GAS DETECTION REFERENCE GUIDE

SCOTT SAFETY

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INTRODUCTION

As an industry leader in gas detection products, Scott Safety is committed to the life safety of workers in potentially dangerous industries such as petrochemical, pharmaceutical, wastewater treatment, and chemical processing. The ability to detect and analyze unseen threats through reliable gas detection products can and will save lives.

The safety concerns with exposure to both toxic and combustible gases are the foundation of the need for reliable gas detection. Left undetected and unmonitored, hazardous gases pose grave threats to our health and safety. Exposure to toxic gases can cause a wide range of health effects including simple irritation, loss of consciousness, chronic illnesses, and even death. Combustible gases pose just as great a safety risk because of their potential to ignite and cause massive destruction.

A well maintained gas detection program will combat the dangers and risks associated with hazardous conditions and **help to safeguard life and property**.

Advanced monitoring techniques provide opportunities for:

- Early Warning of Hazardous Conditions
- Intervention and Correction of the Causes of Hazardous Conditions
- Time for Evacuation from Hazardous Conditions

GAS CHARACTERISTICS

The air we breathe every day is comprised of various gases. Though typically steady in composition, the quality of the air around us can change significantly when different toxic and combustible hazards are introduced into the immediate surrounding areas.

From toxic* and combustible* gases to possibly harmful vapors* and aerosols,* the potential for a hazardous atmosphere* exists every day in work places across the world.

Recognizing the properties and hazards of the gases that can enter and contaminate your workspaces is the first step in developing an effective gas detection program.

Whether it's recognizing the destructive potential of explosive combustible gases or safeguarding workers from the health hazards of toxic gas exposure, modern gas detection techniques are available to keep workers, equipment, and property safe.

** Refer to the glossary for an explanation of this term*

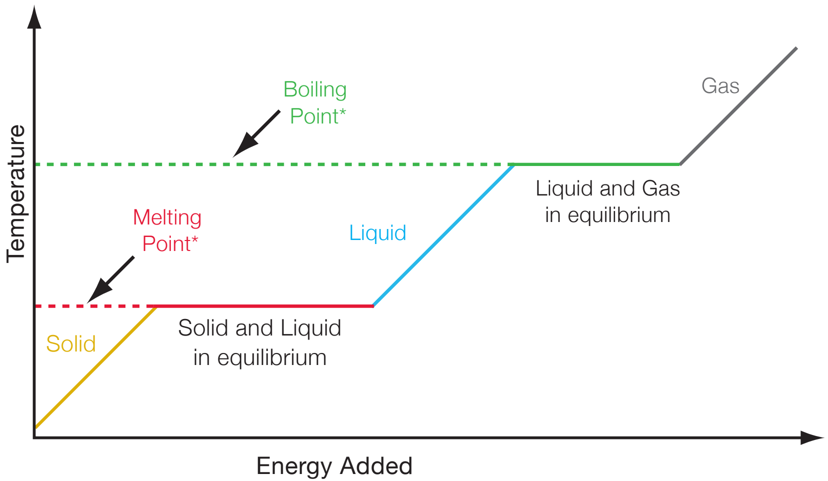
PROPERTIES OF A GAS

1. Gases will easily compress or expand based on the containment of the gas, temperature, pressure, and other factors.

2. Gases are comprised of a large number of weakly attracted molecules that can combine and react with other molecules and are in constant motion.

3. Gases will fill any size or shape container and are constantly in motion trying to escape the containment.

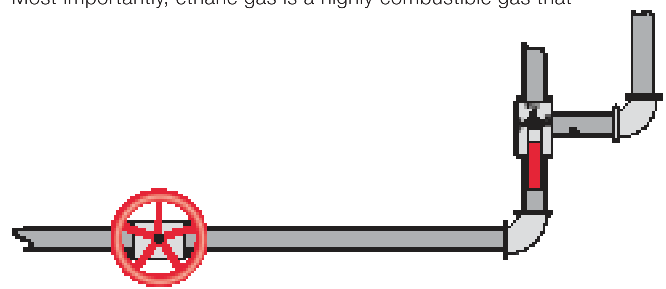
4. Many gases are either colorless or odorless and sometimes both.



Because of these properties, gas monitoring is very important. Gases will always fill the space they occupy until they can escape to another space. Gas leaks can occur suddenly and without warning causing a severe threat to life and property damage.

Q: *If the ethane gas running through this piping system were to escape into your working atmosphere, would there be a need to detect its presence?*

A: Absolutely! Ethane gas is both odorless and colorless making its detection through simple observation nearly impossible. Additionally, ethane can displace oxygen causing a severe breathing hazard. Most importantly, ethane gas is a highly combustible gas that



* *Refer to the glossary for an explanation of this term*

VAPORS AND AEROSOLS

VAPORS

Compounds with a boiling point below room temperature exist as a gas. Some compounds can exist as both a gas and a liquid at room temperature. The gaseous portion in equilibrium with the liquid is referred to as a vapor.

For a combustible or flammable liquid, the vapor is what actually burns. Vapors travel along air currents and, when ignited, will flash back to their source.

Most vapors are heavier than air and will accumulate in low lying areas. Some, like hydrogen, are lighter than air and will rise.

Accumulated combustible vapors can reach their Lower Explosive Limit and present a serious ignition risk. Vapors and gases that have not yet reached their Lower Explosive Limit or have exceeded their Upper Explosive Limit still present a breathing risk as they can displace oxygen or be toxic in nature.

AEROSOLS

An aerosol is a suspension of fine solid particles or liquid droplets in a gas. In effect, aerosols are a gaseous delivery system for contaminants. Smoke, smog, clouds, mists, and combustible emissions are examples of aerosols. Aerosols can cause adverse health effects when inhaled or absorbed through the skin.

Aerosols can accumulate forming mists, smog, etc. These high concentrations can cause serious breathing and combustion risks.

Both vapors and aerosols can create hazardous situations, especially in an enclosed space. Effective gas monitoring in areas where vapors or aerosols may be present can reduce the risks associated with toxic atmospheres and combustible concentrations.

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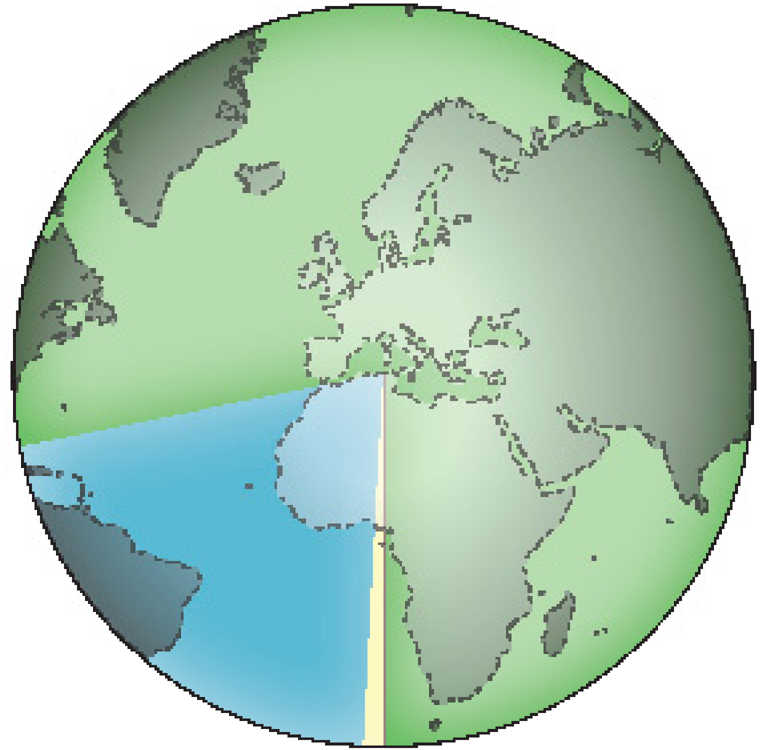
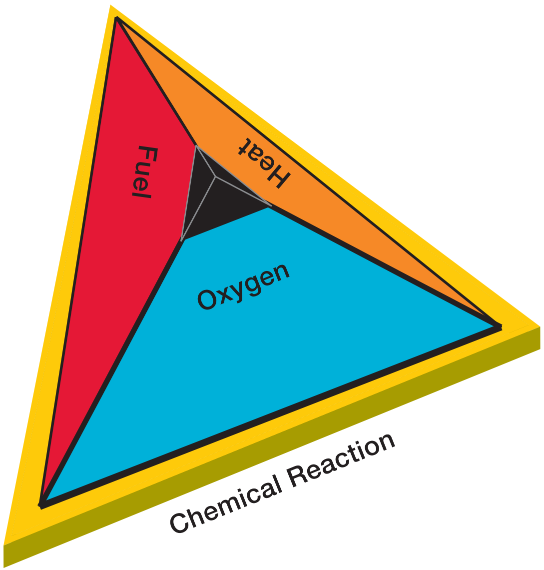
ATMOSPHERE COMPOSITION



H_2, Xe) < 1% Total

FIRE TETRAHEDRON

To support combustion, four elements must be present: heat, oxygen, fuel source, and a chemical reaction. This is illustrated in the four-sided fire tetrahedron. Removal of any of the four elements will eliminate the flame.



HOW DOES GAS MONITORING HELP IN THE PREVENTION OF FIRES?

- Several (combustible) gases can provide the fuel source element of the fire tetrahedron. Monitoring levels can help identify potentially hazardous situations before they occur.
- Many gases can lead to the increased likelihood of the chemical reaction element of the fire tetrahedron. Monitoring the presence of these gases can lead to an awareness of the potential for dangerous reactions to occur.
- Monitoring of oxygen levels can help to identify an oxygen-rich environment that can lead to an increased likelihood of fire.

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WHAT IS A HAZARDOUS ATMOSPHERE?

A hazardous atmosphere is defined as one where one or more of the following conditions exist:

- Flammable gas, vapor, or mist exists with a concentration of > 10% LEL*
- Oxygen levels are < 19.5% or > 23.5%
- Atmospheric concentration of any hazardous substance which could result in exposure in excess of the published dose per Occupational Safety and Health Administration (OSHA) regulations
- Airborne combustible dust > 100% LEL
- Any other atmospheric condition immediately dangerous to life or health (IDLH)*

EXAMPLES OF THE CAUSES OF A HAZARDOUS ATMOSPHERE CONDITION:

- *Oxygen is absorbed by the contents of a vessel or tank*
- *Oxygen is displaced by heavier-than-air gases*
- *Leaking underground storage tanks and pipes*
- *Decomposing organic matter or domestic waste*
- *Piping system leak*
- *Toxic substances being used in a confined space*

** Refer to the glossary for an explanation of this term*

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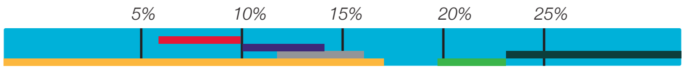
TYPES OF GAS, VAPOR AND AEROSOL HAZARDS

Asphyxiants: • Simple • Chemical	 Causes suffocation by displacing oxygen. (examples: H_2, CO) Causes suffocation by interfering with the blood's ability to carry oxygen. (example: CO)
Irritants/Corrosives	Causes an inflammatory effect on tissue, especially in the respiratory tract, through contact with the compound. (examples: NH_3, Cl_2, O_3, SO_2)
Toxic Agents	Poisonous to one or more organs such as the kidney (nephrotoxic) or liver (hepatotoxic). (examples: CS_2, AsH_3, CCl_4)
Carcinogens	Causes cancer in humans and/or animals. (example: vinyl chloride, benzene)
(CNS) Central Nervous System Depressants	Disturb the proper functions of the CNS. (examples: benzene, acetone)
Combustibles	Liquids with a flash point between 100°F and 200°F. (example: acetic acid)
Flammables	Compounds with a flash point < 100°F or that form a flammable mixture with air at 13%v/v or less. (examples: ethyl alcohol, methane)

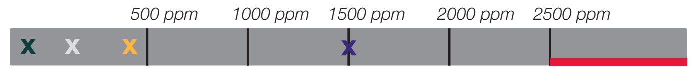
TOXICITY EFFECTS OF COMMON GASES

OXYGEN



- 6-10% - Vomiting, loss of consciousness, death
- 10-14% - Abnormal fatigue
- 12-16% - Muscular coordination becomes impaired
- < 17% - Impaired judgment
- 19.5-23.5% - Safe level as per OSHA requirements
- > 23.5% - Oxygen enriched environment, high probability of fire

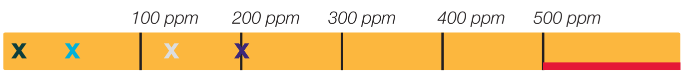
CARBON MONOXIDE



- > 2500 ppm* - Fatal
- 1500 ppm - Mental confusion, possible loss of consciousness
- 400 ppm - Headache within 2 hours
- 200 ppm - Headache after several hours
- 25 ppm - Time weighted average exposure level

ODORLESS

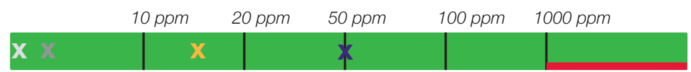
HYDROGEN SULFIDE



- > 500 ppm - Fatal within 30-60 minutes
- 200 ppm - Headache and vomiting, potentially fatal
- 125 ppm - Temporary loss of smell
- 50 ppm- Eye and throat irritation
- 10 ppm - Time weighted average exposure level

Odor threshold at 0.0005 ppm

CHLORINE



- > 1000 ppm - Fatal
- 50 ppm - Potentially fatal after prolonged exposure
- 15 ppm - Throat irritation
- 3 ppm - Eye irritation
- 0.5 ppm - Time weighted average exposure level

Odor threshold at 0.05 ppm

** Refer to the glossary for an explanation of this term*

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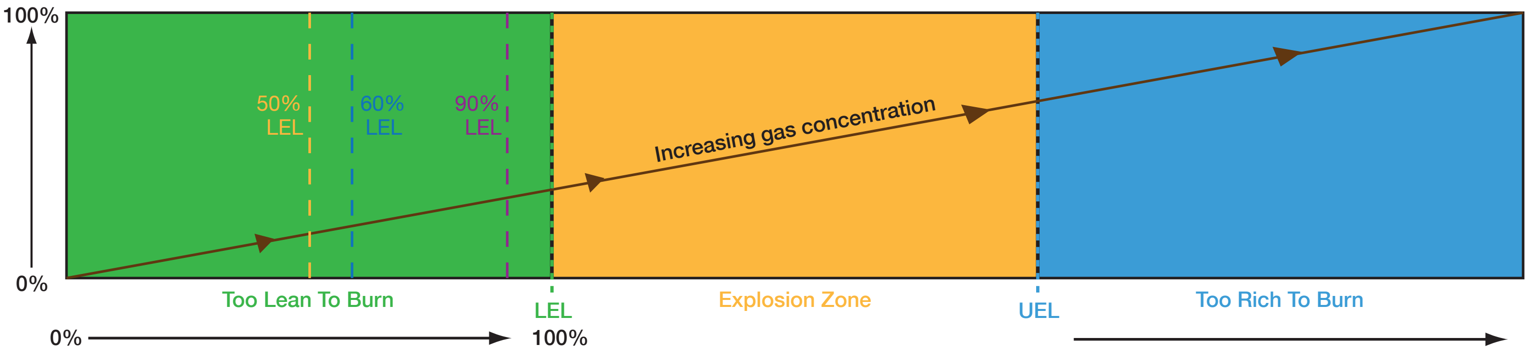
UPPER AND LOWER EXPLOSIVE LIMITS (UEL AND LEL)

The Upper Explosive Limit, or UEL, is the point above which the concentration of gas mixture to atmosphere is too rich to burn. This is sometimes expressed as Upper Flammable Limit (UFL).

The Lower Explosive Limit, or LEL, is the point below which the concentration of gas mixture to atmosphere is too lean to burn. This is sometimes expressed as Lower Flammable Limit (LFL).

Any concentration between these limits may ignite or explode with little to no warning. Gas concentrations above the UEL are also extremely dangerous as they displace oxygen and must travel back through the explosive zone during ventilation efforts to reach safe limits.



