6N_2O_2$
Triethyl Amine (TEA)	121-44-8	$C_6H_{15}N$
Trimethylhexamethylene Diisocyanate (TMDI)		$C_{11}H_{18}N_2O_2$
Unsymetrical Dimethyl Hydrazine (UDMH)	57-14-7	$C_2H_8N_2$
Xylene Diisocyanate (XDI)		

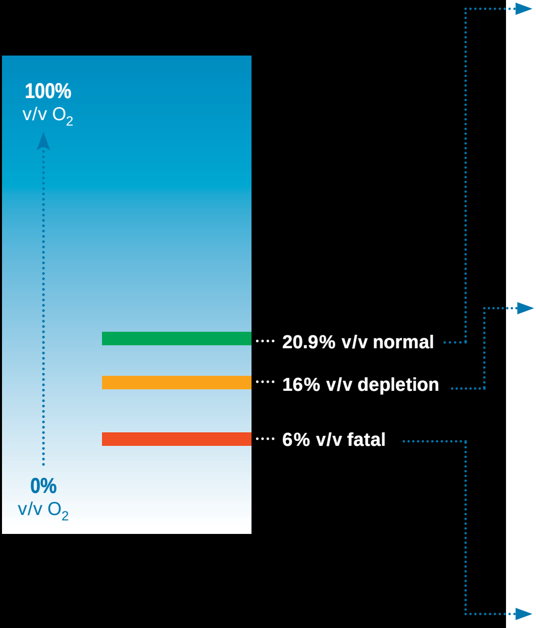
EH40 Workplace Exposure Limit (WEL)				OSHA Permissible Exposure Limits (PEL)		ACGIH Threshold Limit Value (TLV)
Long-term exposure limit (8-hour TWA reference period)		Short-term exposure limit (15-minute reference period)		Long-term exposure limit (8-hour TWA reference period)		8-hour TWA workday and a 40-hour workweek
ppm	**mg.m^{-3}**	**ppm**	**mg.m^{-3}**	**ppm**	**mg.m^{-3}**	**ppm**
				25	30	25
				5 (ceiling)	9 (ceiling)	3
				10	29	10
				5 (ceiling)	15 (ceiling)	5 (ceiling)
		0.2	0.4	0.1	0.2	100 ppb
0.02	0.08	0.06	0.25	0.1	0.4	100 ppb
		0.3	0.42	0.3	0.4	300 ppb
5	12			100	240	2
	0.1				0.1	0.1 mg/mm3
0.5	0.67	1	1.3			5
				0.1	0.5	0.1
				5	13	2
					1	0.05
						0.01mg/m3 for arsenic
						5 as DMA
50	191	150	574			lowest feasible (NIOSH)
		0.02 (ceiling)	0.14 (ceiling)			0.005
2	8	4	17			5
						0.01

7 Asphyxiant (Oxygen Deficiency) Hazard

We all need to breathe the oxygen (O_2) in air to live. Air is made up of several different gases including oxygen. Normal ambient air contains an oxygen concentration of 20.9% v/v. When the oxygen level dips below 19.5% v/v, the air is considered oxygen-deficient. Oxygen concentrations below 16% v/v are considered unsafe for humans.

OXYGEN DEPLETION CAN BE CAUSED BY:

- Displacement
- Combustion
- Oxidation
- Chemical reaction



20.9% v/v normal

16% v/v depletion

6% v/v fatal

8 Oxygen Enrichment

It is often forgotten that oxygen enrichment can also cause a risk. At increased O_2 levels the flammability of materials and gases increases. At levels of 24% items such as clothing can spontaneously combust.

Oxyacetylene welding equipment combines oxygen and acetylene gas to produce an extremely high temperature. Other areas where hazards may arise from oxygen enriched atmospheres include areas manufacturing or storing rocket propulsion systems, products used for bleaching in the pulp and paper industry and clean water treatment facilities

Sensors have to be specially certified for use in O_2 enriched atmospheres.

9 Typical Areas that Require Gas Detection

There are many different applications for flammable, toxic and oxygen gas detection. Industrial processes increasingly involve the use and manufacture of highly dangerous substances, particularly toxic and combustible gases. Inevitably, occasional escapes of gas occur, which create a potential hazard to the industrial plant, its employees and people living nearby. Worldwide incidents involving asphyxiation, explosions and loss of life, are a constant reminder of this problem.

Oil & Gas

The oil and gas industry covers a large number of upstream activities from the on and offshore exploration and production of oil and gas to its transportation, storage and refining. The large amount of highly flammable Hydrocarbon gases involved are a serious explosive risk and additionally toxic gases such as Hydrogen Sulfide are often present.

Typical Applications:

- Exploration Drilling Rigs
- Production Platforms
- Onshore oil and gas terminals
- Refineries

Typical Gases:

Flammable:
Hydrocarbon gases
Toxic:
Hydrogen Sulfide, Carbon Monoxide

Semiconductor Manufacturing

Manufacturing semiconductor materials involves the use of highly toxic substances and flammable gas. Phosphorus, arsenic, boron and gallium are commonly used as doping agents. Hydrogen is used both as a reactant and a reducing atmosphere carrier gas. Etching and cleaning gases include NF_3 and other perfluorocompounds.

Typical Applications:

- Wafer reactor
- Wafer dryers
- Gas Cabinets
- Chemical Vapor Deposition

Typical Gases:

Flammable:
Flammable: Hydrogen, Isopropyl Alcohol, Methane
Toxic:
HCl, AsH_3, BCl_3, PH_3, CO, HF, O_3, H_2Cl_2Si, TEOS, C_4F_6, C_5F_8, GeH_4, NH_3, NO_2 and O_2 Deficiency.
Pyrophoric:
Silane

Chemical Plants

Probably one of the largest users of gas detection equipment are Chemical Plants. They often use a wide range of both flammable and toxic gases in their manufacturing processes or create them as by-products of the processes.

Typical Applications:

- Raw material storage
- Process areas
- Laboratories
- Pump rows
- Compressor stations
- Loading/unloading areas

Typical Gases:

Flammable:
General Hydrocarbons
Toxic:
Various including Hydrogen Sulfide, Hydrogen Fluoride and Ammonia

Power Stations

Traditionally coal and oil have been used as the main fuel for Power Stations.

In Europe and the US most are being converted to natural gas.

Typical Applications:

- Around the boiler pipe work and burners
- In and around turbine packages
- In coal silos and conveyor belts in older coal/oil fired stations

Typical Gases:

Flammable:
Natural Gas, Hydrogen
Toxic:
Carbon Monoxide, SOx, NOx and Oxygen deficincy.

In most industries, one of the key parts of the safety plan for reducing the risks to personnel and plant is the use of early warning devices such as gas detectors. These can help to provide more time in which to take remedial or protective action. They can also be used as part of a total integrated monitoring and safety system for an industrial plant.

Waste Water Treatment Plants

Waste Water Treatment Plants are a familiar site around many cities and towns.

Sewage naturally gives off both Methane and H_2S. The 'rotten eggs' smell of H_2S can often be noticed as the nose can detect it at less than 0.1ppm.

Typical Applications:

- Digesters
- Plant sumps
- H_2S Scrubbers
- Pumps

Typical Gases:

Flammable:
Methane, Solvent vapors
Toxic:
Hydrogen Sulfide, Carbon Dioxide, Chlorine, Sulfur Dioxide, Ozone.

Boiler Rooms

Boiler Rooms come in all shapes and sizes. Small buildings may have a single boiler whereas larger buildings often have large boiler rooms housing several large boilers.

Typical Applications:

- Flammable gas leaks from the incoming gas main
- Leaks from the boiler and surrounding gas piping
- Carbon Monoxide given off badly maintained boiler

Typical Gases:

Flammable:
Methane
Toxic:
Carbon Monoxide

Hospitals

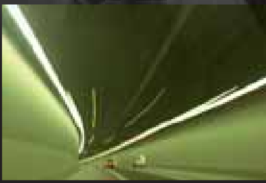
Hospitals may use many different flammable and toxic substances, particularly in their laboratories. Additionally, many are very large and have onsite utility supplies and back up power stations.

Typical Applications:

- Laboratories
- Refrigeration plants
- Boiler rooms

Typical Gases:

Flammable:
Methane, Hydrogen
Toxic:
Carbon Monoxide, Chlorine, Ammonia, Ethylene oxide and Oxygen deficiency



Tunnels/Car Parks

Car Tunnels and enclosed Car Parks need to be monitored for the toxic gases from exhaust fumes. Modern tunnels and car parksuse this monitoring to control the ventilation fans. Tunnels may also need to be monitored for the build up of natural gas.

Typical Applications:

- Car tunnels
- Underground and enclosed car parks
- Access tunnels
- Ventilation control

Typical Gases:

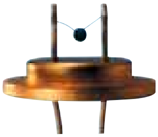
Flammable:
Methane (natural gas), LPG, LNG, Petrol Vapor.
Toxic:
Carbon Monoxide, Nitrogen Dioxide

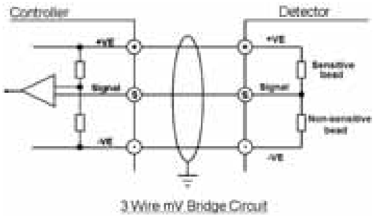
10 Principles of Detection

Combustible gas sensors

Many people have probably seen a flame safety lamp at some time and know something about its use as an early form of 'firedamp' gas detector in underground coal mines and sewers. Although originally intended as a source of light, the device could also be used to estimate the level of combustible gases- to an accuracy of about 25-50%, depending on the user's experience, training, age, colour perception etc. Modern combustible gas detectors have to be much more accurate, reliable and repeatable than this and although various attempts were made to overcome the safety lamp's subjectiveness of measurement (by using a flame temperature sensor for instance), it has now been almost entirely superseded by more modern, electronic devices.

Nevertheless, today's most commonly used device, the catalytic detector, is in some respects a modern development of the early flame safety lamp, since it also relies for its operation on the combustion of a gas and its conversion to carbon dioxide and water.



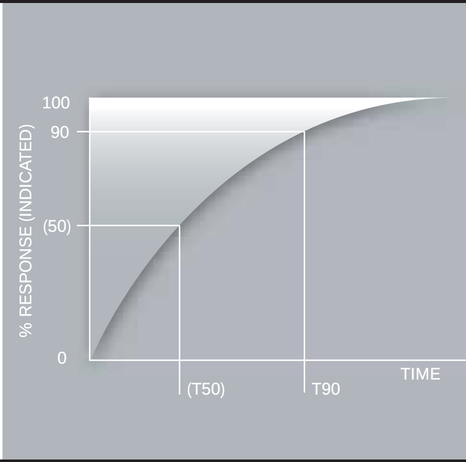


3 Wire mV Bridge Circuit

Catalytic sensor

Nearly all modern, low-cost, combustible gas detection sensors are of the electro-catalytic type. They consist of a very small sensing element sometimes called a 'bead', a 'Pellistor', or a 'Siegistor'- the last two being registered tradenames for commercial devices. They are made of an electrically heated platinum wire coil, covered first with a ceramic base such as alumina and then with a final outer coating of palladium or rhodium catalyst dispersed in a substrate of thoria.

This type of sensor operates on the principle that when a combustible gas/air mixture passes over the hot catalyst surface, combustion occurs and the heat evolved increases the temperature of the 'bead'. This in turn alters the resistance of the platinum coil and can be measured by using the coil as a temperature thermometer in a standard electrical bridge circuit. The resistance change is then directly related to the gas concentration in the surrounding atmosphere and can be displayed on a meter or some similar indicating device.



Sensor output

To ensure temperature stability under varying ambient conditions, the best catalytic sensors use thermally matched beads. They are located in opposing arms of a Wheatstone bridge electrical circuit, where the ‘sensitive’ sensor (usually known as the ‘s’ sensor) will react to any combustible gases present, whilst a balancing, ‘inactive’ or ‘non-sensitive’ (n-s) sensor will not. Inactive operation is achieved by either coating the bead with a film of glass or de-activating the catalyst so that it will act only as a compensator for any external temperature or humidity changes.

A further improvement in stable operation can be achieved by the use of poison resistant sensors. These have better resistance to degradation by substances such as silicones, sulfur and lead compounds which can rapidly de-activate (or ‘poison’) other types of catalytic sensor.

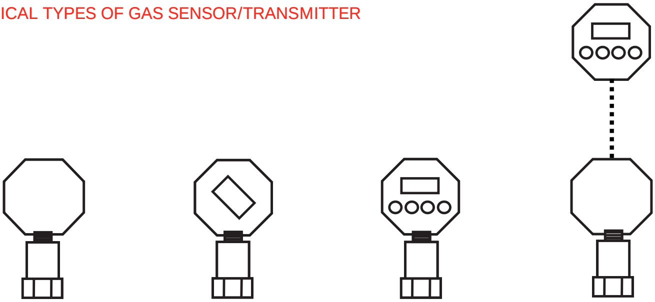
Speed of response

To achieve the necessary requirements of design safety, the catalytic type of sensor has to be mounted in a strong metal housing behind a flame arrestor. This allows the gas/ air mixture to diffuse into the housing and on to the hot sensor element, but will prevent the propagation of any flame to the outside atmosphere. The flame arrestor slightly reduces the speed of response of the sensor but, in most cases the electrical output will give a reading in a matter of seconds after gas has been detected. However, because the response curve is considerably flattened as it approaches the final reading, the response time is often specified in terms of the time to reach 90 percent of its final reading and is therefore known as the T90 value. T90 values for catalytic sensors are typically between 20 and 30 seconds.

(N.B. In the USA and some other countries, this value is often quoted as the lower T60 reading and care should therefore be taken when comparing the performance of different sensors).

Principles of Detection (continued)

TYPICAL TYPES OF GAS SENSOR/TRANSMITTER



Sensor screwed to Junction Box – two man calibration

Sensor screwed to Transmitter with intrusive one man calibration

Sensor screwed to Transmitter with non intrusive one man calibration

Transmitter with remote sensor – one man non intrusive calibration

Calibration

The most common failure in catalytic sensors is performance degradation caused by exposure to certain poisons’. It is therefore essential that any gas monitoring system should not only be calibrated at the time of installation, but also checked regularly and re-calibrated as necessary. Checks must be made using an accurately calibrated standard gas mixture so that the zero and ‘span’ levels can be set correctly on the controller.

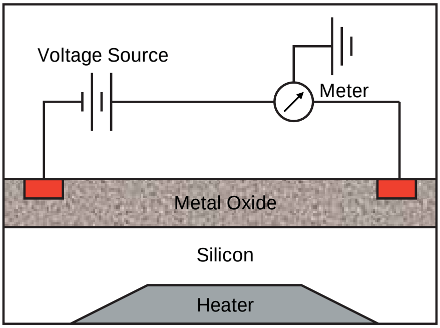
Codes of practice such as EN50073:1999 can provide some guidance about the calibration checking frequency and the alarm level settings. Typically, checks should initially be made at weekly intervals but the periods can be extended as operational experience is gained. Where two alarm levels are required, these are normally set at 20-25% LEL for the lower level and 50-55% LEL for the upper level.

Older (and lower cost) systems require two people to check and calibrate, one to expose the sensor to a flow of gas and the other to check the reading shown on the scale of its control unit. Adjustments are then made at the controller to the zero and span potentiometers until the reading exactly matches that of the gas mixture concentration.

Remember that where adjustments have to be made within a flameproof enclosure, the power must first be disconnected and a permit obtained to open the enclosure.

Today, there are a number of ‘one-man’ calibration systems available which allow the calibration procedures to be carried out at the sensor itself. This considerably reduces the time and cost of maintenance, particularly where the sensors are in difficult to get to locations, such as an off-shore oil or gas platform. Alternatively, there are now some sensors available which are designed to intrinsically safe standards, and with these it is possible to calibrate the sensors at a convenient place away from the site (in a maintenance depot for instance). Because they are intrinsically safe, it is allowed to freely exchange them with the sensors needing replacement on site, without first shutting down the system for safety.

Maintenance can therefore be carried out on a ‘hot’ system and is very much faster and cheaper than early, conventional systems.

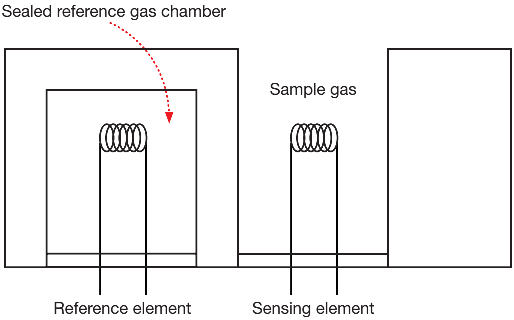


Semiconductor sensor

Sensors made from semiconducting materials gained considerably in popularity during the late 1980's and at one time appeared to offer the possibility of a universal, low cost gas detector. In the same way as catalytic sensors, they operate by virtue of gas absorption at the surface of a heated oxide. In fact, this is a thin metal-oxide film (usually oxides of the transition metals or heavy metals, such as tin) deposited on a silicon slice by much the same process as is used in the manufacture of computer 'chips'. Absorption of the sample gas on the oxide surface, followed by catalytic oxidation, results in a change of electrical resistance of the oxide material and can be related to the sample gas concentration. The surface of the sensor is heated to a constant temperature of about 200-250°C, to speed up the rate of reaction and to reduce the effects of ambient temperature changes.

Semiconductor sensors are simple, fairly robust and can be highly sensitive. They have been used with some success in the detection of hydrogen sulfide gas, and they are also widely used in the manufacture of inexpensive domestic gas detectors. However, they have been found to be rather unreliable for industrial applications, since they are not very specific to a particular gas and they can be affected by atmospheric temperature and humidity variations. They probably need to be checked more often than other types of sensor, because they have been known to 'go to sleep' (i.e. lose sensitivity) unless regularly checked with a gas mixture and they are slow to respond and recover after exposure to an outburst of gas.

Principles of Detection (continued)



Thermal Conductivity

This technique for detecting gas is suitable for the measurement of high (%V/V) concentrations of binary gas mixes. It is mainly used for detecting gases with a thermal conductivity much greater than air e.g. Methane and Hydrogen. Gases with thermal conductivities close to air cannot be detected E.g. Ammonia and Carbon Monoxide. Gases with thermal conductivities less than air are more difficult to detect as water vapor can cause interference E.g. Carbon Dioxide and Butane. Mixtures of two gases in the absence of air can also be measured using this technique.

The heated sensing element is exposed to the sample and the reference element is enclosed in a sealed compartment. If the thermal conductivity of the sample gas is higher than that of the reference, then the temperature of the sensing element decreases. If the thermal conductivity of the sample gas is less than that of the reference then the temperature of the sample element increases. These temperature changes are proportional to the concentration of gas present at the sample element.

Infrared Gas Detector

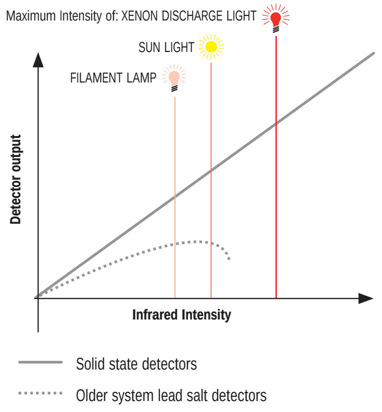
Many combustible gases have absorption bands in the infrared region of the electromagnetic spectrum of light and the principle of infrared absorption has been used as a laboratory analytical tool for many years. Since the 1980's, however, electronic and optical advances have made it possible to design equipment of sufficiently low power and smaller size to make this technique available for industrial gas detection products as well.

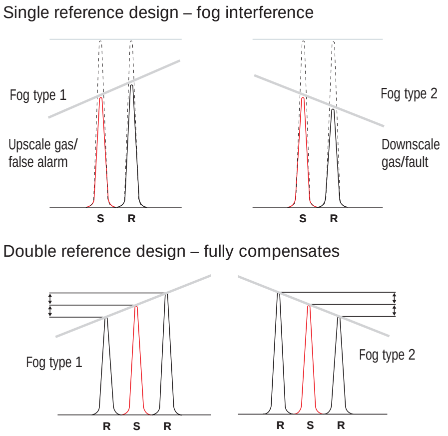
These sensors have a number of important advantages over the catalytic type. They include a very fast speed of response (typically less than 10 seconds), low maintenance and greatly simplified checking, using the self-checking facility of modern micro-processor controlled equipment. They can also be designed to be unaffected by any known 'poisons', they are failsafe and they will operate successfully in inert atmospheres, and under a wide range of ambient temperature, pressure and humidity conditions.

The technique operates on the principle of dual wavelength IR absorption, whereby light passes through the sample mixture at two wavelengths, one of which is set at the absorption peak of the gas to be detected, whilst the other is not. The two light sources are pulsed alternatively and guided along a common optical path to emerge via a flameproof 'window' and then through the sample gas. The beams are subsequently reflected back again by a retro-reflector, returning once more through the sample and into the unit. Here a detector compares the signal strengths of sample and reference beams and, by subtraction, can give a measure of the gas concentration.

This type of detector can only detect diatomic gas molecules and is therefore unsuitable for the detection of Hydrogen.

Principles of Detection (continued)




Single reference design – fog interference

Double reference design – fully compensates

Open Path Flammable Infrared Gas Detector

Traditionally, the conventional method of detecting gas leaks was by point detection, using a number of individual sensors to cover an area or perimeter. More recently, however, instruments have become available which make use of infrared and laser technology in the form of a broad beam (or open path) which can cover a distance of several hundred metres. Early open path designs were typically used to complement point detection, however the latest 3rd generation instruments are now often being used as the primary method of detection. Typical applications where they have had considerable success include FPSOs, add ‘jettys, loading/unloading terminals, pipelines, perimeter monitoring, off-shore platforms and LNG (Liquid Natural Gas) storage areas.

Early designs use dual wavelength beams, the first coinciding with the absorption band peak of the target gas and a second reference beam which lies nearby in an unabsorbed area. The instrument continually compares the two signals that are transmitted through the atmosphere, using either the back-scattered radiation from a retroreflector or more commonly in newer designs by means of a separate transmitter and receiver. Any changes in the ratio of the two signals is measured as gas. However, this design is susceptible to interference from fog as different types of fog can positively or negatively affect the ratio of the signals and thereby falsely indicate an upscale gas reading/ alarm or downscale gas reading/fault. The latest 3rd generation design uses a double band pass filter that has two reference wavelengths (one either side of the sample) that fully compensates for interference from all types of fog and rain. Other problems associated with older designs have been overcome by the use of coaxial optical design to eliminate false alarms caused by partial obscuration of the beam and the use of xenon flash lamps and solid state detectors making the instruments totally immune to interference from sunlight or other sources of radiation such as flare stacks, arc welding or lightning.