To allow for adequate time to respond and recover from potentially hazardous and explosive atmospheres, CSA and ISA testing agencies require combustible sensors to respond to the exposure of a combustible gas in the following manner:

- **50% LEL** - Sensor must respond within 10 seconds (CSA* only)
- **60% LEL** - Sensor must respond within 12 seconds (ISA* only)
- **90% LEL** - Sensor must respond within 30 seconds (CSA and ISA)

** Refer to the glossary for an explanation of this term*

LIMITING EXPOSURE TO HAZARDOUS ATMOSPHERES

TLV - THRESHOLD LIMIT VALUES

Threshold limit values are established by the ACGIH (American Conference of Governmental Industrial Hygienists). They are the level to which a worker can be exposed to a chemical each day for a working lifetime without adverse health concerns. These limits are guidelines and not regulated by law.

STEL - SHORT TERM EXPOSURE LIMIT

Short term exposure limit is defined by ACGIH as the concentration to which workers can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage, or narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue, or reduce work efficiency.

PEL - PERMISSIBLE EXPOSURE LEVEL

Permissible exposure levels are the maximum concentration a worker may be exposed to as defined by Occupational Safety and Health Administration (OSHA). PEL's are defined in two ways, TWA and C.

TWA - TIME WEIGHTED AVERAGE

Time weighted average is an average value of exposure over the course of an eight hour work shift.

C - CEILING LEVEL

Ceiling level is an exposure limit that must never be exceeded.

** The terms used and agencies identified here refer typically to the American market; however, the same general intent is made worldwide through each country's governing body over occupational health and safety.*

COMBUSTIBLE GAS REFERENCE GUIDE

HOW TO USE THIS TABLE:

Combustible Gas: Common name of combustible gases. Note that some gases can be known by multiple names.

Chemical Formula: Formula showing the atomic composition of the gas.

CAS Number: American Chemical Society's identification number for each gas. Useful when a gas has more than one name.

Relative Density Air = 1: Ratio of the density of gas compared with ambient atmosphere. > 1.0 indicates the gas is heavier than air.

Ignition Temp °C: Temperature at which the gas is capable of self combustion.

Boiling Point °C: Temperature at which the compound changes from a liquid to a gas.

Flash Point °C: Temperature at which liquid emits a vapor to form an ignitable mixture in air.

%LEL / %UEL: % of atmosphere concentration when the gas reaches its Upper or Lower Explosive Limit.

Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp °C	Boiling Point °C	Flash Point °C	%LEL	%UEL
n-Butanol	$CH_3(CH_2)_2CH_3OH$	71-36-3	2.55	359	116	29	1.7	12
1-Butene	$CH_2=CHCH_2CH_3$	106-98-9	1.95	449	-6.3	—	1.6	10
2-Butene	$CH_3CH=CHCH_3$	107-01-7	1.94	325	1	Gas	1.6	10
Butyl Acetate	$CH_3COOCH_2(CH_2)_2CH_3$	123-86-4	4.01	370	127	22	1.3	7.5
n-Butyl Acrylate	$CH_2=CHCOOC_4H_9$	141-32-2	4.41	268	145	38	1.2	8

NOTES:

All data is provided as a reference only. Refer to local authority such as NIOSH, ACGIH, OSHA, CCOHS, and others for current published values.

—Indicates data has not been evaluated.

Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp. °C	Boiling Point °C	Flash Point °C	% LEL	% UEL
Acetaldehyde	CH_3CHO	75-07-0	1.52	204	20	-38	4	60
Acetic Acid	CH_3COOH	64-19-7	2.07	464	118	40	4	17
Acetic Anhydride	$(CH_3CO)_2O$	108-24-7	3.52	334	140	49	2	10
Acetone	$(CH_3)_2CO$	67-64-1	2	535	56	< -20	2.5	13
Acetonitrile	CH_3CN	75-05-8	1.42	523	82	2	3	16
Acetyl Chloride	CH_3COCl	75-36-5	2.7	390	51	-4	5	19
Acetyl Fluoride	CH_3COF	557-99-3	2.14	434	20	< -17	5.6	19.9
Acetylacetone	$(CH_3CH_2)_2CO$	96-22-0	3	445	101.5	12	1.6	—
Acetylene	CH=CH	74-86-2	0.9	305	-84	—	2.3	100
Acetylpropyl Chloride	$CH_3CO(CH_2)_3Cl$	5891-21-4	4.16	440	71	61	2	10.4
Acrylaldehyde	$CH_2{=}CHCHO$	107-02-8	1.93	217	53	-18	2.85	31.8
Acrylic Acid	$CH_2{=}CHCOOH$	79-10-7	2.48	406	139	56	2.9	8
Acrylonitrile	$CH_2{=}CHCN$	107-13-1	1.83	480	77	-5	3.05	17
Acryloyl Chloride	$CH_2CHCOCl$	814-68-6	3.12	463	72	-8	2.68	18
Allyl Acetate	$CH_2{=}CHCH_2OOCCH_3$	591-87-7	3.45	348	103	13	1.7	9.3
Allyl Alcohol	$CH_2{=}CHCH_2CH$	107-18-6	2	378	96	21	2.5	18
Allyl Chloride	$CH_2{=}CHCH_2Cl$	107-05-1	2.64	390	45	-32	2.9	11.2
Ammonia	NH_3	7664-41-7	0.59	630	-33	—	15	33.6
Amyl Alcohol	$CH_3(CH_2)_3CH_2OH$	71-41-0	3.03	298	136	38	1.06	10.5
Tert-Amyl Methyl Ether (TAME)	$(CH_3)_2C(OCH_3)CH_2CH_3$	994-05-8	3.5	345	85	< -14	1.5	—
Aniline	$C_6H_6NH_2$	62-53-3	3.22	630	184	75	1.2	11
Benzaldehyde	C_6H_5CHO	100-52-7	3.66	192	179	64	1.4	8.5
Benzene	C_6H_6	71-43-2	2.7	560	80	-11	1.2	7.8
Benzyl Chloride	$C_6H_5CH_2Cl$	100-44-7	4.36	585	179	60	1.2	7.1
Bromoethane	CH_3CH_2Br	74-96-4	3.75	511	38	< -20	6.7	11.3
Butadiene	$CH_2{=}CHCH{=}CH_2$	106-99-0	1.87	430	-4.5	-76	2	12
Butane	C_4H_{10}	106-97-8	2.05	372	-1	—	1.9	8.5

Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp. °C	Boiling Point °C	Flash Point °C	% LEL	% UEL
n-Butanol	$CH_3(CH_2)_2CH_2OH$	71-36-3	2.55	359	116	29	1.7	12
1-Butene	$CH_2{=}CHCH_2CH_3$	106-98-9	1.95	440	-6.3	—	1.6	10
2-Butene	$CH_2CH{=}CHCH_3$	107-01-7	1.94	325	1	Gas	1.6	10
Butyl Acetate	$CH_3COOCH_2(CH_2)_2CH_3$	123-86-4	4.01	370	127	22	1.3	7.5
n-Butyl Acrylate	$CH_2{=}CHCOOC_4H_9$	141-32-2	4.41	268	145	38	1.2	8
n-Butyl Bromide	$CH_3(CH_2)_2CH_2Br$	109-65-9	4.72	265	102	13	2.5	6.6
Tert-Butyl Methyl Ether	$CH_3OC(CH_3)_2$	1634-04-4	3.03	385	55	-27	1.5	8.4
Butylamine	$CH_3(CH_2)_3NH_2$	109-73-9	2.52	312	78	-12	1.7	9.8
Butylmethacrylate	$CH_2{=}C(CH_3)COO(CH_2)_3CH_3$	97-88-1	4.9	289	160	53	1	6.8
n-Butylpropionate	$C_2H_5COOC_4H_9$	590-01-2	4.48	389	145	40	1.1	7.7
Butylraldhyde	$CH_3CH_2CH_2CHO$	123-72-8	2.48	191	75	-16	1.8	12.5
Carbon Disulfide	CS_2	75-15-0	2.64	95	46	-30	0.6	60
Carbon Monoxide	CO	630-08-0	0.97	805	-191	—	10.9	74
Carbonyl Sulfide	COS	463-58-1	2.07	209	-50	—	6.5	28.5
Chlorobenzene	C_6H_5Cl	108-90-7	3.88	637	132	28	1.4	11
1-Chlorobutane	$CH_3(CH_2)_2CH_2Cl$	109-69-3	3.2	250	78	-12	1.8	10
2-Chlorobutane	$CH_3CHClC_2H_5$	78-86-4	3.19	368	68	< -18	2.2	8.8
Chloroethane	CH_3CH_2Cl	75-00-3	2.22	510	12	—	3.6	15.4
2-Chloroethanol	CH_2ClCH_2OH	107-07-3	2.78	425	129	55	5	16
Chloroethylene	$CH_2{=}CHCl$	75-01-4	2.15	415	-15	-78	3.6	33
Chloromethane	CH_3Cl	74-87-3	1.78	625	-24	-24	7.6	19
1-Chloropropane	$CH_3CH_2CH_2Cl$	540-54-5	2.7	520	37	-32	2.4	11.1
2-Chloropropane	$(CH_3)_2CHCl$	75-29-6	2.7	590	47	< -20	2.8	10.7
Chlorotrifluoroethylene	$CF_2{=}CFCl$	79-38-9	4.01	607	-28.4	Gas	4.6	84.3
Cresols	$CH_3C_5H_4OH$	1319-77-3	3.73	555	191	81	1.1	1.4
Crotonaldehyde	$CH_3CH{=}CHCHO$	123-73-9	2.41	280	102	13	2.1	16
Cumene	$C_6H_5CH(CH_3)_2$	98-82-8	4.13	424	152	31	0.8	6.5

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Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp. °C	Boiling Point °C	Flash Point °C	% LEL	% UEL
Cyclobutane	C_4H_8	287-23-0	1.93	427	13	-63.9	1.8	11.1
Cycloheptane	C_7H_{14}	291-64-5	3.39	—	118.5	< 10	1.1	6.7
Cyclohexane	C_6H_{12}	110-82-7	2.9	259	81	-18	1.3	8
Cyclohexanol	$C_6H_{11}OH$	108-93-0	3.45	300	161	61	1.2	11.1
Cyclohexanone	$C_5H_{10}CO$	108-94-1	3.38	419	156	43	1	9.4
Cyclohexene	C_6H_{10}	110-83-8	2.83	244	83	-17	1.2	7.8
Cyclohexylamine	$C_6H_{11}NH_2$	108-91-8	3.42	293	134	32	1.6	9.4
Cyclopentane	C_5H_{10}	287-92-3	2.4	320	50	-37	1.4	9
Cyclopentene	C_5H_8	142-29-0	2.3	309	44	< -22	1.48	—
Cyclopropane	C_3H_6	75-719-4	1.45	498	-33	-94.4	2.4	10.4
Cyclopropyl Methyl Ketone	$C_3H_5COCH_3$	765-43-5	2.9	452	114	15	1.7	—
p-Cymene	$CH_3(C_6H_4)CH(CH_3)_2$	99-87-6	4.62	436	176	47	0.7	6.5
trans-Decahydronaphthalene	$CH_2(CH_2)_3CHCH(CH_2)_3CH_2$	493-02-7	4.76	288	185	54	0.7	4.9
Decane	$C_{10}H_{22}$	124-18-5	4.9	201	173	46	0.7	5.6
Diacetone Alcohol	$CH_3COCH_2C(CH_3)_2OH$	123-42-2	4	680	166	58	1.8	6.9
Dibutyl Ether	$(CH_3(CH_2)_3)_2O$	142-96-1	4.48	198	141	25	0.9	8.5
Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	5.07	648	179	86	2.2	9.2
1,1-Dichlorethane	CH_3CHCl_2	75-34-3	3.42	440	57	-10	5.6	16
1,2-Dichlorethane	CH_2ClCH_2Cl	107-06-2	3.42	438	84	13	6.2	16
Dichlorodiethylsilane	$(C_2H_5)_2SiCl_2$	1719-53-5	1.05	255	128	24	3.4	—
Dichloroethylene	$ClCH{=}CHCl$	540-59-0	3.55	440	37	-10	9.7	12.8
1,2-Dichloropropane	$CH_3CHClCH_2Cl$	78-87-5	3.9	557	96	15	3.4	14.5
Dicyclopentadiene	$C_{10}H_{12}$	77-73-6	4.55	455	170	36	0.8	6.3
Diethyl Ether	$(C_2H_5)_2O$	60-29-7	2.55	160	34	-45	1.9	36
Diethylamine	$(C_2H_5)_2NH$	109-86-7	2.53	312	55	-23	1.7	10
Diethylcarbonate	$(C_2H_5CO)_2O$	105-58-8	4.07	450	126	24	1.4	11.7
1,1-Difluoroethylene	$CH_2{=}CF_2$	75-38-7	2.21	380	-83	—	3.9	25.1

Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp. °C	Boiling Point °C	Flash Point °C	% LEL	% UEL
Diisobutyl Carbinol	$((CH_3)_2CHCH_2)_2CHOH$	108-82-7	4.97	290	178	75	0.7	6.1
Diisobutylamine	$((CH_3)_2CHCH_2)_2NH$	110-96-3	4.45	256	137	26	0.8	3.6
Diisopentyl Ether	$(CH_3)_2CH(CH_2)_2O(CH_2)_2CH(CH_3)_2$	544-01-4	5.45	185	170	44	1.27	—
Diisopropyl Ether	$((CH_3)_2CH)_2O$	108-20-3	3.52	405	69	-28	1	21
Diisopropylamine	$((CH_3)_2CH)_2NH$	108-18-9	3.48	285	84	-20	1.2	8.3
Dimethoxymethane	$CH_2(OCH_3)_2$	109-87-5	2.6	247	41	-21	3	16.9
Dimethyl Ether	$(CH_3)_2O(CH_3)_2NH$	124-40-3	1.55	400	7	-18	2.8	14.4
Dimethylaminopropiononitrile	$(CH_3)_2NHCH_2CH_2CN$	1738-25-6	3.38	317	171	50	1.57	—
N,N-Dimethylformamide	$HCON(CH_3)_2$	68-12-2	2.51	440	152	58	1.8	16
1,4-Dioxane	$OCH_2CH_2OCH_2CH_2$	123-91-1	3.03	379	101	11	1.9	22.5
1,3-Dioxolane	$OCH_2CH_2OCH_2$	646-06-0	2.55	245	74	-5	2.3	30.5
Dipropylamine	$(C_3H_7)_2NH$	142-84-7	3.48	280	105	4	1.6	9.1
Epichlorohydrin	OCH_2CHCH_2Cl	106-89-8	3.3	385	115	28	2.3	34.4
Ethane	C_2H_6	74-84-0	1.04	515	-87	-135	3	12.5
Ethyl Mercaptan	C_2H_5SH	75-08-1	2.11	295	35	< -20	2.8	18
Ethanol	C_2H_5OH	64-17-5	1.59	363	78	12	3.3	19
2-Ethoxyethanol	$CH_3CH_2OCH_2CH_2OH$	110-80-5	3.1	235	135	40	1.8	15.7
2-Ethoxyethylacetate	$CH_3COOCH_2CH_2OCH_2CH_3$	111-15-9	4.72	380	156	47	1.2	12.7
Ethyl Acetate	$CH_3COOC_2H_5$	141-78-6	3.04	460	77	-4	2.2	11
Ethyl Acetoacetate	$CH_3COCH_2COOC_2H_5$	141-97-9	4.5	350	181	65	1	9.5
Ethyl Acrylate	$CH_2=CHCOOC_2H_5$	140-88-5	3.45	350	100	9	1.4	14
Ethyl Butyrate	$CH_3CH_2CH_2COOC_2H_5$	105-54-4	4	435	120	21	1.4	—
Ethyl Formate	$HCOOC_2H$	109-94-4	2.65	440	52	-20	2.7	16.5
Ethyl Isobutyrate	$(CH_3)_2CHCOOC_2H_5$	97-62-1	4	438	112	10	1.6	7.8