Open path detectors actually measure the total number of gas molecules (i.e. the quantity of gas) within the beam. This value is different to the usual concentration of gas given at a single point and is therefore expressed in terms of LEL meters.

Open Path Toxic Infrared Gas Detector

With the availability of reliable solid state laser diode sources in the near infrared region and also the increase in processing power afforded by the latest generation of digital signal processors, it is now feasible to consider the production of a new generation of gas detector for the reliable detection of toxic gases by optical means.

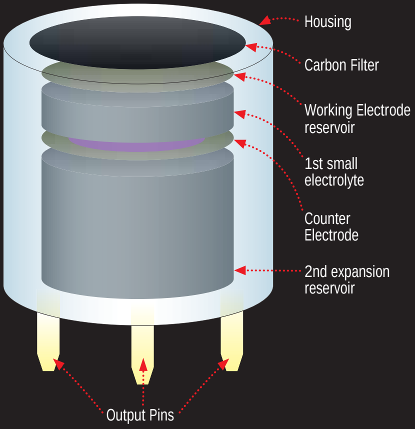
Optical open path and point detection of flammable gas is now well established and has been widely accepted in the Petrochemical industry where they have proved to be a viable and reliable measurement technology. The main challenge in adapting this technology to measure toxic gases is that of the very low levels of gas that must be reliably measured. Typically flammable gases need to be measured at percent levels of concentration. However typical toxic gases are dangerous at part per million (ppm) levels, i.e. a factor of 1000 times lower than for flammable gas detection.

To achieve these very low sensitivities it is not possible to simply adapt the technology used in open path flammable infrared gas detectors. Open path toxic infrared detectors need to utilise a different measurement principle where the instrument probes individual gas lines as opposed to a broad spectral range. This is facilitated by the use of a laser diode light source. The output of the laser is effectively all at a single wavelength and so no light is ‘wasted’ and all of the light emitted is subjected to absorption by the target toxic gas. This provides a significant enhancement of sensitivity compared to open path flammable gas detection techniques and further enhancements are achieved by the use of sophisticated modulation techniques.

Electrochemical Sensor

Gas specific electrochemical sensors can be used to detect the majority of common toxic gases, including CO, H_2S, Cl_2, SO_2 etc. in a wide variety of safety applications.

Electrochemical sensors are compact, require very little power, exhibit excellent linearity and repeatability and generally have a long life span, typically one to three years. Response times, denoted as T_{90}, i.e. time to reach 90% of the final response, are typically 30-60 seconds and minimum detection limits range from 0.02 to 50ppm depending upon target gas type.



Patented Surecell™ Two Reservoir Design

Commercial designs of electrochemical cell are numerous but share many of the common features described below:

Three active gas diffusion electrodes are immersed in a common electrolyte, frequently a concentrated aqueous acid or salt solution, for efficient conduction of ions between the working and counter electrodes.

Depending on the specific cell the target gas is either oxidized or reduced at the surface of the working electrode. This reaction alters the potential of the working electrode relative to the reference electrode. The primary function of the associated electronic driver circuit connected to the cell is to minimize this potential difference by passing current between the working and counter electrodes, the measured current being proportional to the target gas concentration. Gas enters the cell through an external diffusion barrier that is porous to gas but impermeable to liquid.

Many designs incorporate a capillary diffusion barrier to limit the amount of gas contacting the working electrode and thereby maintaining “amperometric” cell operation.

A minimum concentration of oxygen is required for correct operation of all electrochemical cells, making them unsuitable for certain process monitoring applications. Although the electrolyte contains a certain amount of dissolved oxygen, enabling short-term detection (minutes) of the target gas in an oxygen free environment, it is strongly advised that all calibration gas streams incorporate air as the major component or diluent.

Specificity to the target gas is achieved either by optimization of the electrochemistry, i.e. choice of catalyst and electrolyte, or else by incorporating filters within the cell which physically absorb or chemically react with certain interferent gas molecules in order to increase target gas specificity. It is important that the appropriate product manual be consulted to understand the effects of potential interferent gases on the cell response.

The necessary inclusion of aqueous electrolytes within electrochemical cells results in a product that is sensitive to environmental conditions of both temperature and humidity. To address this, the patented Surecell™ design incorporates two electrolyte reservoirs that allows for the ‘take up’ and ‘loss’ of electrolyte that occurs in high temperature/high humidity and low temperature/low humidity environments.

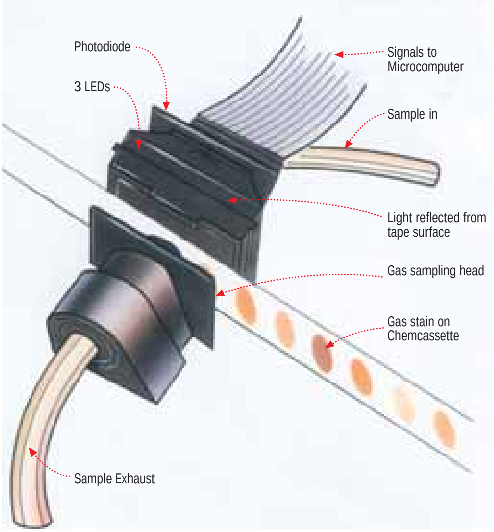
Electrochemical sensor life is typically warranted for 2 years, but the actual lifetime frequently exceeds the quoted values. The exceptions to this are oxygen, ammonia and hydrogen cyanide sensors where components of the cell are necessarily consumed as part of the sensing reaction mechanism.

Chemcassette®

Chemcassette® is based on the use of an absorbent strip of filter paper acting as a dry reaction substrate. This performs both as a gas collecting and gas analyzing media and it can be used in a continuously operating mode. The system is based on classic colorimetry techniques and is capable of extremely low detection limits for a specific gas. It can be used very successfully for a wide variety of highly toxic substances, including di-isocyanates, phosgene, chlorine, fluorine and a number of the hydride gases employed in the manufacture of semiconductors.

Detection specificity and sensitivity are achieved through the use of specially formulated chemical reagents, which react only with the sample gas or gases. As sample gas molecules are drawn through the Chemcassette® with a vacuum pump, they react with the dry chemical reagents and form a coloured stain specific to that gas only. The intensity of this stain is proportionate to the concentration of the reactant gas, ie, the higher the gas concentration, the darker is the stain. By carefully regulating both the sampling interval and the flow rate at which the sample is presented to the Chemcassette®, detection levels as low as parts-per-billion (ie, 10^{-9}) can be readily achieved.

Stain intensity is measured with an electro-optical system which reflects light from the surface of the substrate to a photo cell located at an angle to the light source. Then, as a stain develops, this reflected light is attenuated and the reduction of intensity is sensed by the photo detector in the form of an analog signal. This signal is, in turn, converted to a digital format and then presented as a gas concentration, using an internally-generated calibration curve and an appropriate software library. Chemcassette® formulations provide a unique detection medium that is not only fast, sensitive and specific, but it is also the only available system which leaves physical evidence (i.e. the stain on the cassette tape) that a gas leak or release has occurred.



Comparison of Gas Detection Techniques

Gas	Advantages	Disadvantages
Catalytic	Simple, measures flammability of gases. Low cost proven technology.	Can be poisoned by lead, chlorine and silicones that remains an unrevealed failure mode. Requires oxygen or air to work. High power. Positioning critical.
Electrochemical	Measures toxic gases in relatively low concentrations. Wide range of gases can be detected. Very low power.	Failure modes are unrevealed unless advanced monitoring techniques used. Requires oxygen to work. Positioning critical.
Point Infrared	Uses a physical rather than chemical technique. Less sensitive to calibration errors. No unseen failure modes. Can be used in inert atmospheres.	Flammable gas detection only in %LEL range. Measures concentration of flammable gases which have then to be related to the flammability of the gas. Positioning critical. High/ medium power.
Open Path Infrared	Area coverage- best chance to see a leak. No unseen failure modes. Latest technology. Can detect low concentrations. Positioning not as critical. New toxic version as well as flammable.	Higher initial purchase cost. Not suitable for use in smaller areas. Detection path can be obscured.
Semiconductor	Mechanically robust, works well in constant high humidity conditions.	Susceptible to contaminants and changes in environmental conditions. Non linear response effects complexity.
Thermal Conductivity	Measures %V/V concentrations of binary gas mixtures even with the absence of oxygen.	High gas concentrations only. Limited range of gases. Cannot measures gases with conductivities close to air. Higher maintenance requirements.
Paper Tape	Highly sensitive and selective for toxic gases. Leaves physical evidence of the gas exposure. No false alarms.	Requires extraction system. May need sample conditioning.

11 Portable Gas Detectors

Flammable and toxic gas detection instruments are generally available in two different formats: portable, i.e. ‘spot reading’ detectors and ‘fixed’, permanently sited monitors. Which of these types is most appropriate for a particular application will depend on several factors, including how often the area is accessed by personnel, site conditions, whether the hazard is permanent or transitory, how often testing is needed, and last but not least, the availability of finances.

Portable instruments probably account for nearly half of the total of all modern, electronic gas detectors in use today. In most countries, legislation also requires their use by anyone working in confined spaces such as sewers and underground telephone and electricity ducts. Generally, portable gas detectors are compact, robust, waterproof and lightweight and can be easily carried or attached to clothing. They are also useful for locating the exact point of a leak which was first detected with a fixed detection system.

Portable gas detectors are available as single or multi gas units. The single gas units contain one sensor for the detection of a specific gas while multi gas units usually contain up to four different gas sensors (typically oxygen, flammable, carbon monoxide and hydrogen sulfide). Products range from simple alarm only disposable units to advanced fully configurable and serviceable instruments with features such as datalogging, internal pump sampling, auto calibration routines and connectivity to other units.

Recent portable gas detector design advances include the use of more robust and lightweight materials for their construction. The use of high power microprocessors enables data processing for instrument self checking, running operating software, data storage, and auto calibration routines. Modular designs allow simple routine servicing and maintenance. New battery technology has provided extended operating time between charges in a smaller and more lightweight package.

Future designs are likely to see the integration of other technologies such as GPS, bluetooth and voice communication as well as the incorporation of gas detection into other safety equipment.

12 North American Hazardous Area Standards and Approvals

The North American system for the certification, installation, and inspection of hazardous locations equipment includes the following elements:

- **Installation Codes**
  – E.g. NEC, CEC
- **Standard Developing Organisations (SDOs)**
  – E.g. UL, CSA, FM
- **Nationally Recognized Testing Laboratories (NRTLs)**
  – Third Party Certifiers e.g. ARL, CSA, ETI, FM, ITSNA, MET, UL
- **Inspection Authorities**
  – E.g. OSHA, IAEI, USCG

The installation codes in North America are the NEC (National Electric Code) for the USA, and the CEC (Canadian Electric Code) for Canada. In both countries these guides are accepted and used by most authorities as the final standard on installation and use of electrical products. Details include equipment construction, performance and installation requirements, and area classification requirements. With the issuance of the new NEC these are now almost identical.