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Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp. °C	Boiling Point °C	Flash Point °C	% LEL	% UEL
Ethyl Methacrylate	$CH_2{=}C(CH_3)COOC_2H_5$	97-62-2	3.9	393	118	20	1.5	2.5
Ethyl Methyl Ether	$C_2H_5\text{-}O\text{-}CH_3$	540-67-0	2.1	190	8	—	2	10.1
Ethyl Nitrate	$C_2H_5ONO_2$	109-95-5	2.6	95	18	-35	3	50
Ethylene Oxide	CH_2CH_2O	75-21-8	1.52	435	11	< -18	3	100
Ethylamine	$C_2H_5NH_2$	75-04-7	1.5	425	16.6	< -20	2.68	14
Ethylbenzene	$C_2H_5\text{-}C_6H_5$	100-41-4	3.66	431	135	23	1	7.8
Ethylcyclobutane	$CH_2CH_2CH_2CH\text{-}C_2H_5$	4806-61-5	2.9	212	71	< -16	1.2	7.7
Ethylcyclohexane	$(CH_2)_5CH\text{-}C_2H_5$	1678-91-7	3.87	238	131	< 24	0.9	6.6
Ethylcyclopentane	$(CH_2)_4CH\text{-}C_2H_5$	1640-89-7	3.4	262	103	< 5	1.05	6.8
Ethylene	$CH_2{=}CH_2$	74-85-1	0.97	425	-104	—	2.7	36
Ethylenediamine	$NH_2CH_2CH_2NH_2$	107-15-3	2.07	403	118	34	2.7	16.5
Formaldehyde	HCHO	50-00-0	1.03	424	-19	—	7	73
Formic Acid	HCOOH	64-18-6	1.6	520	101	42	10	57
2-Furaldehyde	OCH=CHCH=CHCHO	98-01-1	3.3	316	162	60	2.1	19.3
Furan	CH=CHCH=CHO	110-00-9	2.3	390	32	< -20	2.3	14.3
Furfuryl Alcohol	$OC(CH_2OH)CHCHCH$	98-00-0	3.38	370	170	61	1.8	16.3
Heptane	C_7H_{16}	142-82-5	3.46	215	98	-4	1.1	6.7
Hexane	C_6H_{14}	110-54-3	2.97	233	69	-21	1.1	7.5
Hexyl Alcohol	$C_6H_{13}OH$	111-27-3	3.5	293	156	63	1.2	8
Hydrogen	H_2	1333-74-0	0.07	560	-253	—	4	77
Hydrogen Cyanide	HCN	74-90-8	0.9	538	26	< -20	5.4	46
Hydrogen Sulfide	H_2S	7783-06-4	1.19	270	-60	-82	4	45.5
Isobutane	$(CH_3)_2CHCH_3$	75-28-5	2	460	-12	Gas	1.3	9.8
Isobutyl Alcohol	$(CH_3)_2CHCH_2OH$	78-83-1	2.55	408	108	28	1.7	10.6
Isobutyl Chloride	$(CH_3)_3CHCH_2Cl$	513-36-0	3.19	416	68	< -14	2	8.6
Isobutylamine	$(CH_3)_2CHCH_2NH_2$	78-81-9	2.52	374	64	-20	1.47	10.8
Isobutylene	$(CH_3)_2C{=}CH_2$	115-11-7	1.93	483	-6.9	-80	1.6	10

Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp. °C	Boiling Point °C	Flash Point °C	% LEL	% UEL
Isobutylisobutyrate	$(CH_3)_2CHCOOH_2CH(CH_3)_2$	97-85-8	4.93	424	145	34	0.8	10.5
Isobutyraldhyde	$(CH_3)_2CHCHO$	78-84-2	2.48	176	63	-22	1.6	11
Isodihydrolavandulyl Aldehyde	$C_{10}H_{18}O$	35158-25-9	5.31	188	189	41	3.05	—
Isopropyl Acetate	$CH_3COOCH(CH_3)_2$	18-21-4	3.51	467	85	4	1.8	8.1
Isopropyl Alcohol	$(CH_3)_2CHOH$	67-63-0	2.07	425	83	12	2	12.7
Isopropyl Chloroacetate	$ClCH_2COOCH(CH_3)_2$	105-48-6	4.71	426	149	42	1.6	—
Isopropyl Nitrate	$(CH_3)_2CHONO_2$	1712-64-7	0.86	175	101	11	2	100
Isopropylamine	$(CH_3)_2CHNH_2$	75-31-0	2.03	340	33	< -24	2.3	8.6
Isovaleraldehyde	$(CH_3)_2CHCH_2CHO$	590-86-3	2.97	207	90	-12	1.7	—
Kerosene (Major Component of Jet Fuel)	—	8008-20-6	4.5	210	150	38	0.7	5
Mesityl Oxide	$(CH_3)_2(CCHCOCH)_3$	141-79-7	3.78	306	129	24	1.6	7.2
Methacryloyl Chloride	CH_2CCH_3COCl	920-46-7	3.6	510	95	17	2.5	—
Methallyl Chloride	$CH_2{=}C(CH_3)CH_2Cl$	563-47-3	3.12	478	71	-16	2.1	9.3
Methane	CH_4	74-82-8	0.55	537	-161	-188	5	15
Methanol	CH_3OH	67-56-1	1.11	386	65	11	6	36
2-Methoxyethanol	$CH_3OC_2H_4OH$	109-86-4	2.63	285	124	39	2.4	20.6
Methyl Acetate	CH_3COOCH_3	79-20-9	2.56	502	57	-10	3.2	16
Methyl Acetoacetate	$CH_3COOCH_2COCH_3$	105-45-3	4	280	169	62	1.3	14.2
Methyl Acrylate	$CH_2{=}CHCOOCH_3$	96-33-3	3	415	80	-3	2.4	25
Methyl Butyl Ketone (MBK)	$CH_3CO(CH_2)_3CH_3$	591-78-6	3.46	533	127	23	1.2	8
Methyl Chlorformate	CH_3OOCC	79-22-1	3.3	475	70	10	7.5	26
Methyl Ethyl Ketone (MEK)	$CH_3COC_2H_5$	78-93-3	2.48	404	80	-9	1.4	11.4
Methyl Formate	$HCOOCH_3$	107-31-3	2.07	450	32	-20	5	23
Methyl Isobutyl Carbinol (MIBC)	$(CH_3)_2CHCH_2CHOHCH_3$	108-11-2	3.5	334	132	37	1.14	5.5
Methyl Isobutyl Ketone (MIBK)	$(CH_3)_2CHCH_2COCH_3$	108-10-1	3.45	475	117	16	1.2	8
Methyl Mercaptan	CH_3SH	74-93-1	1.6	340	6	-18	4.1	21
Methyl Methacrylate	$CH_2{=}C(CH_3)COOCH_3$	80-62-6	3.45	430	100	10	1.7	12.5

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Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp. °C	Boiling Point °C	Flash Point °C	% LEL	% UEL
α-Methyl Styrene	$C_6H_5C(CH_3)=CH_2$	98-83-9	4.08	445	165	40	0.9	6.6
Methylamine	CH_3NH_2	74-89-5	1	430	-6	-18	4.2	20.7
2-Methylbutane	$(CH_3)_2CHCH_2CH_3$	78-78-4	2.5	420	30	< -51	1.3	8
2-Methylbutanol	$CH_3CH_2C(OH)(CH_3)_2$	75-84-4	3.03	392	102	16	1.4	10.2
3-Methylbutanol	$(CH_3)_2CH(CH_2)_2OH$	123-51-3	3.03	339	130	42	1.3	10.5
2-Methylbutene	$(CH_3)_2C=CHCH_3$	513-35-9	2.4	290	35	-53	1.3	6.6
2-Methylbutenyne	$HC{=}CC(CH_3)CH_2$	78-80-8	2.28	272	32	-54	1.4	—
Methylcyclohexane	$CH_3CH(CH_2)_4CH_2$	108-87-2	3.38	258	101	-4	1.16	6.7
Methylcyclopentadiene	C_6H_6	26519-91-5	2.76	432	—	< -18	1.3	7.6
Methylcyclopentane	$CH_3CH(CH_2)_4$	96-37-7	2.9	258	72	< -10	1	8.4
Methylenecyclobutane	$C(=CH_2)CH_2CH_2CH_2$	1120-56-5	2.35	352	41	< 0	1.25	8.6
2-Methylfuranl	$OC(CH_3)CHCHCH$	534-22-5	2.83	318	63	< -16	1.4	9.7
Methylisocyanate	CH_3NCO	624-83-9	1.98	517	37	-7	5.3	26
2-Methylpentenal	$CH_3CH_2CHC(CH_3)COH$	623-69-9	3.78	206	137	30	1.46	—
2-Methylpyridine	$NCH(CH_3)CHCHCHCH$	109-06-8	3.21	533	128	27	1.2	8.6
3-Methylpyridine	$NCHCH(CH_3)CHCHCH$	108-99-6	3.21	537	144	43	1.4	8.1
4-Methylpyridine	$NCHCHCH(CH_3)CHCH$	108-89-4	3.21	534	145	43	1.1	7.8
Methylthiophene	$SC(CH_3)CHCHCHC$	554-14-3	3.4	433	113	-1	1.3	6.5
Morpholine	$OCH_2CH_2NHCH_2CH_2$	110-91-8	3	230	129	31	1.8	15.2
Naphthalene	$C_{10}H_8$	91-20-3	4.42	528	218	77	0.9	5.9
Nitrobenzene	$C_6H_5NO_2$	98-95-3	4.25	480	211	88	1.7	40
Nitroethane	$C_2H_5NO_2$	79-24-3	2.58	410	114	27	3.4	—
Nitromethane	CH_3NO_2	75-52-5	2.11	415	102.2	36	7.3	63
1-Nitropropane	$CH_3CH_2CH_2NO_2$	108-03-2	3.1	420	131	36	2.2	—
Nonane	C_9H_{20}	111-84-2	4.43	205	151	30	0.7	5.6
Octane	C_8H_{18}	111-65-9	3.93	206	126	13	0.8	6.5
1-Octanol	$CH_3(CH_2)_6CH_2OH$	111-87-5	4.5	270	196	81	0.9	7.4

Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp. °C	Boiling Point °C	Flash Point °C	% LEL	% UEL
Paraldehyde	$OCH(CH_3)OCH(CH_3)OCH(CH_3)$	123-63-7	4.56	235	123	27	1.3	17
Pentane-2,4-dione	$CH_3COCH_2COCH_3$	123-54-6	3.5	340	140	34	1.7	—
Pentane	C_5H_{12}	109-66-0	2.48	258	36	-40	1.4	7.8
Pentyl Acetate	$CH_3COO\text{-}(CH_2)_4\text{-}CH_3$	628-63-7	4.48	360	147	25	1	7.1
Petroleum	—	—	2.8	560	—	< -20	1.2	8
Petroleum Ether (Naptha)	—	8030-30-6	2.5	290	35-80	< -18	0.9	6
Phenol	C_6H_5OH	108-95-2	3.24	595	182	75	1.3	9.5
Piperylene	$CH_2=CH\text{-}CH=CH\text{-}CH_3$	504-60-9	2.34	361	42	< -31	1.2	9.4
Propane	C_3H_8	74-98-6	1.56	470	-42	-104	2.1	9.5
Propargyl Alcohol	$HC=CCH_2OH$	107-19-7	1.89	346	114	33	2.4	—
Propene	$CH_2=CHCH_3$	115-07-1	1.5	455	-48	-108	2	11
Propionic Acid	CH_3CH_2COOH	79-09-4	2.55	435	141	52	2.1	12
Propionic Aldehyde	C_2H_5CHO	123-38-6	2	188	46	< -26	2	—
Propyl Acetate	$CH_3COOCH_2CH_2CH_3$	109-60-4	3.6	430	102	10	1.7	8
Propyl Alcohol	$CH_3CH_2CH_2OH$	71-23-8	2.07	405	97	22	2.2	17.5
Propylamine	$CH_3(CH_2)_2NH_2$	107-10-8	2.04	318	48	-37	2	10.4
Propyne	$CH_3C=CH$	74-99-7	1.38	—	-23.2	-51	1.7	16.8
Pyridine	C_5H_5N	110-86-1	2.73	550	115	17	1.7	12
R-1123	$CF_2=CFH$	359-11-5	1.26	319	-57	—	15.3	27
R-143a	CF_3CH_3	420-46-2	1.30	714	-47.6	—	6.8	17.6
Styrene	$C_6H_5CH=CH_2$	100-42-5	3.6	490	145	30	1.1	8
Tetrahydrofuran	$CH_2(CH_2)_2CH_2O$	109-99-9	2.49	224	64	-20	1.5	12.4
Tetrafluoroethylene	$CF_2=CF_2$	116-14-3	3.4	255	-76.6	—	10	59
2,2,3,3,-Tetrafluoropropyl Methacrylate	$CH_2=C(CH_2)COOCH_2CF_2CF_2H$	45102-52-1	6.9	389	124	46	1.9	—
2,2,3,3,-Tetrafluoro Propylacrylate	$CH_2=CHCOOCH_2CF_2CF_2H$	7383-71-3	6.41	357	132	45	2.4	—
Tetrahydrofurfuryl Alcohol	$OCH_2CH_2CH_2CHCH_2OH$	97-99-4	3.52	280	178	70	1.5	9.7
Tetrahydrothiophene	$CH_2(CH_2)_2CH_2S$	110-01-0	3.04	200	119	13	1.1	12.3

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Combustible Gas	Chemical Formula	CAS Number	Relative Density Air = 1	Ignition Temp. °C	Boiling Point °C	Flash Point °C	% LEL	% UEL
N,N,N',N',-Tetramethyldiaminomethane	$(CH_3)_2NCH_2N(CH_3)_2$	51-80-9	3.5	180	85	< -13	1.61	—
Thiophene	CH=CHCH=CHS	110-02-1	2.9	395	84	-9	1.5	12.5
Toluene	$C_6H_5CH_3$	108-88-3	3.2	535	111	4	1.1	7.1
Triethylamine	$(C_2H_5)_3N$	121-44-8	1.2	294	89	-7	1.2	8
Trifluoroethanol	CF_3CH_2OH	75-89-8	1.38	463	77	30	8.4	28.8
3,3,3-Trifluoropropene	$CF_3CH{=}CH_2$	677-21-4	3.3	490	-16	—	4.7	13.5
Trimethylamine	$(CH_3)_3N$	75-50-3	1.6	190	3	-6	2	12
1,2,3-Trimethylbenzene	$CHCHCHC(CH_3)C(CH_3)C(CH_3)$	526-73-8	4.15	470	175	51	0.8	7
1,3,5-Trimethylbenzene	$CHC(CH_3)CHC(CH_3)CHC(CH_3)$	108-67-8	4.15	499	163	44	0.8	7.3
2,2,4-Trimethylpentane	$(CH_3)_2CHCH_2C(CH_3)_3$	540-84-1	3.9	411	98	-12	1	6
1,3,5-Trioxane	$OCH_2OCH_2OCH_2$	110-88-3	3.11	410	115	45	3.2	29
Turpentine	$\sim C_{10}H_{16}$	—	1.01	254	149	35	0.8	—
Vinyl Acetate	$CH_3COOCH{=}CH_2$	108-05-4	3	425	72	-8	2.6	13.4
Vinyl Cyclohexane	$CH_2CHC_6H_9$	100-40-3	3.72	257	126	15	0.8	—
Vinylidene Chloride	$CH_2{=}CCl_2$	75-35-4	3.4	440	30	-18	7.3	16
2-Vinylpyridine	$NC(CH_2{=}CH)CHCHCHCH$	100-69-6	3.62	482	79	35	1.2	—
4-Vinylpyridine	$NCHCHC(CH_2{=}CH)CHCH$	100-43-6	3.62	501	62	43	1.1	—
Xylene	$C_6H_4(CH_3)_2$	1330-20-7	3.66	464	144	30	1	7

TOXIC GAS REFERENCE GUIDE

HOW TO USE THIS TABLE:

- **Toxic Gas**: Common name of toxic gases. Note that some gases can be known by multiple names.
- **Chemical Formula**: Formula showing the atomic composition of the gas.
- **CAS Number**: American Chemical Society's identification number for each gas. Useful when a gas has more than one name.
- **Relative Density Air = 1**: Ratio of the density of gas compared with ambient atmosphere. > 1.0 indicates the gas is heavier than air.
- **TLV (PPM)**: Threshold limit value as established by the ACGIH.
- **STEL (PPM)**: Short term exposure limit as established by EH40/2005.
- **PEL (PPM)**: Permissible exposure limit as established by OSHA.
- **IDLH (PPM)**: Immediately dangerous to life or health level of exposure.
- **Odor Threshold (PPM)**: The lowest airborne concentration that can be detected by smell.