The Standards Developing Organizations (SDOs) work with industry to develop the appropriate overall equipment requirements. Certain SDOs also serve as members of the technical committees charged with the development and maintenance of the North American installation codes for hazardous locations.

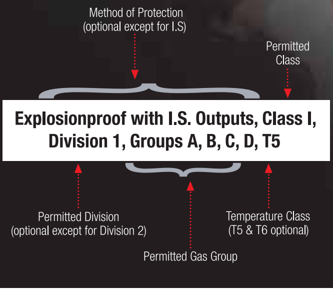
The Nationally Recognized Testing Laboratories (NRTLs) are independent third-party certifiers who assess the conformity of equipment with these requirements. The equipment tested and approved by these agencies is then suitable for use under the NEC or CEC installation standards.

In the United States of America the inspection authority responsible is OSHA (Occupational Health and Safety Administration). In Canada the inspection authority is the Standards Council of Canada. To confirm compliance to all national standards both countries require an additional indication on products tested and approved. As an example CSA approved product to USA standards must add NRTL/C to the CSA symbol. In Canada UL must add a small c to its label to indicate compliance to all Canadian standards.

North American Ex Marking and Area Classification

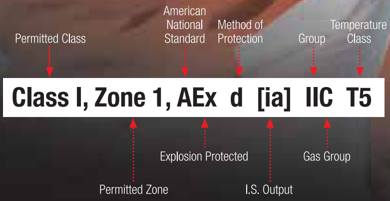
Once approved, the equipment must be marked to indicate the details of the approval.

US (NEC 500)



Explosionproof with I.S. Outputs, Class I, Division 1, Groups A, B, C, D, T5

US (NEC 505)



Class I, Zone 1, AEx d [ia] IIC T5

Class I – Explosive Gases	
Division 1	Gases normally present in explosive amounts
Division 2	Gases not normally present in explosive amounts
Gas Types by Group	
Group A	Acetylene
Group B	Hydrogen
Group C	Ethylene and related products
Group D	Propane and alcohol products

Class II – Explosive Dusts	
Division 1	Dust normally present in explosive amounts
Division 2	Dust not normally present in explosive amounts
Dust Types by Group	
Group E	Metal dust
Group F	Coal dust
Group G	Grain and non-metallic dust

13 European and Rest of World Hazardous Area Standards and Approvals

The standards used in most countries outside of North America are IEC / CENELEC. The IEC (International Electrotechnical Commission) has set broad standards for equipment and classification of areas. CENELEC (European Committee for Electrotechnical Standardization) is a rationalizing group that uses IEC standards as a base and harmonizes them with all member countries standards. The CENELEC mark is accepted in all European Community (EC) countries.

All countries within the EC also have governing bodies that set additional standards for products and wiring methods. Each member country of the EC has either government or third party laboratories that test and approve products to IEC and or CENELEC standards. Wiring methods change even under CENELEC this is primarily as to the use of cable, armoured cable, and type of armoured cable or conduit. Standards can change within a country depending on the location or who built a facility. Certified apparatus carries the 'EEx' mark.

Approved National Test Houses which are cited in the EC Directives may use the EC Distinctive Community Mark:

Note: This is not a Certification Mark

CENELEC MEMBER COUNTRIES:

Austria
Belgium
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Latvia
Lithuania
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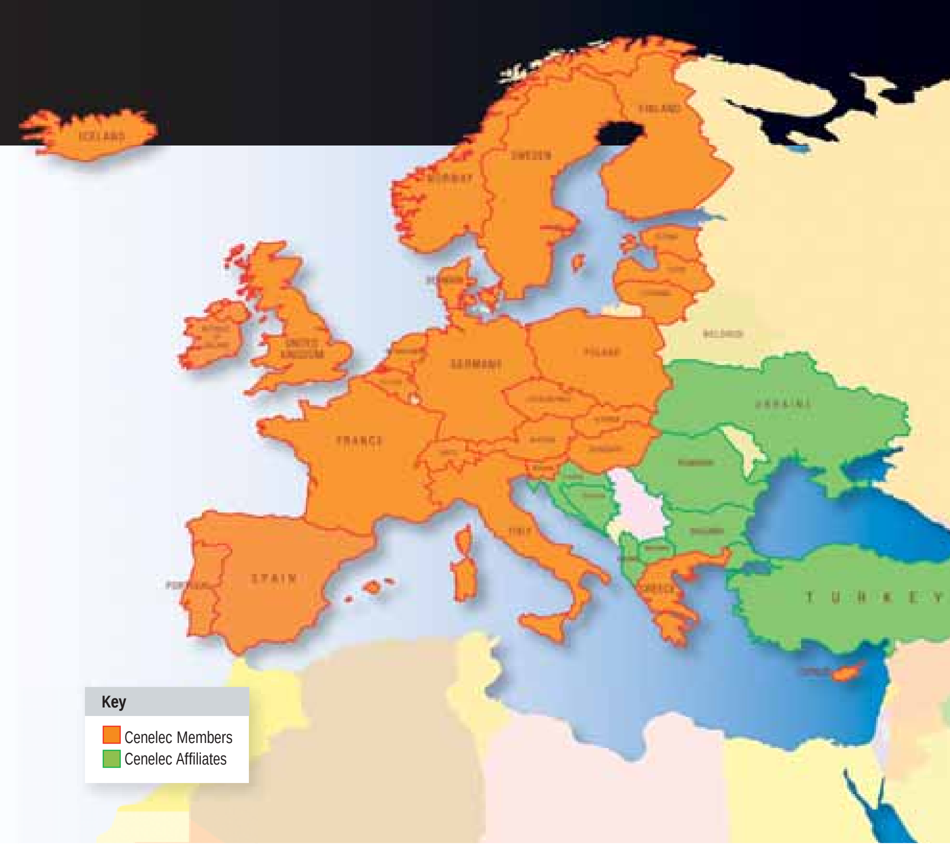
Slovakia
Slovenia
Spain
Sweden
Switzerland
United Kingdom



14 ATEX

ATEX = ATmospheres EXplosibles

There are two European Directives that have been law since July 2003 that detail the manufacturers and users obligations regarding the design and use of apparatus in hazardous atmospheres.

Responsibility	Directive	Article
Manufacturer	94/9/EC	100a
Employer (End User)	1992/92/EC	137

The ATEX directives set the MINIMUM standards for both the Employer and Manufacturer regarding explosive atmospheres. It is the responsibility of the Employer to conduct an assessment of explosive risk and to take necessary measures to eliminate or reduce the risk.

ATEX DIRECTIVE 94/9/EC ARTICLE 100A

Article 100a describes the manufacturers responsibilities:

- The requirements of equipment and protective systems intended for use in potentially explosive atmospheres (e.g. Gas Detectors).
- The requirements of safety and controlling devices intended for use outside of potentially explosive atmospheres but required for the safe functioning of equipment and protective systems (e.g. Controllers).
- The Classification of Equipment Groups into Categories
- The Essential Health and Safety Requirements (EHSRs). Relating to the design and construction of the equipment / systems

In order to comply with the ATEX directive the equipment must:

- display a CE mark.
- have the necessary hazardous area certification.
- meet a recognized performance standard e.g. EN 61779-1:2000 for flammable gas detectors.

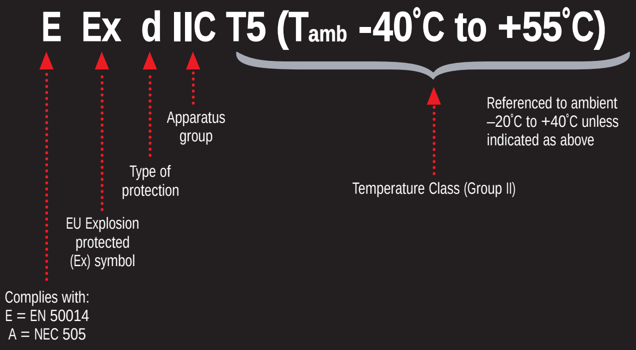
The classification of hazardous areas has been re-defined in the ATEX directive

EN 50014 Series	Definition	ATEX
Zone 0	Areas in which explosive atmospheres caused by mixtures of air and gases, vapors, mists or dusts are present continuously or for long periods of time	Category 1
Zone 1	Areas in which explosive atmospheres caused by mixtures of air and gases, vapors, mists or dusts are likely to occur	Category 2
Zone 2	Areas in which explosive atmospheres caused by mixtures of air or gases, vapors, mists or dusts are likely to occur or only occur infrequently or for short periods of time	Category 3

ATEX Category	Permitted Certification Type
Category 1	EEx ia
Category 2	EEx ib, EEx d, EEx e, EEx p, EEx m, EEx o, EEx q
Category 3	EEx ib, EEx d, EEx e, EEx p, EEx m, EEx o, EEx q, EEx n

Equipment Markings

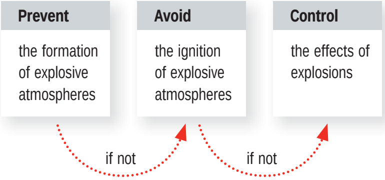
CENELEC / IEC



ATEX DIRECTIVE 1992/92/EC ARTICLE 137

Article 137 describes the responsibilities of the Employer. New plant must comply from July 2003. Existing plants must comply from July 2006. In the UK, this directive (also known as the 'Use' Directive) is implemented by the Health and Safety Executive (HSE) as The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).

It sets out to:

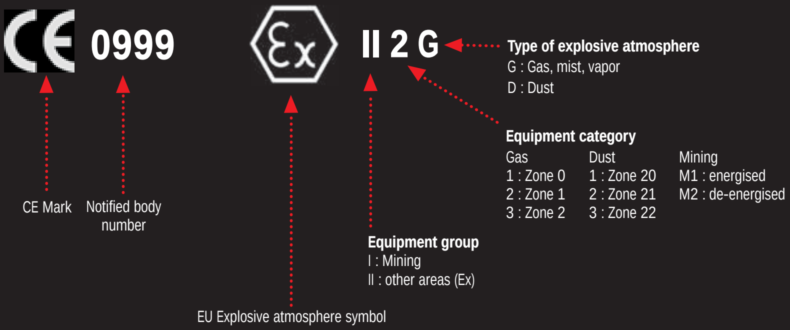


Assessment of Explosion Risks

The employer must conduct a risk assessment including:

1. **Probability of explosive atmosphere**
   Zone Area classification
2. **Probability of ignition source**
   Equipment Categories
3. **Nature of flammable materials**
   Gas groups, ignition temperature (T rating), gas, vapor, mists and dusts
4. **Scale of effect of explosion**
   Personnel, plant, environment

ATEX additional markings



EXPLOSIVE ATMOSPHERES WARNING SIGN

The employer must mark points of entry to places where explosive atmospheres may occur with distinctive signs:

In carrying out the assessment of explosion risk the employer shall draw up an Explosion Protection Document that demonstrates:

- explosion risks have been determined and assessed
- measures will be taken to attain the aims of the directive
- those places that have been classified into zones
- those places where the minimum requirements will apply
- that work place and equipment are designed, operated and maintained with due regard for safety

The employer may combine existing explosion risk assessments, documents or equivalent reports produced under other community acts. This document must be revised with significant changes, extensions or conversions.

15 Area Classification

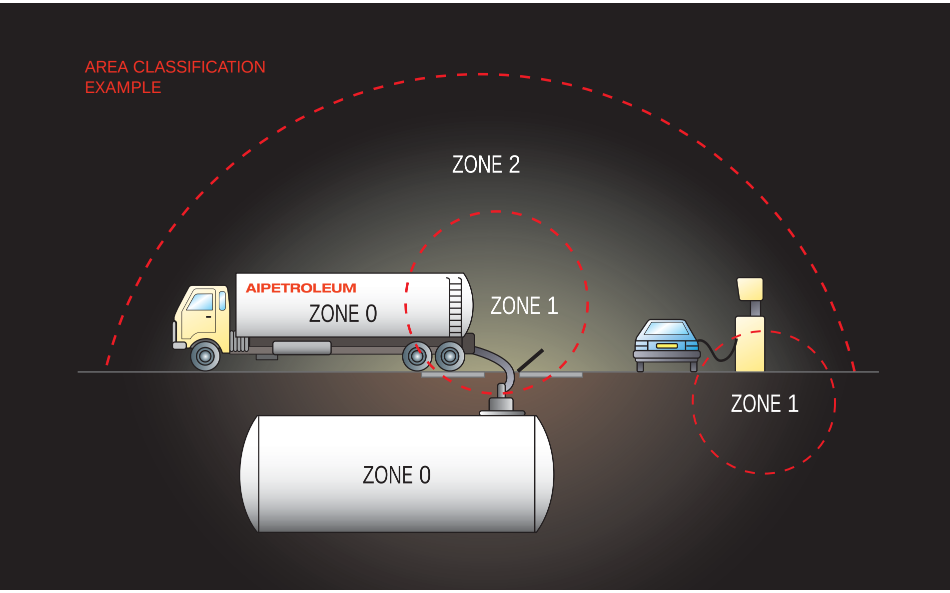
Not all areas of an industrial plant or site are considered to be equally hazardous. For instance, an underground coal mine is considered at all times to be an area of maximum risk, because some methane gas can always be present. On the other hand, a factory where methane is occasionally kept on site in storage tanks, would only be considered potentially hazardous in the area surrounding the tanks or any connecting pipework. In this case, it is only necessary to take precautions in those areas where a gas leakage could reasonably be expected to occur.

In order to bring some regulatory control into the industry, therefore, certain areas (or 'zones') have been classified according to their perceived likelihood of hazard. The three zones are classified as:

ZONE 0	ZONE 1	ZONE 2
In which an explosive gas/ air mixture is continuously present, or present for long periods	In which an explosive gas/ air mixture is likely to occur in the normal operation of the plant	In which an explosive gas/ air mixture is not likely to occur in normal operation

In North America the classification most often used (NEC 500) includes only two classes, known as 'divisions'.
Division 1 is equivalent to the two European Zones 0 and 1 combined, whilst Division 2 is approximately equivalent to Zone 2.

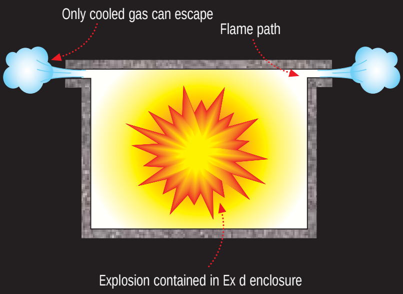
	Continuous hazard (>1000hrs/annum)	Intermittent hazard (>10<1000hrs/annum)	Possible hazard (<10hrs/annum)
Europe/IEC	Zone 0	Zone 1	Zone 2
North America (NEC 505)	Zone 0	Zone 1	Zone 2
North America (NEC 500)	Division 1		Division 2


AREA CLASSIFICATION
EXAMPLE
ZONE 2
AIPETROLEUM
ZONE 0
ZONE 1
ZONE 1
ZONE 0

16 Apparatus Design

To ensure the safe operation of electrical equipment in flammable atmospheres, several design standards have now been introduced. These design standards have to be followed by the manufacturer of apparatus sold for use in a hazardous area and must be certified as meeting the standard appropriate to its use. Equally, the user is responsible for ensuring that only correctly designed equipment is used in the hazardous area.

FLAMEPROOF



For gas detection equipment, the two most widely used classes of electrical safety design are ‘flameproof’ (sometimes known as ‘explosion-proof’ and with an identification symbol Ex d) and ‘intrinsically safe’ with the symbol Ex i.

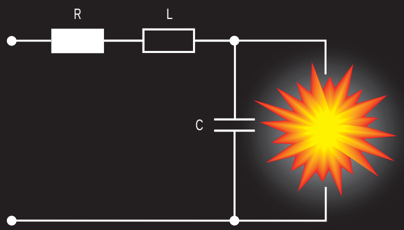
Flameproof apparatus is designed so that its enclosure is sufficiently rugged to withstand an internal explosion of flammable gas without suffering damage. This could possibly result from the accidental ignition of an explosive fuel/ air mixture inside the equipment. The dimensions of any gaps in the flameproof case or box (e.g. a flange joint) must therefore be calculated so that a flame can not propagate through to the outside atmosphere.

Intrinsically safe apparatus is designed so that the maximum internal energy of the apparatus and interconnecting wiring is kept below that which would be required to cause ignition by sparking or heating effects if there was an internal fault or a fault in any connected equipment. There are two types of intrinsic safety protection. The highest is Ex ia which is suitable for use in zone 0, 1 and 2 areas, and Ex ib which is suitable for use in zone 1 and 2 areas. Flameproof apparatus can only be used in Zone 1 or 2 areas.

Increased safety (Ex e) is a method of protection in which additional procedures are applied to give extra security to electrical apparatus. It is suitable for equipment in which no parts can produce sparking or arcs or exceed the limiting temperature in normal service.

A further standard, Encapsulation (Ex m) is a means of achieving safety by the encapsulation of various components or complete circuits. Some products now available, achieve safety certification by virtue of using a combination of safety designs for discrete parts. Eg. Ex e for terminal chambers, Ex i for circuit housings, Ex m for encapsulated electronic components and Ex d for chambers that could contain a hazardous gas.

INTRINSICALLY SAFE



INCREASED SAFETY

Hazardous Area Design Standards

Division	Zone	Ex	Type of protection
1	0	Ex ia	intrinsically safe
		Ex s	special (specially certified)
	1	**Any design suitable for zone 0 plus:**	
		Ex d	flameproof
		Ex ib	intrinsically safe
		Ex p	pressurized / continuous dilution
		Ex e	increased safety
		Ex s	special
		Ex m	encapsulation
2	2	**Any design suitable for zone 1 plus:**	
		Ex n or N	non-sparking (non-incendive)
		Ex o	oil
		Ex q	powder / sand filled

Ex s is not used in the latest standards but may be found on older equipment still in use.

17 Apparatus Classification

As an aid to the selection of apparatus for safe use in different environmental conditions, two designations, apparatus group and temperature classification, are now widely used to define their limitations.

As defined by standard No EN50014 of the European Committee for Electrical Standards (i.e. Comite Europeen de Normalisation Electrotechnique or CENELEC), equipment for use in potentially explosive atmospheres is divided into two apparatus groups:

Group I
for mines which are susceptible to firedamp (methane)

Group II
for places with a potentially explosive atmosphere, other than Group I mines

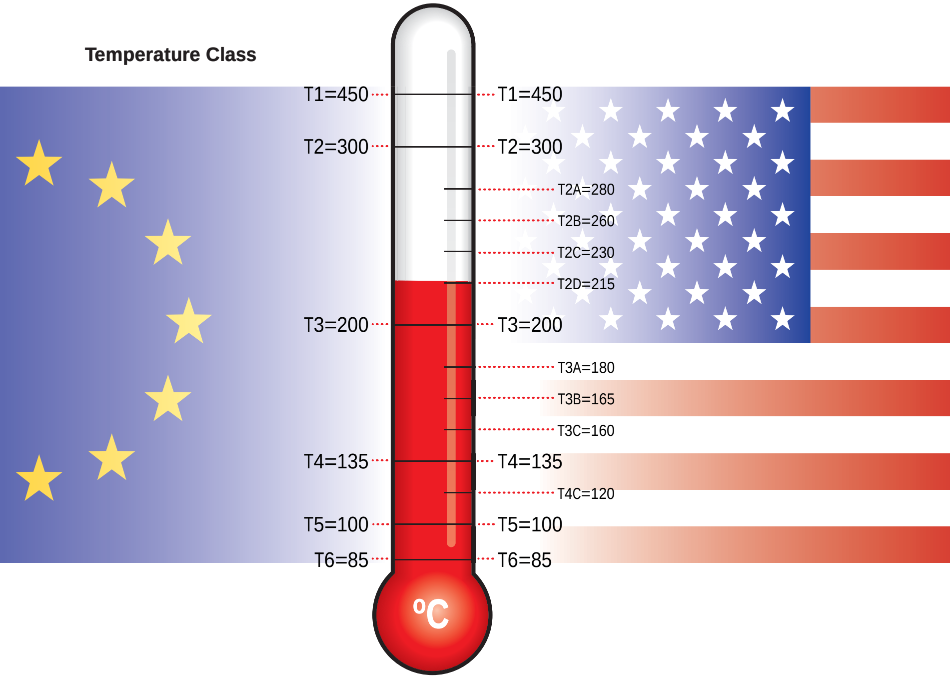
Group II clearly covers a wide range of potentially explosive atmospheres and includes many gases or vapors that constitute widely different degrees of hazard. Therefore, in order to separate more clearly the differing design features required when used in a particular gas or vapor, Group II gases are sub-divided as indicated in the table. Acetylene is often considered to be so unstable that it is listed separately, although still included in Group II gases. A more comprehensive listing of gases can be found in European Standard EN50014.

The Temperature Class rating for safety equipment is also very important in the selection of devices to detect gas or mixture of gases. (In a mixture of gases, it is always advisable to take the ‘worst case’ of any of the gases in the mixture). Temperature classification relates to the maximum surface temperature which can be allowed for a piece of apparatus. This is to ensure that it does not exceed the ignition temperature of the gases or vapors with which it comes into contact.

The range varies from T1 (450°C) down to T6 (85°C). Certified apparatus is tested in accordance with the specified gases or vapors in which it can be used. Both the apparatus group and the temperature classification are then indicated on the safety certificate and on the apparatus itself.

North America and the IEC are consistent in their temperature or T-Codes. However unlike the IEC, North America includes incremental values as shown opposite.

Temperature Class



Apparatus Group

Representative Gas	Gas Classification		Ignitability
	Europe and IEC countries	US and Canada	
Acetylene	Group IIC	Class I, Group A	
Hydrogen	Group IIC	Class I, Group B	
Ethylene	Group IIB	Class I, Group C	
Propane	Group IIA	Class I, Group D	
Methane	Group I	No classification	

18 Ingress Protection of Enclosures

Coded classifications are now widely used to indicate the degree of protection given by an enclosure against entry of liquids and solid materials. This classification also covers the protection of persons against contact with any live or moving parts inside the enclosure. It should be remembered that this is supplementary to and not an alternative to the protection classifications for electrical equipment used in hazardous areas.