Toxic Gas	Chemical Formula	CAS Number	Relative Density Air = 1	TLV (PPM)	STEL (PPM)	PEL (PPM)	IDLH (PPM)	Odor Threshold (PPM)
Boron Trifluoride	BF_3	7637-07-2	2.18	1*	—	1 (C)	25	1.5
Bromine	Br_2	7726-95-6	0.6	0.10	0.20	0.10	3	0.066
Carbon Dioxide	CO_2	124-38-9	1.5	5,000	30,000	5,000	40,000	74,000
Carbon Disulfide	CS_2	75-15-0	2.6	10	—	20	500	0.096
Carbon Monoxide	CO	630-08-0	1.0	25	—	50	1200	100,000

NOTES:

All data is provided as a reference only. Refer to local authority such as NIOSH, ACGIH, OSHA, CCOHS, and others for current published values.

— Indicates data has not been evaluated.

"C" Indicates ceiling level value.

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Toxic Gas	Chemical Formula	CAS Number	Relative Density Air = 1	TLV (PPM)	STEL (PPM)	PEL (PPM)	IDLH (PPM)	Odor Threshold (PPM)
Ammonia	NH_3	7664-41-7	0.6	25	35	50	300	5.75
Arsine	AsH_3	7784-24-1	2.7	0.05	—	0.05	3	< 1.0
Benzene	C_6H_6	71-43-2	0.88	0.5	2.5	—	500	8.65
Boron Trichloride	BCl_3	10294-34-5	4.1	—	—	—	—	—
Boron Triflouride	BF_3	7637-07-2	2.18	1	—	1 (C)	25	1.5
Bromine	Br_2	7726-95-6	0.6	0.10	0.20	0.10	3	0.066
Carbon Dioxide	CO_2	124-38-9	1.5	5,000	30,000	5,000	40,000	74,000
Carbon Disulfide	CS_2	75-15-0	2.6	10	—	20	500	—
Carbon Monoxide	CO	630-08-0	1.0	25	—	50	1200	100,000
Carbonyl Sulfide	COS	463-58-1	2.1	—	—	—	2	—
Chlorine	Cl_2	7782-50-5	2.5	0.5	1.0	1.0	10	0.05
Chlorine Dioxide	ClO_2	10049-04-4	2.3	0.1	0.3	0.1	5	9.24
Cyanogen Chloride	CNCl	506-77-4	2.1	0.3	0.3	0.3	—	0.976
Diborane	B_2H_6	19287-45-7	2.9	0.10	—	0.10	15	1.8 - 3.5
Dichlorosilane	SiH_4Cl_2	4109-96-0	3.5	—	—	—	—	—
Dimethyl Amine (DMA)	C_2H_7N	124-40-3	0.7	5	6	10	500	0.081
Disilane	Si_2H_6	1590-87-0	2.1	—	—	—	—	—
Ethylene Oxide	CH_2OCH_2	75-21-8	1.5	1.0	—	1.0	800	851

Toxic Gas	Chemical Formula	CAS Number	Relative Density Air = 1	TLV (PPM)	STEL (PPM)	PEL (PPM)	IDLH (PPM)	Odor Threshold (PPM)
Fluorine	F_2	7782-41-4	1.3	1.0	2.0	0.1	25	0.126
Formaldehyde	CH_2O	—	—	0.3	—	—	20	0.871
Germane	GeH_4	7782-65-2	2.7	0.2	—	—	—	—
Hydrazine	N_2H_4	302-01-2	1.1	0.0	—	1.0	50	3.6
Hydrogen Bromide	HBr	10035-10-6	2.8	—	3 (C)	3.00	3	1.99
Hydrogen Chloride	HCl	7647-01-0	1.3	—	5 (C)	5 (C)	50	0.77
Hydrogen Cyanide	HCN	74-90-8	0.9	—	4.7 (C)	10.00	50	0.603
Hydrogen Fluoride	HF	7664-39-3	0.7	3	3 (C)	3	30	0.036
Hydrogen Iodide	HI	10034-85-2	4.5	—	—	—	—	—
Hydrogen Peroxide	H_2O_2	7722-84-1	1.2	1.0	—	1.00	75	—
Hydrogen Selenide	H_2Se	7783-07-5	2.8	0.05	—	0.05	100	0.3
Hydrogen Sulfide	H_2S	7783-06-4	1.2	1	5	20 (C)	100	0.0005
Methanol	CH_3OH	67-56-1	0.8	200	250	200	25,000	—
Methyl Iodide	CH_3I	74-88-4	2.9	2	2	5	100	—
Methyl Mercaptan	CH_3SH	74-93-1	0.9	—	—	10 (C)	150	0.001
Monomethyl	$CH_3(NH)NH_2$	60-34-4	1.6	0.01	—	0.2	50	1.71
Nitric Acid	HNO_3	7697-37-2	1.4	2	4	2	25	0.267
Nitric Oxide	NO	10102-43-9	1.0	25.0	—	25.00	100	—

Toxic Gas	Chemical Formula	CAS Number	Relative Density Air = 1	TLV (PPM)	STEL (PPM)	PEL (PPM)	IDLH (PPM)	Odor Threshold (PPM)
Nitrogen Dioxide	NO_2	10102-44-0	2.6	3	5	5	20	0.186
Nitrogen Trifluoride	NF_3	7783-54-2	2.4	10	—	10	1000	—
n-Butyl Amine	$CH_3(CH_2)_2CH_2\text{-}NH_2$	109-73-9	0.74	5 (C)	—	5 (C)	300	0.053
Oxygen Deficiency	O_2	—	0.9	—	—	<19.5%	<18%	—
Oxygen Enrichment	O_2	—	0.9	—	—	>23.5%	—	—
Ozone	O_3	10028-15-6	1.7	0.1	—	0.10	5	0.051
Phosgene	$COCl_2$	75-44-5	3.4	0.1	—	0.1	2	0.55
Phosphine	PH_3	7803-51-2	1.2	0.3	1.0	0.30	50	0.14
Propylene Oxide	C_3H_6O	75-56-9	1.6	2	—	100	400	33.1
Silane	SiH_4	7803-62-5	1.3	5	—	—	—	—
Silicon Tetrafluoride	SiF_4	7783-60-0	—	—	—	—	3	—
Stibine	SbH_3	7803-52-3	2.26	0.1	—	0.1	5	—
Sulfur Dioxide	SO_2	7446-09-5	2.3	—	0.25	5	100	0.708
Styrene	$C_6H_5CH{=}CH_2$	100-24-5	3.6	20.0	40	10.00	700	—
Tetraethyl Orthosilicate (TEOS)	$(C_2H_5O)_4Si$	78-10-4	7.2	100	10	10	700	—
Triethylamine (TEA)	$C_6H_{16}N$	121-44-8	1.2	5	4	—	200	0.309
Vinyl Chloride (VCM)	$CH_2{=}CHCl$	75-01-4	2.0	1	—	—	Carcinogen	35.5

SYSTEM ARCHITECTURE AND APPLICATION

The most common applications in hazardous atmosphere monitoring occur with the use of mounted fixed gas detection systems. These systems are set in place to provide continuous monitoring in areas where leaks, ruptures, or releases of hazardous gases are likely to occur whether indoor or outdoor.

THERE ARE SEVERAL FACTORS TO CONSIDER WHEN INSTALLING A FIXED DETECTION SYSTEM. AMONG THE MORE BASIC ONES:

How many monitors are needed to provide adequate protection?

What areas will be monitored locally and which will be monitored from a remote location?

What types of safety measures can be activated should a hazardous situation occur?

Will the environment the sensors are located in affect performance?

Is there sufficient oxygen for the sensor type to respond?

Is the target gas heavier or lighter than air?

Where are the receptor and release* points in the process?*

Is the environment the sensor will be installed in subjected to high traffic or wash downs?

What is the area classification of the location for installation?

Are there other gases present that may react or cause a cross interference with target gases?

** Refer to the glossary for an explanation of this term*

DESIGNING A GAS DETECTION SYSTEM

A fixed gas detection system is a highly customizable application comprised of any number of combinations of point detectors, networked monitoring, automatic response functions, or audible and visual alarms. Each process* that requires gas detection must be carefully evaluated to identify and understand the potential risk factors and what the best potential monitoring and response functions are to reduce those risks. Scott Safety will work with customers to help identify the risks and provide design solutions that maximize value and safety.

Five areas of consideration can help with a system design. Sometimes, a solution is as simple as a single point of detection. More frequently, however, careful evaluation of an overall process yields an opportunity to significantly reduce the risks and hazards of a plant process. These areas are:

1. **UNDERSTAND THE APPLICATION**
2. **IDENTIFY POTENTIAL DANGER POINTS**
3. **ESTABLISH DESIGN GOALS**
4. **DETERMINE GAS CHARACTERISTICS**
5. **PROFILE THE FACILITY**

** Refer to the glossary for an explanation of this term*

UNDERSTAND THE APPLICATION

Legal requirements, local and federal regulations, fire and building codes, and industry safety standards all play a significant role in determining the applicability of minimum safety requirements when monitoring for toxic and combustible hazards in the workplace.

Certain requirements for gas monitoring are based on the physical design and layout of plant processes. Semiconductor facilities, wastewater treatment plants, and natural gas delivery systems all have their own unique requirements for monitoring and automatic response functions to alarms. Physical factors to consider when designing a system include indoor/outdoor use, amount and direction of ventilation, enclosed spaces, possible ignition sources, power availability for installation, receptor points, release points, and whether exposure to other toxic substances may occur.

Workers should only be subjected to certain limits of different types of contaminants. These restricted limits are defined as STEL, TWA, IDLH, and ceiling limits among other factors. Agencies such as NIOSH, ACGIH, OSHA, CCOHS, IOHA* and others set and recommend these levels to protect individuals from exposures to harmful levels of hazardous substances.

Another major consideration in understanding the application is to know the characteristics of the monitored hazardous substances. Gases can be both toxic and combustible; however, the importance of monitoring is to reduce the risk from whichever characteristic is more likely to occur. Carbon monoxide, for example, is a combustible hazard when it reaches a concentration of 12.8% LEL or 128,000 ppm. However the established STEL is 400 ppm and becomes IDLH at only 1200 ppm. In areas where workers can be exposed to carbon monoxide, the appropriate application is to monitor for toxic levels.

** Refer to the glossary for an explanation of this term*

IDENTIFY POTENTIAL DANGER POINTS

Danger points are identified in one of two ways, release points and receptor points.

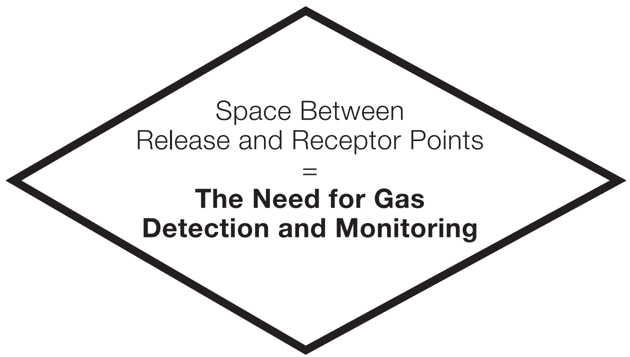
RELEASE POINT - Location where hazardous gases can potentially be released, also referred to as the source

RECEPTOR POINT - Location where hazardous gases cause a threat to personnel, property, or facilities

In general, all areas of a facility where gases are transported, stored, processed, delivered, or utilized are danger points. However, by focusing on the points where the occurrence of gas is most likely to occur, or most likely to pose a danger to people, property, or equipment, a balance of safety and cost can be considered. The areas between release points and receptor points typically have the highest need for gas detection. Scott Safety can assist with identifying the potentially dangerous release points and the most likely receptor points.

COMMON RELEASE POINTS

- Seals, flanges, gaskets, piping manifolds, and valve stems
- Weld-beads
- Liquid and gas storage areas
- Battery rooms
- Sumps, sewers, wastewater treatment areas
- Gas transportation routes
- Semiconductor processing areas



COMMON RECEPTOR POINTS

- Analyzer shelters
- Confined spaces
- Maintenance areas
- Ventilation distribution points
- Personnel facilities
- Pump rooms
- Storage areas
- Fresh air intakes

ESTABLISH DESIGN GOALS

When designing a gas detection system to meet the needs of your process or facility, planners will need to plan the goals, or response functions, of the gas detectors when warning and alarm conditions occur.

RESPONSE FUNCTIONS

NOTIFICATION AND ANNUNCIATION

Warnings and alarms are projected through the use of lights, bells, whistles, buzzers, horns, sirens, or any other method to get the attention of personnel and responders.

VENTILATION CONTROL

Warnings and alarms may trigger automatic ventilation actions to occur. In some instances, ventilation may be secured to control the spread of a gas. Other times, ventilation may be increased to aid in the purging of dangerous gases.

PROCESS SHUTDOWN

Warnings and alarms may trigger both automatic and human initiated process shutdowns ranging from closing flow control valves and manifolds to securing power to equipment to isolating areas.

EVACUATION AND EMERGENCY RESPONSE

Warnings and alarms may trigger human initiated evacuations and automatic notification to emergency responders.

KEY CONSIDERATIONS

HUMAN RESPONSE TIME OF AN ALARM EVENT

Will the detectors be continuously manned or will automatic functions be required?
What are the consequences of not responding quickly?

REDUNDANCY OF DETECTION EQUIPMENT

What are the costs associated with a false alarm?
What zone/voting configurations are required?

MARGIN OF SAFETY

What are the reaction by-products that could occur if one gas mixes with another?
What effects will temperature, humidity, high pressure releases, vapor clouds, and oxygen displacement have on process monitoring?

LEGAL AND REGULATORY REQUIREMENTS

Are all the requirements of local laws, codes, SIL, and other industry standards being met?

** Refer to the glossary for an explanation of this term*

SCOTT SAFETY

DETERMINE GAS CHARACTERISTICS

Simply knowing whether a particular gas needs to be monitored at toxic or combustible levels is not enough. Other factors play just as large a role in determining the optimum locations for points of detection.

VAPOR DENSITY*

Heavier than air gases and vapors tend to sink and accumulate in lower lying areas. They typically will not disperse quickly and may displace oxygen. Sensors for these gases and vapors should be located approximately 18–24" (46–61 cm) above floor level. Lighter than air gases will tend to rise in the atmosphere and sensors should be placed above the release point. It is not uncommon for these sensors to be placed at or near the ceilings of indoor facilities.

GAS RELEASE TEMPERATURES

Temperature and vapor density have an inversely proportionate relationship; that is, as temperature increases the vapor density will decrease and as temperature cools, vapor density will increase. This is important to consider as some heated or cooled gases and vapors will not initially rise or fall as they would if they were at ambient temperatures.

VENTILATION AND AIR CURRENTS

Lighter than air gases may disperse and travel across ventilation and air currents quicker than they would otherwise rise. Consideration may be given to placing sensors near exhaust paths or exhaust ducts to account for this air flow.

RATE OF EVAPORATION

Vapors that evaporate slowly over standing liquids tend to be dense so sensors should be placed closer to liquids or potential spill locations to account for this. Vapors with a higher rate of evaporation can act similar to lighter than air gases and be taken with air currents.

HIGH PRESSURE GASES AND VAPORS

Gases under pressure can tend to emit from a release point as a gas jet. If the physical structure of the release point is such that the jet's path is predictable, sensors should be placed directly in the path of the jet. If the release point does not provide a predictable path, multiple sensors should be utilized around the release point. Gas jets may produce heavy aerosols. Lighter than air vapors and gases will not immediately rise when released under pressure as part of these aerosols.

** Refer to the glossary for an explanation of this term*

PROFILE THE FACILITY

The last consideration that needs to be made is to identify the physical, environmental, and air flow constraints that are in place at the facility where the gas detectors and sensors will be installed. These constraints will be unique to each facility and proper foresight can prevent costly repairs, relocation of equipment, and help to minimize false alarms.