In Europe the designation used to indicate the Ingress Protection consists of the letters IP followed by two ‘Characteristic Numbers’ which indicate the degree of protection. The first number indicates the degree of protection for persons against contact with live or moving parts inside, and the second number shows the enclosure’s protection against entry of water. For example, an enclosure with a rating of IP65 would give complete protection against touching live or moving parts, no ingress of dust, and would be protected against entry from water spray or jet. This would be suitable for use with gas detection equipment such as controllers, but care should be taken to ensure adequate cooling of the electronics. The two digit IP rating is a short form more commonly used in Britain. The full international version has three digits after the IP rather than two, e.g. “IP653”. The third digit is impact resistance. The meanings of the numbers are given in the following table.

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	$H_2$0.00005%
9	Impact of 6.0 Joule (5Kg weight dropped from 40cm)

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 -75º to 90º
Objects greater than 2.5mm	3	3	Splashed water
Objects greater than 1.0mm	4	4	Splashed 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 enclosures are rated using the NEMA system. The table below provides an approximate comparison of NEMA ratings with IP ratings.

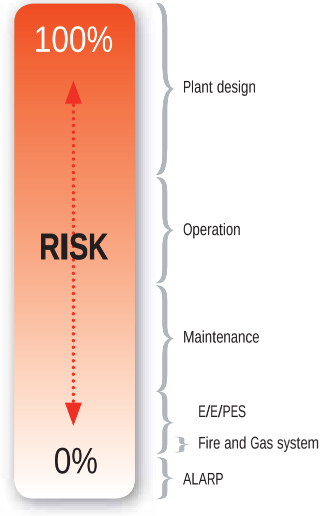
NEMA, UL and CSA type rating	Aproximate IEC/IP Code	Description
1	IP20	Indoor, from contact with contents
2	IP22	Indoor, limited, falling dirt and water
3	IP55	Outdoor from rain, sleet, windblown dust and ice damage
3R	IP24	Outdoor from rain, sleet and ice damage
4	IP66	Indoor and outdoor, from windblown 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

19 Safety Integrity Levels (SIL)

Certification has essentially been concerned with the safety of a product in its working environment i.e. that it won't create a hazard in its own right. The certification process (particularly in Europe with the introduction of the ATEX standard pertaining to Safety Related Devices) has now moved on to also include the measurement/physical performance of the product. SIL adds a further dimension by being concerned with the safety of the product in terms of being able to carry out its safety function when called to do so (ref: IEC 61508 manufacturers requirement). This is increasingly being demanded as installation designers and operators are required to design and document their Safety Instrumented Systems (ref: IEC 61511 user's requirement).

Individual standards applicable to specific types of equipment are being developed from IEC61508. For gas detection equipment the relevant standard is EN50402:2005 Electrical apparatus for the detection and measurement of combustible or toxic gases or vapors or of oxygen. Requirements on the functional Safety of fixed gas detection systems.

Managing safety is about risk reduction. All processes have a risk factor. The aim is to reduce the risk to 0%. Realistically, this is not possible so an acceptable risk level that is 'As Low As Reasonably Practical' (ALARP) is set. Safe plant design and specification is the major risk reduction factor. Safe operational procedures further reduce the risk as does a comprehensive maintenance regime. The E/E/PES (Electrical/Electronic/Programmable Electronic System) is the last line of defence in the prevention of accidents. SIL is a quantifiable measure of safety capability of the E/E/PES. In typical applications, this relates to the F&G systems- detectors, logic resolvers and safety actuation/annunciation.



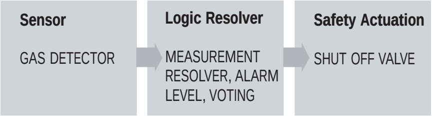
It is recognized that all equipment has failure modes. The key aspect is to be able to detect when the failures have occurred and take appropriate action. In some systems, redundancy can be applied to retain a function. In others, self checking can be employed to the same effect. The major design aim is to avoid a situation where a fault which prevents the system carrying out its safety function goes undetected. There is a critical distinction between reliability and safety. A product which appears to be reliable may have unrevealed failure modes whereas a piece of equipment which appears to declare a large number of faults may be safer as it is never/rarely in a condition where it is unable to do its function or has failed to annunciate its inability to do so.

There are 4 levels of SIL defined. In general, the higher the SIL, the greater the number of failure modes that are accommodated. For Fire and Gas systems the levels are defined in terms of "average probability of failure to perform the intended function on demand".

SIL	Probability of failure on demand
1	$> 10^{-2}$ to $< 10^{-1}$
2	$> 10^{-3}$ to $< 10^{-2}$
3	$> 10^{-4}$ to $< 10^{-3}$
4	$> 10^{-5}$ to $< 10^{-4}$

Many current fire and gas detection products were designed long before the introduction of SIL and therefore on individual assessment may only achieve a low or no SIL rating. This problem can be overcome by techniques such as decreasing the proof test intervals or combining systems with different technologies (and hence eliminating common mode failures) to increase the effective SIL rating.

For a safety system to achieve a specified SIL, the sum of the PFDavg must be considered.



For SIL 2
PDF (Sensor) + PFD (Resolver) + PDF (Actuator) < 1x10^{-2}

The selection of SIL required for the installation must be made in conjunction with the level of safety management within the design of the process itself. The E/E/PES should not be considered the primary safety system. Design, operation and maintenance have the most significant combination to the safety of any industrial process.

20 Gas Detection Systems

The most common method employed to continuously monitor for leakage of hazardous gases is to place a number of sensors at the places where any leaks are most likely to occur. These are often then connected electrically to a multi-channel controller located some distance away in a safe, gas free area with display and alarm facilities, event recording devices etc. This is often referred to as a fixed point system. As its name implies, it is permanently located in the area (e.g. an off-shore platform, oil refinery, laboratory cold storage etc).

The complexity of any gas detection system depends on the use to which the data will be put. Data recording allows the information to be used to identify problem areas and assist in the implementation of safety measures. If the system is to be used for warnings only, then the outputs from the system can be simple and no data storage is necessary. In choosing a system, therefore, it is important to know how the information will be used so that the proper system components can be chosen. In toxic gas monitoring, the use of multi-point systems has rapidly demonstrated their potential for solving a wide variety of workplace exposure problems and is invaluable for both identifying problems and for keeping workers and management aware of pollutant concentrations in the workplace.

In the design of multi-point systems, considerable thought should be given to the various components and to their interconnection. When using catalytic detection sensors, for instance, the electrical cable connections to the sensors would have three cores, each of 1mm squared, carrying not only the output signal, but also power to the electrical bridge circuit, which is located at the sensor to reduce signal voltage drop along the cables.

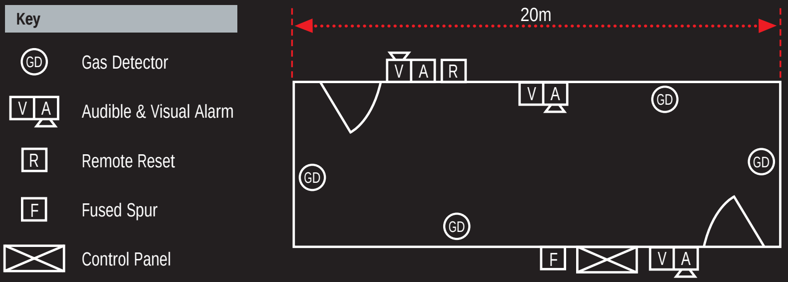
In the case of toxic (and some flammable) gas monitoring systems, the atmosphere is often sampled at locations remote from the unit and the gases are drawn by pumps to the sensors through a number of synthetic material, narrow-bore tubes. Care in design of such systems will include selection of suitable sized pumps and tubes, a sequential sampling unit for sampling each tube in turn and filters to stop particulates or water cutting off the flow of gas.

The bore size of tubing can be critical, since it needs to be both large enough to allow rapid response times with standard size pumps, but at the same time should not be so large as to allow excessive dilution of the sample by air. Each sampling point must be connected to a separate tube and if a number of points are connected to a single, central sensor, it will be necessary to purge the sensor with clean air between samples.

The controllers used in fixed systems can be centrally located or distributed at various locations in a facility according to the application requirements. They come in a control panel and come in either single channel (i.e. one control card per sensor) or multi-channel configurations, the latter being useful where power, space or cost limitations are important.

The control units include a front panel meter or LCD to

Typical small gas detection system protecting a room



Eg.
- Small Pump Station
- Generator House
- Normally Unmanned

Alarms
- Warning AV prior to entry
- AV internal to evacuate (if occupied)
- Remote reset to silence alarm

indicate the gas concentration at each sensor and will also normally have internal relays to control functions such as alarm, fault and shutdown. The number of alarm levels available varies between controllers but typically up to three levels can be set, depending on statutory requirements or working practices within the industry. Other useful features would include alarm inhibit and reset, over-range indication and analog 4-20mA outputs. Often digital outputs are also available for interfacing the controller to a DCS/BMS. It is important to remember that the main purpose of a gas detection system is to detect the build up of a gas concentration before it reaches a hazardous level and to initiate a mitigation process to prevent a hazard occurring. If the gas concentration continues towards a hazardous level then executive shut down and hazard warning alarms are initiated. It is not enough to just log the event or measure the gas levels to which personnel have been exposed.

CABLES AND JUNCTION BOXES

In a typical industrial gas detection system such as that just described, sensors are located at a number of strategic points around the plant and at varying distances from the controller. When installing electrical connections to the controller, it is important to remember that each sensor cable will have a different electrical loop resistance depending upon its length. With constant voltage type detectors the calibration process will require a person at both the sensor in the field and at the controller. With constant current detectors or those with a local transmitter, calibration of the field device can be carried out separately to that of the controller.

The sensor cables are protected from external damage either by passing them through metal ducting, or by using a suitable mechanically protected cable. Protective glands have to be fitted at each end of the cable and the sensor is mounted on a junction box to help in making simple, low-resistance, ‘clean’ terminations. It is also very important to ensure that all the gland sizes and screw threads are compatible with the junction box and the external diameter of the cables being used. The correct sealing washer should be used to ensure a weatherproof between the detector and junction box. A further point to remember is that sensor manufacturers normally indicate the maximum loop resistance (not line resistance) of their sensor connections when providing the information to calculate cable core diameters for installation.

Location of Sensors

'How many detectors do I need?' and 'where should I locate them?' are two of the most often asked questions about gas detection systems, and probably two of the most difficult to answer. Unlike other types of safety related detectors, such as smoke detectors, the location and quantity of detectors required in different applications is not clearly defined.

Considerable guidance is available from standards such as EN50073 Guide for selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen. Similar international codes of practice e.g. National Electrical Code (NEC) or Canadian Electrical Code (CEC) may be used where applicable. In addition certain regulatory bodies publish specifications giving minimum gas detection requirements for specific applications. These references are useful, but tend to be either very generic and therefore too general in detail, or application specific and therefore irrelevant in most applications.

The placement of detectors should be determined following the advice of experts having specialist knowledge of gas dispersion, experts having knowledge of the process plant system and equipment involved, safety and engineering personnel. The agreement reached on the location of detectors should also be recorded.

Detectors should be mounted where the gas is most likely to be present. Locations requiring the most protection in an industrial plant would be around gas boilers, compressors, pressurized storage tanks, cylinders or pipelines. Areas where leaks are most likely to occur are valves, gauges, flanges, T-joints, filling or draining connections etc.

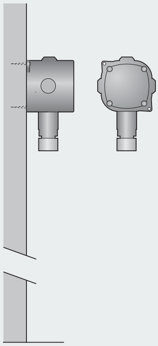
There are a number of simple and quite often obvious considerations that help to determine detector location:

- To detect gases that are lighter than air (e.g. Methane and Ammonia), detectors should be mounted at high level and preferably use a collecting cone.
- To detect heavier than air gases (e.g. Butane and Sulfur Dioxide), detectors should be mounted at a low level.
- Consider how escaping gas may behave due to natural or forced air currents. Mount detectors in ventilation ducts if appropriate.
- When locating detectors consider the possible damage caused by natural events e.g. rain or flooding. For detectors mounted outdoors it is preferable to use the weather protection assembly.
- Use a detector sunshade if locating a detector in a hot climate and in direct sun.
- Consider the process conditions. Butane and Ammonia, for instance are normally heavier than air, but if released from a process line that is at an elevated temperature and/or under pressure, the gas may rise rather than fall.
- Detectors should be positioned a little way back form high pressure parts to allow gas clouds to form. Otherwise any leak of gas is likely to pass by in a high speed jet and not be detected.
- Consider ease of access for functional testing and servicing.
- Detectors should be installed at the designated location with the detector pointing downwards. This ensures that dust or water will not collect on the front of the sensor and stop the gas entering the detector.
- When siting open path infrared devices it is important to ensure that there is no permanent obscuration or blocking of the IR beam. Short-term blockage from vehicles, site personnel, birds etc can be accommodated.
- Ensure the structures that open path devices are mounted to are sturdy and not susceptible to vibration.

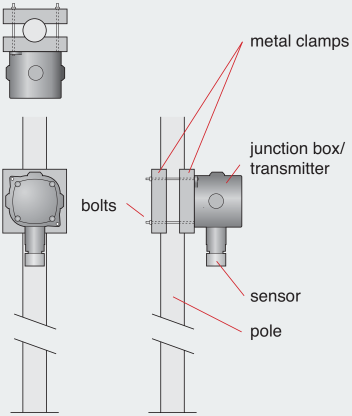
! Perhaps the most important point of all is not to try and economize by using the minimum number of sensors possible. A few extra sensors could make all the difference if a gas leak occurs!

Typical Sensor Mounting Options

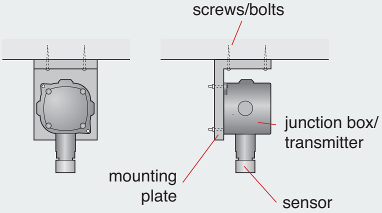
WALL MOUNTED



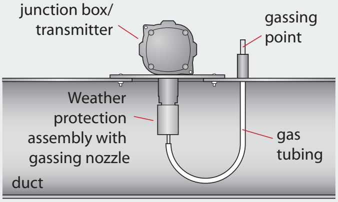
POLE MOUNTED



CEILING MOUNTED

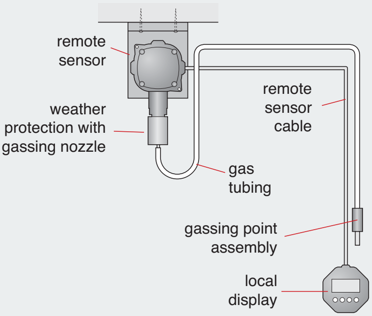


DUCT MOUNTED

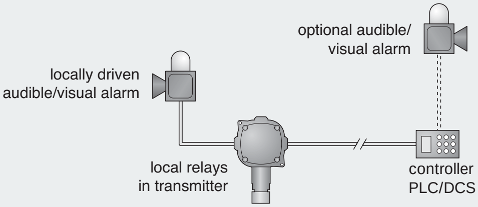


Typical System Configurations

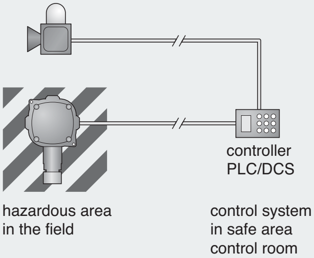
REMOTE SENSOR, LOCAL DISPLAY/GASSING



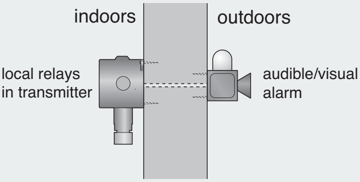
LOCALLY DRIVEN ALARM SYSTEM



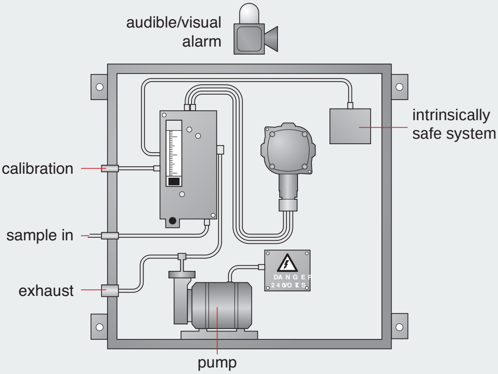
TYPICAL SENSOR/CONTROLLER SYSTEM



STANDALONE SYSTEM



TYPICAL SAMPLING/ASPIRATING SYSTEM



Installation Methods

Essentially three installation methods are used Worldwide for electrical equipment in hazardous locations:

1. Cable with indirect entry
2. Cable with direct entry
3. Conduit

Cable Systems

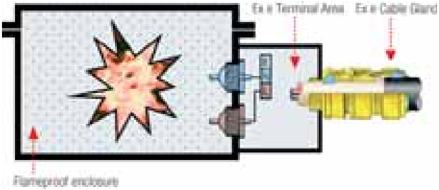
These are mainly used in Europe (although the US and Canadian Electrical Codes list Metal Clad and Mineral Insulated cables for use in Class 1 Div 1 or Zone 1). Explosion proof standards state that cable systems with suitable mechanical protection must be used. The cable is often Steel Wire Armoured (SWA) if used in areas where mechanical damage may occur, or it may be laid in protective conduit which is open at both ends. Certified cable glands are used to safely connect the cable to the enclosure.

Cross section of typical SWA cable

Cut away of typical cable gland

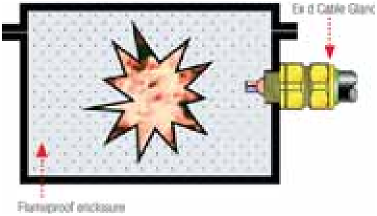
Indirect Cable Entry

Indirect entry is into an increased safety ‘Ex e’ terminal area. Line barriers are used on the wires between the terminal chamber and the main enclosure. The installer need only open access the terminal area, not the flameproof enclosure.



Direct Cable Entry

Direct Entry is made into the flameproof enclosure. Only specially certified glands may be used. The type and structure of the cable must be carefully matched to the correct type of gland. The integrity of the protection is reliant on the correct installation by the installer.



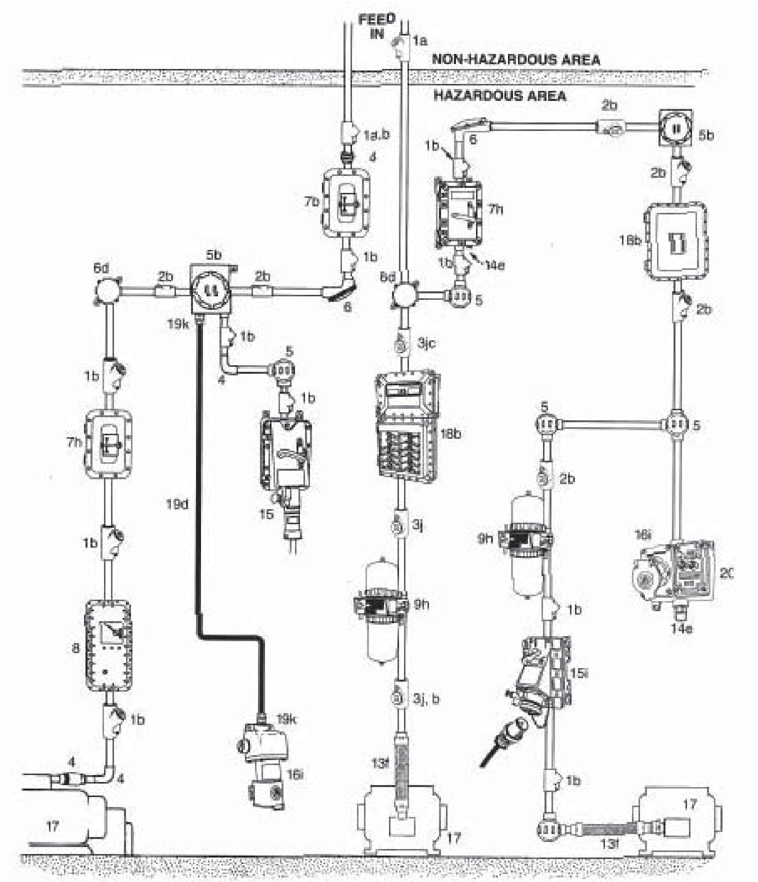
Conduit

Conduit is the main method of installation in hazardous areas throughout the USA. The electrical wires are run as individual wires inside enclosed metal tubes. The tubes are connected to the housings by means of unions and must have a seal within 18 inches of each entrance point. The entire conduit system is flameproof.

Typical Class 1 Div 1 conduit installation

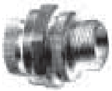
Installation Methods

Typical Conduit Installation



Fittings and Seals for Conduit


EXGJH/EXLK


UNY


EYS


ELF


EYM


EYDM

Boxes


GR


GRF

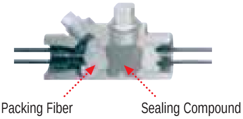

GRSS


CPU

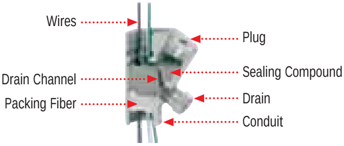
Conduit Seals

The seals prevent any explosions in the tubing from spreading. Drains must be installed at low points where condensation may accumulate.

Horizontal Seal



Vertical Seal with Drain



21 Global Service and Support Network

A vital part of ensuring that fixed and portable gas detection equipment operates correctly is periodic servicing, maintenance and calibration. Unlike some other types of safety related equipment (e.g. fire detection), gas detection does not have specific legislation or clear guidelines that specify how often it should be serviced. Relevant documents simply state that inspection and maintenance should be carried out frequently by competent, trained personnel and in line with the manufacturers recommendations.

Gas detection applications vary widely and therefore so do the factors that affect the frequency of servicing required to ensure proper operation.
It is important that a suitable service period is established for the equipment that takes account of each individual application's unique set of factors.

Traditionally, gas detection users had their own in-house service departments that were responsible for servicing, maintenance and calibration of their gas detection equipment as well as other safety related equipment. Increasingly, many users now choose to outsource part or all of this function in order to reduce fixed costs and at the same time ensure that people with specialist knowledge of the equipment are responsible for it.

It is also becoming more common for leading gas detection companies to also offer service of third party gas detection equipment as well as their own. As users continue to demand better efficiencies from outsourced suppliers, the trend in the future is likely to require gas detection companies to offer a 'one stop shop' for the service and maintenance of complete safety systems.