USE IN A HAZARDOUS LOCATION

Not all gas detection equipment is designed equally for use in classified areas. Note the highest zone or division the classified area is and ensure the detection equipment selected is suitable for use in these areas.

INDOOR/OUTDOOR USE

Perhaps the simplest of considerations, and most important to the basic design of a fixed gas detection system is whether the monitors are to be used indoors or outdoors. Outdoor applications present challenges in the number of detectors to be used because gases will rapidly disperse into the atmosphere. Open path* technology can help to lower the number of sensors and increase their effective range, but they will not work for all gases and must have a clear line of sight between the sensor and receiver. Indoor applications that confine a gas release may require lower warning and alarm settings as the concentration of released gas will rise rapidly in an enclosed environment.

PHYSICAL INTERFERENCE

Gas releases will move more rapidly over smooth surfaces such as floors, concrete, water, and grass. Areas where physical barriers such as cabinets, buildings, lockers, piping, and storage tanks exist will change the flow of a released gas, and may confine the gas. Sensors mounted in low lying areas should be kept clear of transportation routes and protected from areas where routine cleaning or precipitation would splash and possibly effect the ability of sensors to function properly.

AIR FLOW

Prevailing winds and humidity levels make a big difference in how the flow of a released gas will disperse in outdoor applications. Gas dispersion models can be used to predict likely release paths and help target the best locations for gas detectors. Indoor applications are effected by the volume of air flow in ventilated areas and whether enclosed areas have exhaust lines. Smoke studies, where a puff of visible smoke is released, can be done to follow the air current and predict the path of a released gas.

** Refer to the glossary for an explanation of this term*

PROFILE THE FACILITY

The last consideration that needs to be made is to identify the physical, environmental, and air flow constraints that are in place at the facility where the gas detectors and sensors will be installed. These constraints will be unique to each facility and proper foresight can prevent costly repairs, relocation of equipment, and help to minimize false alarms.

ENVIRONMENTAL CONDITIONS

All gas detectors have temperature restrictions that effect the environment in which they can be used. Sensor technologies vary in performance from arid to high humidity conditions. Weather shields and other accessories are usually available to help protect gas detection equipment. Filters may help to prevent dust and particulates from interfering with sensor performance.

ACCESSIBILITY OF THE MONITOR AND SENSOR

When mounting a gas detector and the sensor, use foresight and planning to anticipate needing to perform routine calibrations* and sensor replacements. Mounting a sensor in a remote area that is difficult to access can cause problems when routine maintenance needs arise. Similarly, when facility changes and expansions are done, an evaluation should be conducted to verify the mounted gas detectors are still performing as expected and will still be able to be accessed as needed. Sensors should never be painted over.

WIRING AND INSTALLATION

Wiring and installation costs can significantly impact the cost of a well designed gas detection system. Proper planning should occur prior to installation to verify the infrastructure is in place to provide the proper power to each component and account for voltage loss that will occur over long cable runs. Mounting of transmitters* should be done in such a way that meets all applicable building codes and minimizes the effects of any residual vibration from nearby equipment.

EMI* AND RFI*

Electromagnetic and radio frequency interference are legitimate concerns when installing gas detectors. Interference and electrical noise spikes can generate false alarms in equipment. Verify all wiring is properly shielded and encased in suitable conduit. Detectors should always be grounded. Wireless surveys should be done to analyze the suitability of using wireless detectors and sensor heads* as the technology emerges.

** Refer to the glossary for an explanation of this term*

INDUSTRIAL HAZARDS

Combustible hazards
Toxic hazards

Hazardous gas monitoring has a place in most industries worldwide for the safety of personnel, property, and facilities. Fixed and portable detection units can mean the difference in saving lives and preventing costly incidents. Whether it's handling, manufacturing, transporting, processing, or treating potentially hazardous substances, Scott Safety can help customers determine what products can best fit their needs for each necessary application.

PETROCHEMICAL, OIL, AND GAS

Potential activities requiring gas detection:

Refining operations

On/off shore drilling

Compressor stations

Notable gases of interest:

Hydrocarbon gases - Ethane, Methane

Carbon Monoxide, Hydrogen Sulfide, Hydrogen Fluoride

PHARMACEUTICAL

Potential activities requiring gas detection:

Chemical processing

Storage facilities

Volatile emissions

Notable gases of interest:

VOCs*, Methane

Solvents, Silicones, Oxygen, Ethylene Oxide

WASTEWATER TREATMENT FACILITIES

Potential activities requiring gas detection:

Standing water operations

Enclosed tanks and sewers

Chemical processing

Pump stations

Notable gases of interest:

VOCs*, Methane

Sulfur Dioxide, Chlorine, Hydrogen Sulfide, Ammonia, Ozone, Oxygen (depletion)

** Refer to the glossary for an explanation of this term*

INDUSTRIAL HAZARDS

Combustible hazards
Toxic hazards

SEMICONDUCTOR FABRICATION

Potential activities requiring gas detection:

Chemical vapor deposition

Gas storage

Reacting agents and chemical drying processes

Notable gases of interest:

Hydrogen

Silane, Carbon Monoxide, Arsine

GENERAL INDUSTRY/ CHEMICAL PROCESSES

Potential activities requiring gas detection:

Gas delivery and transportation

Pump and piping systems

Laboratory operations

Notable gases of interest:

Methane, Flammable Vapors, VOCs

Hydrogen Sulfide, Hydrogen Chloride, Carbon Monoxide, Oxygen (deficiency), Chlorine, Sulfur Dioxide, Hydrogen Chloride

FOOD AND BEVERAGE

Potential activities requiring gas detection:

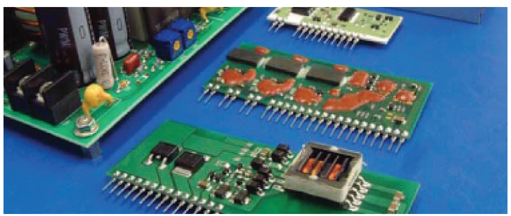
Refrigeration

Sanitizing processes

Notable gases of interest:

Carbon Monoxide

Carbon Dioxide, Ammonia, Chlorine, Oxygen (deficiency), Sulfur Dioxide



** Refer to the glossary for an explanation of this term*

COMMON HAZARDS BY INDUSTRY

	Agriculture	Aviation	Chemical Plants	Construction	Electrical Utilities	Fire Service/ HAZMAT	Food and Beverage Service	Gas Utilities	Steel	Shipping	POG	Pulp and Paper	Pharmaceutical	Power Plants	Public Works	Water Treatment
Ammonia (NH_3)	X	X	X			X	X				X		X	X		X
Carbon Dioxide (CO_2)	X	X	X				X							X		
Carbon Monoxide (CO)	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Chlorine (Cl_2)			X			X	X					X	X			X
Combustible Gases	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hydrogen (H_2)		X	X		X									X		
Hydrogen Chloride (HCl)			X			X	X						X			
Hydrogen Cyanide (HCN)						X	X		X				X			
Hydrogen Sulfide (H_2S)	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nitrogen Dioxide (NO_2)	X			X					X							
Nitric Oxide (NO)	X			X					X							
O_2 Enrichment/Deficient	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Phosphine (PH_3)	X					X	X									
Sulfur Dioxide (SO_2)	X		X	X	X		X		X		X	X	X	X	X	X
Volatile Organic Compounds (VOC)*	X	X	X	X	X	X	X		X		X	X	X	X		X

** Refer to the glossary for an explanation of this term*

FIXED VS. PORTABLE DETECTION

FIXED GAS DETECTION refers to a permanently mounted sensor or system of sensors. At a minimum, the sensors are connected to a transmitter or controller*, and commonly are connected to a network consisting of multiple points of detection, alerts, alarms, and response functions.

Fixed gas detection is used for continuous monitoring of gas concentrations to protect people, facilities, and equipment. It provides around the clock monitoring in local or remote locations and does not require a constant human monitor or response.

ADVANTAGES

1. Continuous, real-time monitoring
2. Customizable automatic response functions
3. Easy to maintain routine maintenance and calibration

LIMITATIONS

1. Costs more than portable
2. Requires independent reliable power source
3. Not easily relocated when process needs change

PORTABLE GAS DETECTION refers to a handheld system of sensors that provides protection for an individual user. Alarm functions in the form of visual, audible, and vibratory alerts notify users when detection of a hazardous situation has occurred and requires a human response.

Portable units are typically used in confined space entries, areas where fixed gas detection is not available or providing continuous monitoring, or to verify an atmosphere is not hazardous when servicing a fixed gas detection system.

ADVANTAGES

1. Costs less than fixed systems
2. Can be taken any-where a user can go
3. Typically battery powered, not tied to a power source

LIMITATIONS

1. Does not provide automatic response functions
2. Users must be properly trained to ensure proper usage

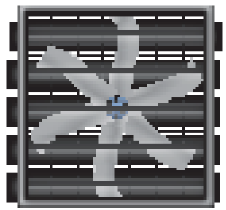
** Refer to the glossary for an explanation of this term*

SCOTT SAFETY

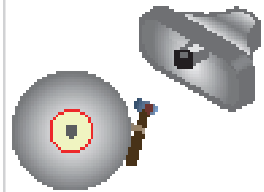
WARNINGS, ALARMS AND RESPONSE FUNCTIONS

Through the use of relays and customizable alarm point settings, users are able to configure their systems and transmitters to respond to changing hazardous conditions. Relays may be activated to perform any number of functions including activating visual and audible alarms, closing electronic isolation valves, and starting or stopping exhaust fans.

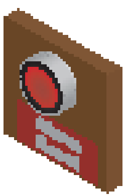
This type of automatic system response can save lives and alert workers to hazardous situations.



Exhaust fans
and valve isolation



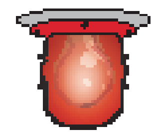
Audible bells
and annunciators



Remote alarm
reset

Most systems also have an option for a remote alarm reset. This enables users to acknowledge alarm conditions from a remote (safe) location.

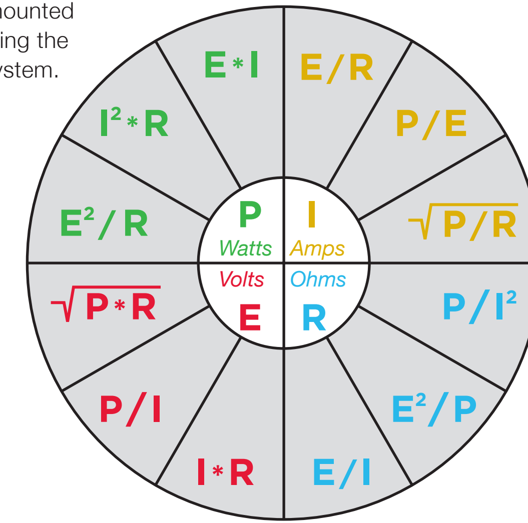
Automatic data logging of significant events such as calibrations, alarms, and power interruptions can usually aid users when performing troubleshooting or historical trend analysis.



Indicating
warning lights

OHM'S LAW

One of the challenges that can go into designing an effective fixed gas detection system is understanding the maximum cable lengths that can be utilized for remote detector heads, alarm systems, remotely mounted transmitters, etc. Voltages can be lost over long lengths of cable. Proper planning and understanding the relationships in an electrical system will help the design and effectivity of the fixed gas detection system.



Ohm's Law defines the relationships between (P) power, (E) voltage, (I) current, and (R) resistance.

P - This is the total power generated in a circuit. It is the product of current and voltage, measured in *watts*.

E - This is the difference in electrical potential between two points of a circuit, measured in *volts*. Volts are the muscle to move current.

I - This is the current, or what flows on a wire, measured in *amps*.

R - This the resistance of the circuit, or what determines how much electricity can flow in a circuit. As resistance increases, current flow becomes less and vice versa. Measured in *ohms*.

* **ONE VOLT OF ELECTRICITY WILL CARRY ONE AMP OF CURRENT THROUGH ONE OHM OF RESISTANCE TO PRODUCE ONE WATT OF POWER.**

Notes

- Wire sizes and materials will vary from manufacturer to manufacturer resulting in different resistance values. Always consult manufacturer's technical specifications for accurate resistance values.
- The voltage output from a power source will not be the voltage received at the other end of the wire run. Voltage loss will occur over the length of a wire run.
- 1 amp = 1000 mA (milliamps), 1000 volts = 1 kV (kilovolt)

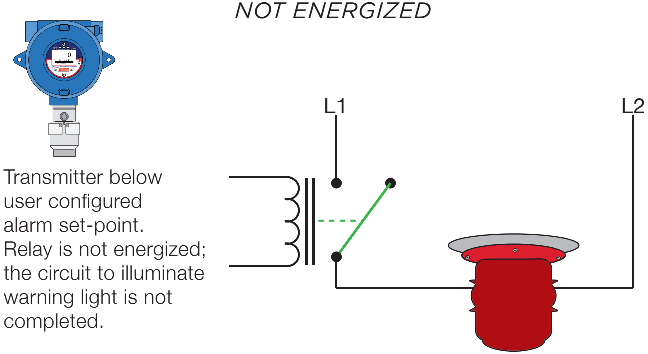
RELAY LOGIC

A key feature of most fixed point gas detection systems are standard and optional relays. Relays open or close contacts to complete or break an electrical circuit when user configured set points have been met. Relays can be used to activate any of a myriad of options including the activation of warning lights, alarms, exhaust fans, automatic valve operation, etc.

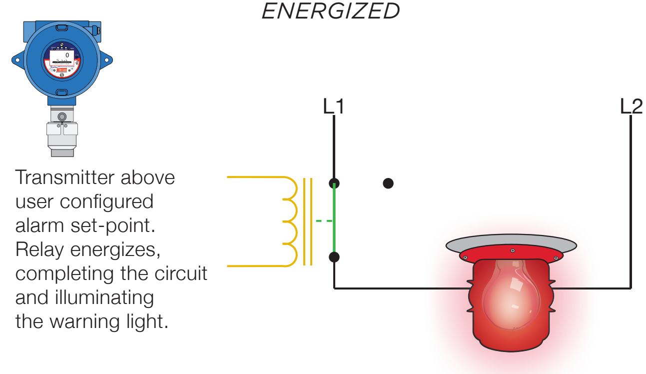
Typically, users will use system integrated logic to program a detector or controller to activate a relay when an alarm or combination of alarm set points have been reached. In a fail-safe* operation, relays are normally energized and de-energized upon alarm activation. In a non-fail-safe* operation, the relays are normally de-energized.

Relays have normally open (NO) or normally closed (NC) contacts. The NO or NC designations refer to the state of the contacts when they have not been activated; i.e., power is not applied to the relay. NO contacts are those that are not completing a circuit unless the relay becomes energized. NC contacts will open when the relay is energized.

WARNING LIGHT RELAY CIRCUIT
NOT ENERGIZED



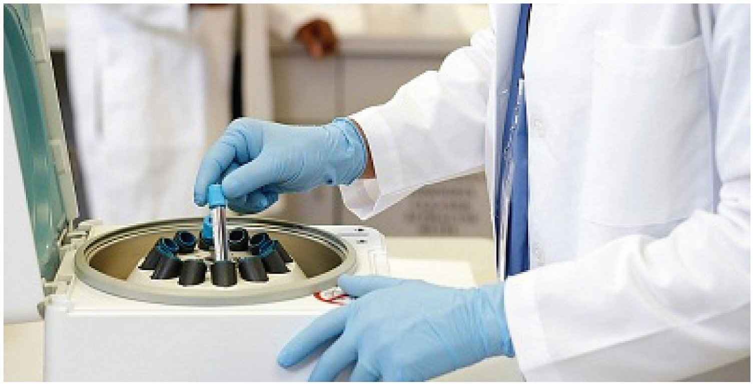
WARNING LIGHT RELAY CIRCUIT
ENERGIZED



* *Refer to the glossary for an explanation of this term*

SENSOR TECHNOLOGY

The science behind gas and flame detection has vastly improved in recent years and continues to evolve. Miniaturization of components, more efficient power utilization, and new detection methods lead the way in providing solutions to safeguarding people and equipment from the hazards of toxic and combustible gases, vapors and aerosols.