Gas detection company service departments should also offer other services including site surveys, installation, commissioning and training. Advice from experts in gas detection when conducting a site survey helps ensure the selection of the most suitable detection technologies and most appropriate detector locations. Installation must be carried out in accordance with any site, local or national codes of practice and legislation.

Properly commissioning a system ensures that it is fully functioning as designed and accurately detecting gas hazards. Many companies require that employees who use personal gas detection equipment, or work in areas that have fixed systems installed, are formally trained on the use and routine maintenance of the equipment. Service training departments should be able to offer certified training courses designed to suit all levels of ability from basic gas detection principles through to advanced custom designed technical courses.

Some gas detectors now offer ‘smart’ sensors that are pre-calibrated and can be simply fitted and used without the need for additional calibration and set up in the field. The additional use of Intrinsically Safe (I.S) design can also allow the ‘hot swap’ of these sensors without the need for removing power from the detector. Other recent innovations include the use of ‘auto-cal’ routines where the user is taken through a sequence of ‘on-screen’ calibration steps thereby ensuring correct set up. All of these innovations help keep service times to a minimum while ensuring accurate calibration of the detector.

The modular design of modern gas detectors enables more efficient servicing. The replacement of modules rather than component level service/repair greatly reduces turnaround time and therefore system down time. The economies of scale achieved by volume module level servicing also enables overall servicing costs to be reduced.

Take your service to the next level

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22 Glossary

Glossary	
ACGIH	American Conference of Governmental Industrial Hygienists.
AIT	Auto Ignition Temperature.
Analogue/analog output	Standard mA output from a sensor or transmitter. Normally described as 4-20mA. The alternative is a mV bridge output from a catalytic type sensor or a digital output.
Apparatus group	The classification of flammable gases into groups that are associated with required apparatus design standards.
Asphyxiation	Death resulting from lack of oxygen.
ATEX	European Explosive Atmospheres Directives (ATmospheres EXplosibles).
Baseefa	British Approvals Service for Electrical Equipment in Flammable Atmospheres – UK Safety Certification.
BMS	Building Management System.
Binary mixture of gas	A mixture of two gases only.
Breathing Zone	Height where toxic gas monitoring is often carried out- head height.
Bridge Circuit	Wheatstone Bridge circuit used in catalytic detector design.
CAS number	Chemical Abstracts Service. CAS Registry number used to identify substances without the ambiguity of chemical nomenclature.
Calibration	The process of adjusting the output of the detector to give an accurate reading of gas concentration over its measuring range.
Carcinogenic	Capable of causing Cancer.
Catalytic Sensor	For detection of combustible gases. These are made of an electrically heated platinum wire coil, covered first with a ceramic base such as alumina and then with a final outer coating of palladium or rhidium catalyst dispersed in a substrate of thoria.
CE	Indicates compliance to all relevant European directives.
CEC	Canadian Electrical Code.
Cell	An individual sensor.
CENELEC	Comite Europeen de Normalisation Electrotechnique – European Safety Certification.
Cesi	Centro Electrotechnico Sperimentale Italiano – Italian Safety Certification.
Channel	One line or point of gas detection.
Chemcassette®	Registered name of a paper tape cartridge used in toxic gas analyzers.
Conduit	Metal tubing mainly used in the US for installation of wires in hazardous areas.
COSHH	Control of Substances Hazardous to Health.
CSA	Canadian Standards Association.
dBA	Decibels, relative to the A weighting scale (as affected by the human ear).
DCS	Distributed Control System.
Domestic Gas Detector	Gas detector designed specifically for use in domestic or residential properties.
Division	North American area classification of a hazardous area (Division 1 or 2) that defines the length of time a hazard in present.
Electrochemical Sensor	A gas sensitive electrode, formed by a permeable membrane and special electrolyte.
EMC	Electromagnetic compatibility.
ESD	Electrostatic discharge.

Glossary continued	
Exd	Flameproof – any flame is contained within the housing of the product. Suitable for zones 1 & 2.
Exi	Intrinsic safety – any ignition is limited due to the low energy in the circuit even with one fault (Ex ib) or two faults (Ex ib). Zones 0, 1 & 2.
Exe	Increased safety – No sparks or hot surfaces. Zones 1 & 2.
Exm	Encapsulated to keep gas out of product. Zones 1 & 2.
Explosimeters	Combustible gas monitor.
Explosion Proof	A name for Ex d apparatus design.
Fail Safe	Description of a detector that has no unseen failure modes.
Fieldbus	Digital communication standard.
Firedamp	A mixture of methane and other hydrocarbon gases that forms in coalmines.
Fixed point system	Gas detection system using individual fixed point gas sensors and/or transmitters. Not mobile or transportable.
Flame arrestor	A structure that allows gas to diffuse through it into a detector but prevents propagation of any flame back out.
Flameproof	A name for Ex d apparatus design.
Flammable Range	Band of gas/air mixture that produces that is flammable.
Flash Point	This is the lowest temperature at which vapor is given off at sufficient rate to form an explosive mixture with air.
FM	Factory Mutual – USA Safety Certification.
Gas Analyzer	Normally refers to equipment used to measure extremely small concentrations of gas (low or sub ppm) or one specific gas in the presence of several others.
Gas Detector	Refers to equipment used in applications where there is normally no toxic or explosive gas risk and therefore is used to signal the presence of gas in otherwise safe conditions.
Gas Monitor	Equipment used in applications where a gas or gas mixture is constantly present and is therefore used to signal a change in the concentration or mixture of the gas.
GOSST	Russian hazardous area approvals body. Widely accepted in eastern Europe or as a base for own local approvals.
Hazardous Areas	Areas where there is the possibility of the presence of an explosive mixture of flammable gas or vapor and air are known as 'Hazardous' and other areas as 'safe' or 'non-hazardous'. Any electrical equipment used in hazardous areas must be tested and approved to ensure that, in use even under fault conditions, it can not cause an explosion.
HSE	Health and Safety Executive (UK)
Ignition Temperature	The lowest temperature that will cause a mixture to burn or explode.
Ineris	Institut Nationale de L'Environment Industriel et des Riscues.
Infrared Detector	Gas Detector that uses the principle that infrared light is absorbed by gas molecules at specific frequencies.
International Electrotechnical Committee	International Standards and conformity assessment for government, business and society for all electrical, electronic and related technologies.
Intrinsically safe (IS)	Method of design so that the maximum internal energy of the apparatus and wiring is not sufficient to cause ignition by sparking or heating effects resulting from a fault.
IP	Ingress Protection – a measure of protection against the ingress of dust and water.
Kema	Hazardous Area Approvals Body. Dutch Safety Certification.

Glossary continued	
LCD	Liquid Crystal Display.
LED	Light Emitting Diode.
LEL	Lower Explosive Limit – is the lowest concentration of 'fuel' in air which will burn and for most flammable gases and vapors it is less than 5% by volume.
LEL%	Percentage of the Lower Explosive Limit (for example, 10% LEL of methane is approx 0.5% by volume).
LEL metres	Scale for measurement for flammable gases by open path infrared detectors.
LFL	Lower Flammable Limit.
LNG	Liquefied Natural Gas.
LPG	Liquefied Petroleum Gas made up of Propane and Butane.
LTEL	Long Term Exposure Limit. The 8 hour LTEL is the time-weighted average concentration for a normal 8 hour day to which most workers may be repeatedly exposed, day after day, without adverse effect.
mA	Milliamp – measurement of current.
MAC	Toxic gas level described by ACGIH- Maximum Allowable Concentrations (replaced by TLVs)
MAK	Maximale Arbeitsplatz Konzentration.
MEL	Maximum exposure limit.
Milligrams per cubic metre	Alternative scale of measurement for toxic gases.
Modbus	Digital communication protocol.
multi-channel	More than one gas channel.
Multi gas	Portable gas detector with typically up to 4 gas sensors fitted.
mV	Millivolt – measurement of Voltage.
Natural Gas	Fossil fuel formed almost entirely of Methane.
NEC 500	National Electrical Code (US).
NEC 505	Latest version of NEC.
NEMA	National Electrical Manufacturers Association. US standards developing organisation. NEMA rating of enclosures is similar to the IP rating system.
NRTLs	Nationally Recognized Testing Laboratories (US).
OEL	Occupational Exposure Limit – The 8 hour OEL is the time-weighted average concentration for a normal 8 hour day or 40 hour working week to which most workers may be repeatedly exposed, day after day, without adverse effect.
Open path	Infrared gas detection with transmitter and receiver devices located at a distance apart.
OSHA and NIOSH	Occupational Safety and Health Association.
Oxygen Deficiency	Concentrations of oxygen less than 20.9% V/V.
Oz	Ounce (weight).
Peak	Maximum, or minimum, measurement since switch on.
Perimeter Monitoring	Monitoring the outer edge of a plant or storage area as opposed to monitoring specific points.
Pellistor	Registered trade name for a commercial device – A very small sensing element used in catalytic sensors and sometimes also called a 'bead' or a 'siegistor'.
PLC	Programmable Logic Controller.

Glossary continued	
PELs	Permissible Exposure Limits (OSHA).
Point detection	Detecting or measuring gas at a fixed point/position.
Poison resistant	Capability of a catalytic sensor to reduce the effect of inhibiting substances or contaminants, such as silicones.
PPB	Parts per billion concentrations in the atmosphere.
PPM	Parts per million concentrations in the atmosphere.
PTB	Physikalisch – Technische Bundesanstalt.
RELs	Recommended Exposure Levels (NIOSH).
Response curve	The line that shows detector response to gas at points over time.
Retro reflector	Reflecting panel that returns an infrared signal.
RFI	Radio Frequency Interference.
RH	Relative Humidity.
RS485/232/422	Digital communication protocols.
SAA	Standards Australia Quality Assurance Services Pty Ltd. Australian safety certification.
Safe Area	Work area in which there is no danger of contamination with explosive gases.
Semiconductor Sensor	Type of sensor that uses semiconductor material in construction.
SIL	Safety Integrity Levels.
Single channel	One point of gas detection.
Sira	Sira Test and Certification Service (UK).
Smart	Used to describe a sensor with a PCB and eprom that stores sensor information such as calibration details, date of manufacture, gas type etc.
Span	The level at which calibration is made (typically 50% of full scale).
STEL	Short Term Exposure Limit, usually monitored over 15 minute periods.
T90	Time taken for a detector to reach 90% of its final reading.
T60	Time taken for a detector to reach 60% of its final reading.
Temperature classification/class	Product classification based on the hottest surface where igniting the product would destroy the protection. 6 bands exist T1 – T6. When selecting equipment T Class must be below Alt of gas to be detected.
Thermal Conductivity	Method of detecting the level of gas using its properties of thermal conductivity.
TLV	Threshold Limit Value.
TWA	Time-Weighted Average.
UEL	Upper Exposure Limit.
UL	Underwriters Laboratories (USA).
%VOL	Concentration of explosive gas, measured in percentage by volume.
V/V	Another way of representing %VOL.
Vapor Density	A measure of the density of gas or vapor relative to air. Gases or vapors with a vapor density less than 1 are lighter than air.
WELs	Work Exposure Limits (EH40)
Zone	Area classification of a hazardous area (Zone 0, 1 or 2) that defines the length of time a hazard in present. Mainly used in Europe.

Notes

Notes

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