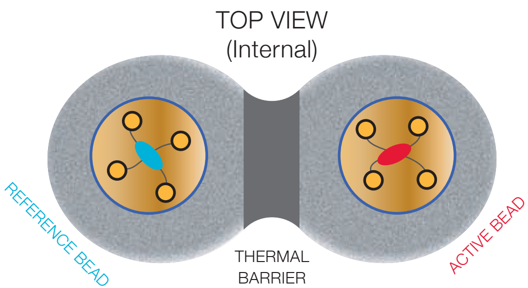


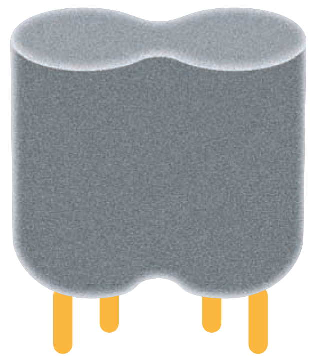
To understand the best methods available to meet different process needs, Scott Safety constantly tests and evaluates emerging technologies. Our team of experts can explain the benefits and limitations of the different sensor types available and how they can be best utilized to provide the safest protection.

SCOTT SAFETY

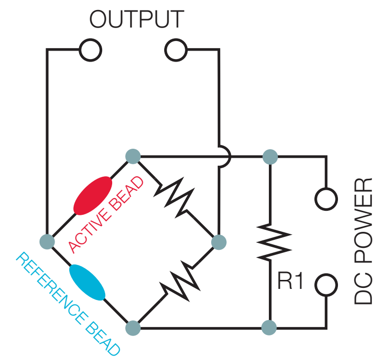
CATALYTIC BEAD (CAT BEAD) SENSORS

Beads consist of a wrapped coil of platinum wire covered with a ceramic base and then coated with a precious metal to act as the catalyst. The active, or sensing, bead is heated to temperatures up to 1000°C to allow the oxidation* of combustible gases to occur. The reference, or nonsensitive, bead remains at a lower temperature and is separated from the active bead by a thermal barrier. The resistance of the two beads is measured and compared using a Wheatstone bridge.





WHEATSTONE BRIDGE CIRCUIT: When gas burns on the active bead causing the temperature to increase, the resistance of the bead changes. As the bridge becomes unbalanced, the offset voltage is used to determine the measured value.



R1 balances the right side of the circuit. The combustion that occurs across the active bead leads to an unbalanced output of the circuit. This value is then used to determine the concentration of combustible gas present.

ADVANTAGES

1. Proven technology
2. Low cost
3. Can be used to detect wide range of combustible gases
4. Proven technology for the detection of hydrogen

LIMITATIONS

1. High power
2. Susceptible to poisoning from chlorine, silicones and acid gases
3. Cannot be used in an oxygen deficient atmosphere
4. Unable to discriminate between different types of combustible gas

** Refer to the glossary for an explanation of this term*

INFRARED SENSORS

Infrared light is a part of the electromagnetic spectrum that is close to, but not, visible light and can be felt as heat. The wavelength profile of infrared is expressed in microns between 0.7 µm and 300 µm. Hydrocarbon combustible gas molecules can absorb certain wavelengths of IR called absorption bands and allow other wavelengths to transmit through. Each gas has a specific set of IR wavelengths that will absorb, called the absorption spectrum. This provides a unique identifier to monitor and detect target gases.

Infrared sensors are designed to detect specific types of gases utilizing filters that will only allow a narrow band of wavelengths to pass through to a detector. This works on the same principle as a pair of sunglasses that filter out some of the sun's UV rays and visible light from your eyes.

The infrared light source pulses on and off at a set frequency to increase the detectors' sensitivity and reduce noise.

The infrared light source and the detectors are isolated from the gas sample through the use of mirrors, lenses, or filters preventing any contamination of the sensor.

Absorption of the infrared light occurs as the beam shines through a gas sample. Not all of the light is absorbed though, some IR light transmits through the gas sample at a lower intensity from the original source light.

Each detector has separate filters. The reference detector has a filter that is tuned to part of the spectrum where the IR is fully transmitted. The filter of the active detector is tuned at the same wavelength of the absorption band of the target gas. The difference in outputs from each detector is what makes the detection of a target gas possible.

ADVANTAGES

1. Long life
2. Fast response time
3. Resistant to contamination
4. Open path can detect over a large area

LIMITATIONS

1. Unable to detect hydrogen
2. Open path can be interfered with from precipitation, fog or IR sources
3. Can be costly
4. Unable to discriminate between different types of hydrocarbons

OPEN PATH TECHNOLOGY

Open path technology works on much the same principle as a stand alone sensor over a much larger scale. Open path infrared sensors separate the light source from the detectors. The beam from the infrared light source is projected across a large path to a detector. This is useful in outdoor applications or when detecting gases across a perimeter of a specified area. However, while larger areas can be covered with fewer sensors using open path technology, the projected beam can be blocked or absorbed and interfere with accurate results.

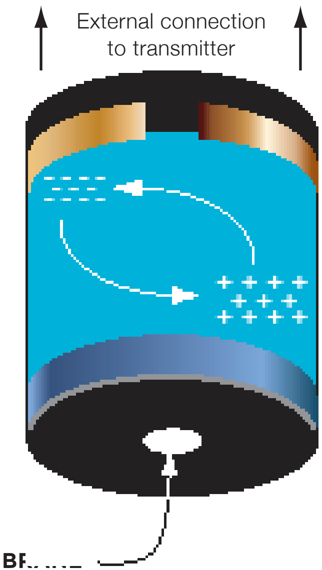
SCOTT SAFETY

ELECTROCHEMICAL (E-CHEM) SENSORS

Electrochemical sensors provide monitoring for a wide variety of toxic gases. An aqueous electrolyte solution provides a conductive path for ions* to travel between electrodes*. Target gases are either reduced or oxidized at the working electrode resulting in a current flow between the working and the counter electrode. The reference electrode provides a zero reference point from which the resulting difference in potential between the counter and working electrodes can be compared. Target gas levels can be measured in parts per million (ppm).

RULE OF THUMB: If you can't put your head into the environment being monitored, don't use an E-chem sensor to do the monitoring.

-No liquid environments
-No extreme temperatures or pressures
-No high velocity duct mounts



COUNTER ELECTRODE
Provides surface for the opposing reaction of the target gas from the working electrode

Either electrode may be the anode or cathode depending on the target gas

WORKING ELECTRODE
Acts as a catalyst for the chemical reaction of the gas

REFERENCE ELECTRODE
Stable source for comparison with the working electrode.
No current flows through the reference electrode

ELECTROLYTE
Provides the ion flow between electrodes during the chemical reaction

GAS PERMEABLE MEMBRANE
Gas diffuses through this membrane, and it also provides physical barrier for electrolyte

ADVANTAGES

1. Low power
2. Wide range of gases can be detected
3. Low cost

LIMITATIONS

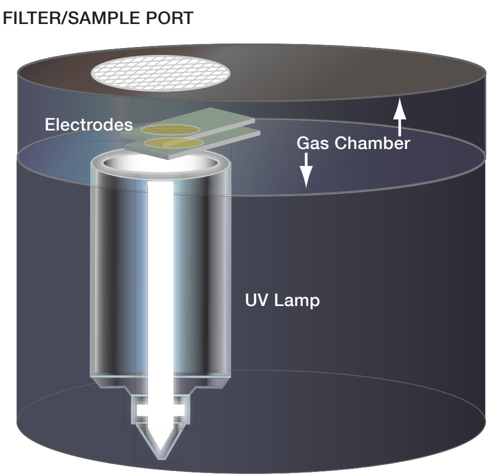
1. Typically requires oxygen to work
2. Life span shortened in arid or high humidity conditions

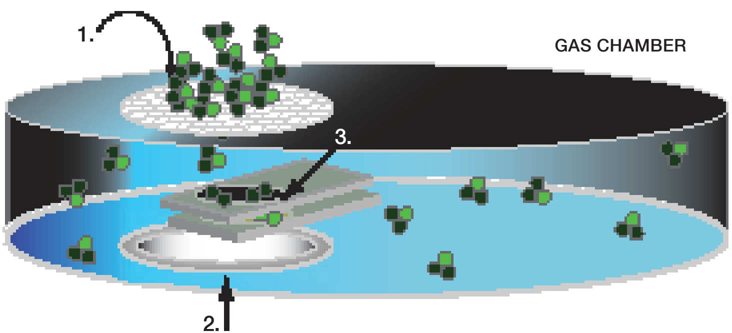
** Refer to the glossary for an explanation of this term*

PHOTO IONIZATION DETECTOR (PID)

Photo ionization detectors (PIDs) use ultraviolet light to ionize volatile organic compounds (VOCs)* and detect them as current through two oppositely charged electrodes. VOCs easily evaporate at room temperature. Many VOCs are present in a wide variety of applications as a by-product of aerosols, solvents, wastewater management facilities and pharmaceutical processing.

A single PID sensor is capable of detecting a wide number of VOCs. However, the sensor cannot distinguish between two different types of VOCs. Any molecule in the space between the two electrodes is ionized if its ionization potential (IP) is smaller than the energy of the lamp in electron volts (eV). The ions created in the space between the two oppositely charged electrodes migrate to the electrode with the opposite charge as the ion molecule. The output of the sensor as an ionic current is directly proportional with the concentration of VOCs in ppm levels.





DETECTION PROCESS

1. Gas enters through the porous membrane and fills the gas chamber.
2. UV light emits from the lamp into the gas chamber and ionizes molecules between the electrodes.
3. Positively charged ions migrate to the negative electrode and negative ions migrate to the positive electrode to create an ionic current. The ionic current is translated by the gas detector as a ppm of the overall gas sample. The higher the current, the greater the number of ionized VOCs.

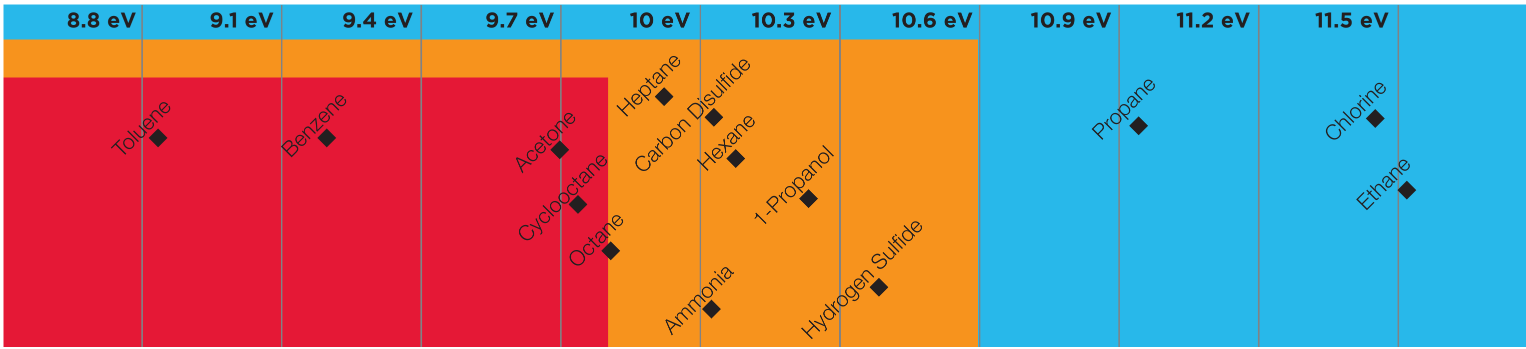
** Additional information regarding this topic can be found in the glossary*

PHOTO IONIZATION DETECTOR (PID)

ULTRAVIOLET (UV) LAMP

The UV lamp is the source of radiation that ionizes VOCs. The UV energy of the lamp and the ionization potential of the VOCs is measured in electron volts (eV). The most common lamp ratings are 9.8 eV, 10.6 eV and 11.7 eV.

9.8 eV	This lamp requires the lowest power and has the highest life-span, but limited detecting capability.
10.6 eV	This is the most commonly used lamp. It offers a broad detection of gases, high stability and a 2-3 year lifespan.
11.7 eV	This lamp can detect the broadest spectrum of VOCs, however, has a very short life span, typically only a few hundred hours. Humidity, oxygen and CO_2 levels can interfere and affect the sensitivity of detection.



ADVANTAGES

1. PID sensors detect a wide range of VOCs and can be used in a wide range of applications.
2. Concentration of organic vapors is detected in ppm levels.

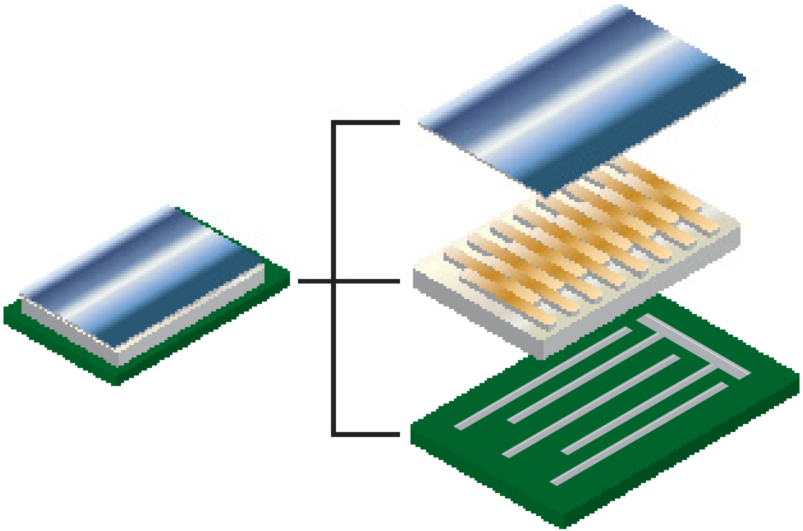
LIMITATIONS

1. Because the sensor ionizes any molecule with an ionization potential less than the lamp's potential, the sensor cannot specifically identify which gas is present.
2. PIDs are sensitive to humidity and window contamination that may affect sensor accuracy.

SCOTT SAFETY

METAL OXIDE SEMICONDUCTER (MOS) SENSORS

Metal oxide semiconductor gas sensors utilize thin films of metal oxides placed upon a silica substrate. The substrate is heated around 200-600°C while the resistance of the metal oxide is continuously monitored. The sensor responds to changes in the atmosphere as the resistance value of the metal oxide changes when exposed to target gases.



Thin layer of metal oxide (SnO_2, TiO_2, In_2O_3, WO_3, NiO, etc.)

Silica substrate with sensing electrodes to measure resistance value of the metal oxide

Heater coil

ADVANTAGES

1. Performs well in high/low humidity
2. Long life span
3. Can detect both low ppm of toxic gases and higher concentrations of combustible gases

LIMITATIONS

1. Nonlinear response
2. Subject to false alarms due to cross-interferences from reactive gases
3. Subject to dormant response if not tested regularly

SENSOR PERFORMANCE FACTORS

Choosing the right sensor type for gas monitoring involves an assessment of many factors.

Target Gas	Identify the target gases that have a potential for providing a hazard in the process. Most sensors are applicable to mostly toxic or mostly combustible gas monitoring. However, some sensor types are capable of monitoring for either. Situations where several gases may pose a threat may be monitored for a presence of a hazardous gas.	**GENERALLY TOXIC** Electrochemical **GENERALLY COMBUSTIBLE** Infrared Catalytic Bead **GENERALLY BOTH** PID MOS
Cost	Cost of different sensor types should play a factor in determining what sensors best suit the needs of a gas monitoring situation. Maintenance and calibration can also play a significant role in determining the overall cost of ownership over the lifetime of a sensor. Sensors that may have a higher initial cost, may in fact have a lower overall cost of ownership over the life of the sensor and vice versa due to sensor life, calibration, bump testing* and potential sensor contamination. At no time should cost be considered over safety. Always use the correct sensor type for the job.	**LOWER INITIAL COST** Electrochemical PID Catalytic Bead **LOWER LIFETIME COST** MOS IR
Sensor Placement	Sensor effectiveness is directly impacted by sensor placement. Even the best sensor will not be able to detect a hazard if placed too far from release or receptor points. Consider zoned or voting coverage areas where multiple sensor points effectively provide a maximum, redundant coverage area to minimize false alarms and account for barriers and air currents, all potential release points.	Refer to designing a gas detection system for more information.

** Refer to the glossary for an explanation of this term*

SENSOR PERFORMANCE FACTORS

Choosing the right sensor type for gas monitoring involves an assessment of many factors.

Temperature/ Humidity	Monitoring processes in severe environments can affect certain sensor types. All sensor types are rated for use in a specific temperature range. Some sensors can be affected in high humidity environments where water vapors can interfere with readings.	Refer to Sensor Technology on Pages 44-51 for more information.
Oxygen Content	In applications where oxygen may be displaced or not present in a gas sample, the sensor type should be considered.	E-chem, cat bead, MOS, and paper tape sensors will not perform as designed without oxygen present.
Power Consumption	Some sensor types consume much more power than others. This factor is important when considering whether a technology is appropriate for use in a fixed or portable detection device. Fixed detection systems must have appropriate power supplies to maintain the current necessary for sensor operation.	Follow sensor manufacturer's installation instructions.
Cross Interference*	Nearly all sensor types can be susceptible to interferences from other than target gases. Sensor manufacturers employ different methods to counter the effects of this through the use of filters, sensor construction materials, and preprogrammed expected response functions based on target gas characteristics. Always refer to manufacturer's recommendations when performing calibrations and installation instructions to ensure the highest quality of gas detection response. In some technologies, a sensor can be calibrated with an appropriate cross interferent gas, if the target gas is unobtainable or difficult to be applied in field conditions. In this case, a K-factor* should be applied to the calibration values.	Follow manufacturer's calibration methods to achieve desired sensor performance.

** Refer to the glossary for an explanation of this term*

SCOTT SAFETY

FLAME DETECTION

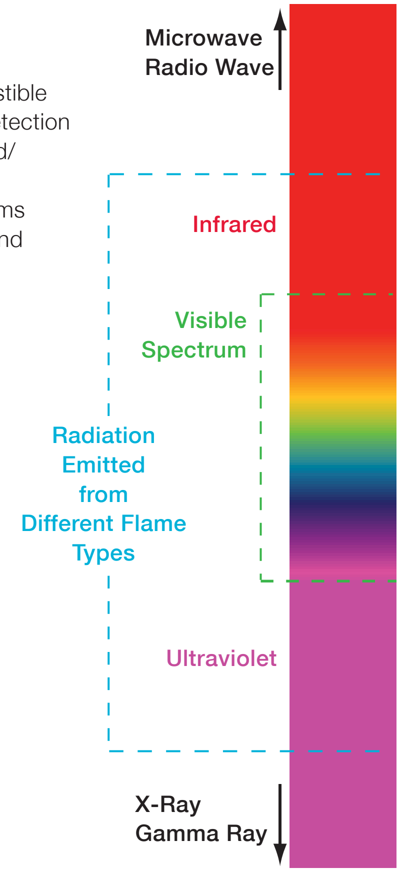
Flame detection is an important part of overall process monitoring, especially when the process involves combustible gases or materials. Flame sources generate radiation that may or may not be visible to the human eye. Flame detection technology is able to detect flame across a wider view of the electromagnetic spectrum by detecting infrared and/or ultraviolet sources of radiation. The combustible fuel source affects what type of radiation is generated. Flame detection sensor technologies are available for indoor or outdoor use and some have high immunity to false alarms that could be generated from solar radiation, welding or hot spots. Common technologies include single, multi and triple IR detection, UV detection, and combined UV/IR detection.

FLAME DETECTION SENSOR TYPES

IR Array	Long Range, Able to Locate the Angular Position of the Flame within the Field of View
Single IR	Low Cost, Indoor Use
Multi IR	Low Cost, High Speed of Response, Indoor and Outdoor Use, Low False Alarms, Detects Hydrogen Based Flames
Triple IR	Indoor and Outdoor Use, Long Detection Range, Highest Immunity to False Alarms
UV	Detects Hydrogen Based Flames and Hydrocarbon Based Fuel and Gas Fires
UV/IR	Indoor and Outdoor Use, Long Detection Range, High Immunity to False Alarms

THE ELECTROMAGNETIC SPECTRUM

Flame and gas detection technology use sensors that can detect across a much wider range of the spectrum than what the human eye or closed circuit cameras are able to see. Many fuel sources and gases produce flames and radiation beyond the visible spectrum. These invisible sources of radiation are easily detected using advanced sensor technology.



STANDARDS AND APPROVALS

Navigating through the certifications and approvals of gas detection equipment can sometimes prove to be a challenge. With so many markings available, it is important to understand the significance and value of these certifications and how they apply to gas detectors.

Different markets and regions may require adherence to different standards, but the overall goal is to ensure equipment will perform safely in hazardous locations and comply with an established protection method such as intrinsic safety.

A ***hazardous location*** exists when:

- Flammable gas, vapor, or mist exists with a concentration of > 10% LEL
- Oxygen levels are < 19.5% or > 23.5%
- Atmospheric concentration of any hazardous substance which could result in exposure in excess of the published dose per OSHA regulations
- Airborne combustible dust > 100% LEL
- Any other atmospheric condition immediately dangerous to life or health (IDLH)

GAS DETECTION PRODUCTS THAT MAY REQUIRE APPROVAL

-Portable and fixed gas detectors
-Open path detectors
-Sensors installed within detectors
-Multi-gas gas detectors
-Multi-gas sensors
-Flammable gas detectors
-Combustible gas detectors
-Some remote accessories connected to detectors
-Flame detectors

Intrinsic safety is a design technique applied to electrical equipment and wiring used in hazardous or potentially hazardous locations. Limiting the energy, electricity, and thermal properties of the equipment to prevent ignition of a hazardous atmosphere are the cornerstones of intrinsic safety.

Note: None of the markings on this page constitute any approval authority or that certification has been given to this document.

HAZARDOUS AREA CLASSIFICATIONS

Hazardous area classifications can be best understood by knowing the standard to which they apply. Generally, there are three standards of classification. European/IEC/Cenelec standards use the zone classification. In North America, two standards may be used, NEC* 500 (Division Classification) or NEC 505 (Zone Classification—mirrors the European/IEC*/Cenelec* standards).

ZONE 0 — Explosive gas or air is continuously present
Greater than 1000 hours/year

ZONE 1 — Explosive gas or air is likely to exist
Greater than 10 but less than 1000 hours/year

ZONE 2 — Explosive gas or air is not likely to exist
Less than 10 hours/year

DIVISION 1 — Is equal to either Zone 0 or Zone 1
Greater than 10 hours/year

DIVISION 2 — Is equal to Zone 2
Less than 10 hours/year

GROUPINGS	NEC 500	NEC 505 European/IEC/CENELEC
Gases	CLASS I	
Acetylene	Group A	Group II C
Hydrogen	Group B	Group II C
Ethylene	Group C	Group II B
Propane	Group D	Group II A
Methane	N/A	Group I
Dust	CLASS II	
Magnesium	Group E	
Coal	Group F	
Grain	Group G	
Fibers	CLASS III	

*European/IEC/Cenelec standards do not subdivide into classes or materials.

TEMPERATURE CODES

Temperature codes are used to identify the maximum surface temperature a certified gas detector may achieve and still be intrinsically safe.

Max Surface Temp (°C)	NEC 500	NEC 505 European/IEC/CENELEC	Max Surface Temp (°C)	NEC 500	NEC 505 European/IEC/CENELEC
450	T1	T1	180	T3 A	-
300	T2	T2	165	T3 B	-
280	T2 A	-	160	T3 C	-
260	T2 B	-	135	T4	T4
230	T2 C	-	120	T4 A	-
215	T2 D	-	100	T5	T5
200	T3	T3	85	T6	T6

** Refer to the glossary for an explanation of this term*

SCOTT SAFETY

PROTECTION METHODS AND STANDARDS

Protection methods are added to markings and certifications to demonstrate to what level of product safety that the gas detector has been designed. There are several different standards by which equipment may be tested in order to demonstrate product safety.

Protection Method (Meaning)	North America - Class I (Flammable Gas or Vapor)							Global (IEC) Europe (CENELEC)		
	Division	Canada CSA	US	Zone	Canada CSA	ANSI/UL*	ANSI/ISA	Zone	Cenelec	IEC
ia - *Intrinsic Safety up to 2 faults*	-	-	-	0	E60079-11	60079-11	12.02.01	0	EN 60079-11	60079-11
Exia - *Canada, Intrinsically Safe*	1	C22.2 No. 157	FM3610/UL913	-	-	-	-	-	-	-
ib - *Intrinsic Safety to a single fault*	-	-	-	1	E60079-11	60079-11	12.02.01	1	EN 50020	60079-11
Intrinsically Safe System	-	-	-	-	-	-	-	0/1	EN 50039	60079-25
Explosion Proof	1	C22.2 No. 30	FM3615/UL1203	-	-	-	-	-	-	-
d - *Flame Proof*	-	-	-	1	E60079-1	60079-1	12.22.01	1	EN 60079-1	60079-1
p - *Pressurization*	-	-	-	1	E60079-2	-	12.04.01	1/2	EN 60079-2	60079-2
(X, Y) - *Purged/Pressurized*	1	NFPA 496	NFPA 496	-	-	-	-	-	-	-
(Z) - *Purged/Pressurized*	2	NFPA496	NFPA496	-	-	-	-	-	-	-
e - *Increased Safety*	-	-	-	1	E60079-7	60079-7	12.16.01	1	EN 60079-7	60079-7
m - *Encapsulation*	-	-	-	0	E60079-18	60079-18	12.23.01	1	EN 60079-18	60079-18
o - *Oil Immersion*	-	-	-	1	E60079-6	60079-6	12.26.01	1	EN 50015	60079-6
q - *Powder Filled*	-	-	-	1	E60079-5	60079-5	12.25.01	1	EN 50017	60079-5
Non-Incendive/Non-Ignition	2	C22.2 No. 213	FM3611/UL1604	-	-	-	-	-	-	-
Capable Arching/Heating Parts		-	-	-	-	-	-	-	-	-
n - *Protection*	-	-	-	2	E60079-15	60079-15	12.22.02	2	EN 60079-15	60079-15
Special Requirements	-	-	-	-	-	-	12.00.01	0	EN 50284	60079-26
2 protection methods										

Standards are continuously being revised and are subject to change. Consult local regulatory agencies for most current standards.

** Refer to the glossary for an explanation of this term*

NEMA CLASSIFICATIONS/INGRESS PROTECTION

National Electrical Manufacturers Association (NEMA) classifications represent an electrical enclosure's ability to protect internal components against the external environment.

Location	Use	Type	Description
NONHAZARDOUS LOCATIONS	Indoor	1	Prevents hand contact with internals
		2	Protects against falling dirt and water
		5	Protects against settling airborne dust, lint, fibers; protects against dripping and light splashing of liquids
		12	Protects against falling airborne dust, lint, fibers; protects against dripping and light splashing of liquids; no knockouts
		12K	Protects against falling airborne dust, lint, fibers; protects against dripping and light splashing of liquids; with knockouts
		13	Protects against falling airborne dust, lint, fibers; protects against spraying, splashing, and seepage of water and oil
	Indoor/Outdoor	3	Protects against windblown dust, rain, and sleet; undamaged by ice
		3R	Protects against falling rain and sleet; undamaged by ice
		3S	Protects against falling dust, rain, and sleet; undamaged by ice
		4	Protects against falling dust, rain, sleet, splashing and hose directed water; undamaged by ice
		4X	Protects against falling dust, rain, sleet, splashing and hose directed water; undamaged by ice, corrosion protected
		6	Protects against falling dust, rain, sleet, splashing and hose directed water; prevents water entry when briefly submerged; undamaged by ice
		6P	Protects against falling dust, rain, sleet, splashing and hose directed water; prevents water entry during prolonged submerging; undamaged by ice
HAZARDOUS LOCATIONS	Indoor	7	For use in Class I, Groups A, B, C, and D
		9	For use in Class II, Groups E, F, and G
	Indoor/ Outdoor	8	For use in Class I, Groups A, B, C, and D
	Mining	10	Meets the requirements of MSHA (Mine Safety and Health Administration)

IEC Publication 60529 *Classification of Degrees of Protection Provided by Enclosures* provides a system for specifying protection provided by enclosures of electrical equipment. The rating consists of the letters IP followed by two digits. The first digit is representative of the protection provided against the ingress of solids. The second digit is representative of the protection provided against the ingress of liquids.

	1st Number: Protection Against Solids		2nd Number: Protection Against Liquids
0	No protection provided	0	No protection provided
1	Protection from objects greater than 50 mm	1	Protection from vertically falling water drops
2	Protection from objects greater than 12 mm	2	Protection from falling water drops up to an angle of 15°
3	Protection from objects greater than 2.5 mm	3	Protection from spraying water up to 60° from vertical
4	Protection from objects greater than 1.0 mm	4	Protection from splashing water
5	Protection from dust	5	Protection from low pressure water jets in all directions
6	Dust tight enclosure	6	Protection from high pressure water jets in all directions
		7	Protection from temporary submersion up to 1 meter
		8	Protection from submersion in water greater than 1 meter

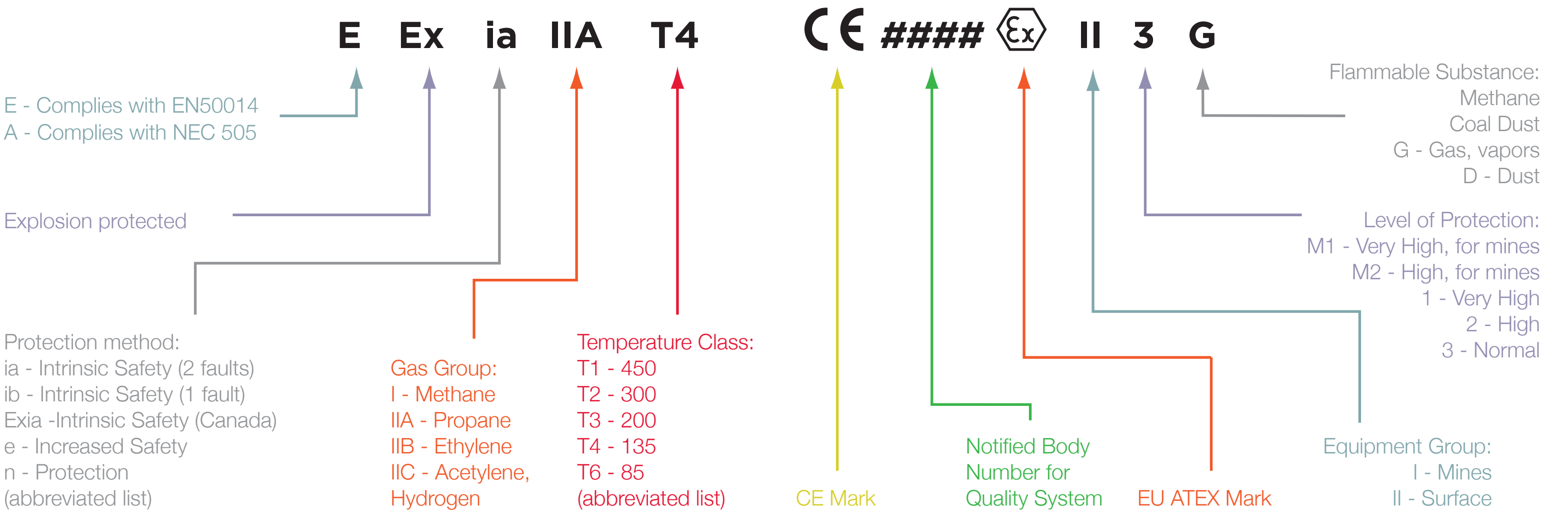
SCOTT SAFETY

ATEX

ATEX directives provide for the minimum standards applicable to equipment used in explosive atmospheres. Directive 94/9/EC, article 100a defines the classifications and intended uses with respect to safety, design, and manufacturing of these devices. Directive 1992/92/EC, article 137 defines under what conditions these devices should be used by end users to prevent, avoid, and control the hazards associated with explosive atmospheres.

ATEX MARKINGS

CENELEC ATEX MARKINGS   ADDITIONAL ATEX MARKINGS



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CE MARKING

CE is an abbreviation for the French phrase Conformité Européene, meaning European Conformance. CE marking is a declaration from the manufacturer that their product conforms to all applicable directives adopted by the EEA (European Economic Area) and is a requirement for the product to be sold into any of the countries in this group. Unlike hazardous location approvals, the manufacturers are solely responsible for ensuring their product's conformance to these directives which were developed using IEC and Cenelec standards.

Further guidance on affixing the CE mark to products can be found in the *Guide to the Implementation of Directives Based on the New Approach and the Global Approach*; commonly referred to as "The Blue Book" and published by the European Commission.

TARGET MARKETS: EUROPEAN ECONOMIC AREA

Austria	Greece	The Netherlands
Belgium	Hungary	Norway
Bulgaria	Iceland	Poland
Cyprus	Republic of Ireland	Portugal
Czech Republic	Italy	Romania
Denmark	Latvia	Slovakia
Estonia	Liechtenstein	Slovenia
Finland	Lithuania	Spain
France	Luxembourg	Sweden
Germany	Malta	United Kingdom

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CSA INTERNATIONAL

CSA International is an organization that provides performance testing in agreement with national and international standards. CSA tests products to meet standards directed by the American National Standards Institute (ANSI), Underwriters Laboratories (UL), and Canadian Standards Association (CSA). CSA is also a Nationally Recognized Testing Laboratory (NRTL) by the Occupational Safety and Health Administration (OSHA) in the U.S., and in Canada by the Standards Council of Canada (SCC). CSA works closely with ATEX and IECEx to operate worldwide. CSA provides certification testing for product safety operating in a hazardous area.

DIVISION SYSTEM*

DIVISION 1 Flammable gas, vapor, or combustible dusts continuously, intermittently, or periodically present.

DIVISION 2 Volatile flammable liquids or flammable gases present, but confined within closed containers or systems; could escape by abnormal operation or fault conditions.

ZONE SYSTEM

ZONE 0 Gas, vapor, or mist is present continuously or for long periods.

ZONE 2 Gas, vapor, or mist is likely to be present.

ZONE 2 Gas, vapor, or mist is not likely to be present. If it is present, it will only be for a short period of time.

CLASS I	Group A	Acetylene	Group IIC
CLASS I	Group B	Hydrogen	Group IIC
CLASS I	Group C	Ethylene	Group IIB
CLASS I	Group D	Propane	Group IIA
	N/A	Methane	Group I
CLASS II	Group E	Metal dust, magnesium	
CLASS II	Group F	Carbon dust	
CLASS II	Group G	Flour, starch, grain	
CLASS III		Fibers, cotton	

COUNTRIES THAT ACCEPT CSA CERTIFICATION

AMERICAS
Argentina
Brazil
Canada
Mexico
United States

ASIA PACIFIC
Australia
China
India
Japan
New Zealand
South Korea
Taiwan

EUROPE
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Iceland
Ireland
Italy
Liechtenstein
Luxembourg
Netherlands
Norway
Portugal
Romania
Slovenia
Spain
Sweden
Switzerland

OTHER
Russia
South Africa

CSA uses both the division system and the zone classifications. Refer to page 54 for more information.

** Refer to the glossary for an explanation of this term*

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UNDERWRITERS LABORATORIES

Underwriters Laboratories (UL) is both a Standard Developing Organization (SDO) and Nationally Recognised Testing Laboratory (NRTL) that develops standards and performs testing to ensure products are safe for use in hazardous environments. UL is not a government agency; however, it is approved by the Occupational Safety and Health Administration (OSHA). UL works closely with ATEX and IECEx standards to operate worldwide.

UL CERTIFICATIONS ARE ACCEPTED BY 98 COUNTRIES WORLDWIDE, INCLUDING:

ASIA PACIFIC	EUROPE		LATIN AMERICA
Australia	Austria	Italy	Argentina
China	Belgium	Latvia	Brazil
Hong Kong	Bulgaria	Lithuania	
India	Cyprus	Luxembourg	**NORTH AMERICA**
Indonesia	Czech Republic	Malta	Canada
Japan	Denmark	Netherlands	U.S.A.
Korea	Estonia	Poland	Mexico
Malaysia	Finland	Slovakia	
New Zealand	France	Slovenia	**NON-EUROPEAN**
Philippines	Germany	Spain	Croatia
Singapore	Greece	Sweden	Norway
Taiwan	Hungary	Switzerland	Russia
Thailand	Ireland	U.K.	Ukraine

Note: None of the markings on this page constitute any approval authority or that certification has been given to this document.

IECEx

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

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

THE SCHEME PROVIDES:

A single international Certificate of Conformity (CoC) that requires manufacturers to successfully complete:

- Testing and assessment of samples for compliance with Standards resulting in a Test and Assessment Report (ExTR)
- Assessment and auditing of manufacturers facilities resulting in a Quality Assessment Report (QAR)
- Ongoing surveillance audits of manufacturers' facilities

The IECEx System comprises several systems. The United States participates in the full IECEx Certified Equipment Scheme. Currently Australia, New Zealand, and Singapore accept that the IECEx Certificate of Compliance meets all of the national requirements for Ex Certification meaning no further national testing is required. Countries that do require a national certification will typically accept the results from the test report (ExTR). Many countries have national standards that are already based upon IEC standards, such as Russia (GOST-R), China (CQST), Brazil (InMetro), and Canada (CSA accepts IEC standards).

IECEx PARTICIPATING COUNTRIES	
Australia	Brazil
Canada	China
Croatia	Czech Republic
Denmark	Finland
France	Germany
Hungary	India
Italy	Japan
Korea	Malaysia
Netherlands	New Zealand
Norway	Poland
Serbia	Romania
Russia	Singapore
Slovenia	South Africa
Sweden	Switzerland
Turkey	United Kingdom
United States	

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FACTORY MUTUAL

The Factory Mutual Approvals Division determines the safety and reliability of equipment, materials, or services utilized in hazardous locations in the United States and elsewhere. Factory Mutual certifies to NEC (National Electrical Code) standards for hazardous locations, NEC Standard 500 (Division classification) and NEC Standard 505 (Zone classification).

FM APPROVED

For a product to receive approval, it must meet two criteria. First, it must perform satisfactorily, reliably, and repeatedly as applicable for a reasonable life expectancy. Second, it must be produced under high quality control conditions. Factory Mutual also has inter-laboratory agreements and can certify to Canadian and European standards.

Factory Mutual certifications are globally recognized and they can test to ATEX and IECEx standards for gas detection devices being used in hazardous locations.

FM standards 3610 (Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II and III, Division 1, Hazardous (Classified) Locations), 3611 (Nonincendive Electrical Equipment for Use In Class I and II, Div. 2 and Class III, Divisions 1 and 2 Hazardous (Classified) Locations), and 3615 (Explosion Proof Electrical Equipment General Requirements) as well as other relevant recognized standards are used to certify gas detection equipment.

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SAFETY INTEGRITY LEVEL (SIL) RATINGS

SIL or Safety Integrity Level, defined by standard IEC (EN) 61508 (Manufacturer's requirements), is the measure of risk reduction offered by the safety function provided to a process. SIL ratings use statistical analysis to prove safety systems are designed in such a way as to prevent dangerous failures or to control hazards when they arise. Gas detection equipment may be SIL rated, or suitable for use as part of a larger SIL rated system. However, having a gas detection device that has a SIL rating does not assure safety. Sensor placement is the most important factor in gas detection. Sensors that are not in position to detect hazardous gases and allow a safety action to occur when hazards reach unsafe levels, are essentially ineffective, regardless of SIL rating.

The risk reduction factor (RRF) is the expected reduction in risk to the process hazard analysis using a SIL rated system.

Probability of failure on demand (PFD) is the expected number of failures of the safety system. A SIL 2 system would be expected to fail no more than once out of every 100 times.

In the worst case scenario, should a safety system not perform and respond to identified hazards, the potential consequences are listed.

SAFER SYSTEM ↑

SIL	RISK REDUCTION FACTOR	PROBABILITY OF FAILURE ON DEMAND (PFD)	POTENTIAL CONSEQUENCES OF FAILURE
4	100,000 to 10,000	10^{-5} to 10^{-4}	Fatalities in surrounding community
3	10,000 to 1,000	10^{-4} to 10^{-3}	On-site fatalities
2	1,000 to 100	10^{-3} to 10^{-2}	On-site injuries, perhaps a fatality
1	100 to 10	10^{-2} to 10^{-1}	On-site minor injuries

SIL 2 is typically a cost effective target to achieve. Hazards that require a SIL 3 or 4 rating can usually be engineered or have the process changed to lower the risk at less of a cost than designing a safety system to mitigate the hazard.

GLOSSARY OF GAS DETECTION TERMS

% v/v
Volume/volume percentage of a gas mixture. For example, the Earth's atmosphere is comprised of a mixture of 20.9% oxygen, 78% nitrogen, and 1.1% trace gases. This means there is 20.9% v/v oxygen in the atmosphere.

4-20 mA
An analog signal where 4 mA represents a signal equal to 0% of full scale and 20 mA equals 100% full scale. The power usually comes directly from a power supply.

4-20 mA CURRENT LOOP
An analog signal where 4 mA represents a signal equal to 0% of full scale and 20 mA equals 100% full scale. The current loop is isolated from the power supply but shares a common ground with the transmitter or controller.

ABSORPTION
Occurs as a wavelength of infrared radiation passes through a gas molecule. The wavelength loses intensity as it is absorbed by the gas.

AC VOLTAGE
Alternating Current. Provides power in which electrons travel in both directions. AC power does not degrade rapidly over distance and is relatively easy to convert into lower currents and voltages.

ACGIH
American Conference of Industrial Hygienists.

AEROSOL
A suspension of fine solid particles or liquid droplets in a gas.

ANSI
American National Standards Institute.

SCOTT SAFETY

GLOSSARY OF GAS DETECTION TERMS

ASPHYXIANT
Refers to a gas whose primary hazard is as a gas that rapidly displaces oxygen.

ATEX
ATmosphéres EXplosibles, a directive of the European Union that specifies the minimum requirements for improving safety and health protection of workers potentially at risk from explosive atmospheres.

AUTO IGNITION TEMPERATURE
Temperature higher than the flash point at which a substance will sustain self-combustion independent of a flame or heated element. Sometimes referred as SIT, Spontaneous Ignition Temperature.

BOILING POINT
Temperature at which a compound changes from a liquid to a gas.

BREATHING ZONE
Atmosphere immediately surrounding a worker, regardless of whether safe or hazardous.

BRIDGE SENSOR CIRCUIT (WHEATSTONE BRIDGE)
A circuit that isolates a reference resistor from an active resistor used in a Cat Bead Sensor. As the temperature increases across the active resistor, the resistance will change. The resulting difference in potential from the two resistors translates into an output voltage.

BUMP TEST
Bump testing verifies the Span Calibration by subjecting the monitor to a known exposure of gas to demonstrate the response is within an acceptable range of the actual concentration. Bump testing also can be used to demonstrate proper activation of alarms and relay circuits.

C (CEILING LEVEL)
Ceiling level is an exposure limit that must never be exceeded, even for short periods of time.

SCOTT SAFETY

GLOSSARY OF GAS DETECTION TERMS

CAS NUMBER
Chemical Abstract Service Registry number as determined by the American Chemical Society to uniquely identify each substance in spite of how many common names a substance may have.

CALIBRATION
Typically occurs in two stages, zero calibration and span calibration. Zero calibration is performed to establish baseline readings of atmospheres that are known to be free of toxic or combustible gases. Span calibration is performed to ensure a monitor detects target gases within specified operating parameters.

CATALYTIC BEAD (CAT BEAD OR PELLISTOR)
Combustible sensor type that uses an active and reference bead to translate differences in resistance from heat produced through the combustion of gases to translate into a %LEL.

CCC
China Compulsory Certification mark.

CCM
Cubic Centimeters per Minute, a measure of the flow of gas particularly important during calibration of sensors. 1 CCM =0.001 LPM = 0.00212 SCFH.

CCOHS
Canadian Center for Occupational Health and Safety.

CE
Conformité Européene; a manufacturers' mark that a product conforms to directives adopted by the European Economic Area.

CEC
Canadian Electric Code.

GLOSSARY OF GAS DETECTION TERMS

CENELEC
European Committee for Electrotechnical Standardization, technical organization that develops safety and health standards for the European market.

CoC
Certificate of Conformity; part of the IECEx Scheme.

COLD BOOT
Resetting a gas detector by removing power completely, and then reapplying power. This may cause additional warm-up time for sensors before the detector reaches its full effectiveness.

COMBUSTIBLE
Refers to a gas whose primary hazard is the ability to ignite. It is important to note many gases have both combustible and toxic properties.

CONFORMAL COATING
Protective material applied to printed circuit boards to remove the risk of potential contaminants that could interfere with the proper operation of the electronics such as dust, moisture, and temperature variations.

CONTROLLER
Part of a fixed gas detection system than can be used to accept multiple inputs to one centralized location for easy monitoring of a large area.

CQST
China National Quality Supervision and Test Centre for Explosion.

CROSS SENSITIVITY/CROSS INTERFERENCE
Refers to the ability of gas sensors to detect gases other than what they are intended to. This can be a result of any number of factors ranging from oxidation, catalyst type being used, similar gas properties, or reaction of certain compounds. Proper calibration techniques, filters, and an understanding of the operation of particular types of sensors can help reduce the effects of cross sensitivity.

GLOSSARY OF GAS DETECTION TERMS

CSA
Canadian Standards Association, a certifying agency that evaluates products through a formal process involving examination, testing and follow-up inspection to verify the product complies with applicable standards for safety and performance.

DATA ACQUISITION DEVICE
A device that performs automatic collection of data from sensors, instruments and devices.

DC VOLTAGE
Direct Current. Provides power in which electrons flow only in one direction. Power source is usually a battery or solar cell. DC power degrades rapidly over distance.

DILUTION ORIFICE
A sample gas detection method that introduces ambient air into an otherwise confined space through an opening in the sampling device to allow for greater accuracy on % LEL concentrations. Necessary in sampling gas concentrations that would otherwise lack the necessary amount of oxygen for proper sensor performance.

DISTRIBUTED CONTROL SYSTEM (DCS)
A control system in which the controller elements are not in a central location, but are distributed throughout the system with each component sub-system controlled by one of more controllers. The entire control system is networked for communication and monitoring.

DIVISION
Division is the North American method of specifying the probability that a location is made hazardous by the presence, or potential presence, of flammable concentrations of gases and vapors.

EEA
European Economic Area.

GLOSSARY OF GAS DETECTION TERMS

ELECTROCHEMICAL (E-CHEM)
A gas sensor that measures the current that results from the reaction of the target gas against two or more electrodes. The current generated in the sensor is generally proportional to the gas concentration.

ELECTRODE
A conductor through which electric current is passed.

ELECTRON
A particle that carries a negative electric charge.

EMI (ELECTROMAGNETIC INTERFERENCE)
Electrical interference from conducted voltages and currents through a signal path. EMI can be a particular problem in circuits with low current such as 4-20 mA or in relay protection circuits as the signal noise generated from EMI can cause false readings, alarms, or relay activation.

eV (ELECTRON VOLTS)
The measurement of ionization potential.

EXPLOSION PROOF
Electrical devices designed to contain explosions or flames produced within them without igniting the external flammable gases or vapors.

ExTR
Test and Assessment report; part of the IECEx Scheme.

FAILSAFE
Refers to an electronically activated circuit, such as a relay, that will fail to a preferred position upon a loss of power.

GLOSSARY OF GAS DETECTION TERMS

FIXED GAS DETECTION SYSTEM
A permanently mounted combination of sensors, transmitters, controllers and relay controlled devices that allow for local and remote monitoring and activation of safety devices. Fixed gas detection systems are highly customizable applications that are designed to mitigate the risk of hazardous areas and dangers posed to workers and equipment.

FLASH POINT
Temperature at which the vapor emitted by a substance reaches concentrations equal to the lower flammability limit.

FM
Factory Mutual, a certifying agency that evaluates products will perform as expected and support property loss prevention.

GAS STRATIFICATION
Failure of gases to mix evenly in the atmosphere due to differences in vapor density, temperatures, and pressure.

GENERAL PURPOSE LOCATION
Any atmosphere that is not a hazardous location.

GOST-R
Gosudarstvennyy Standard; Certificate of Conformity for Russia.

HAZARDOUS ATMOSPHERE (Hazardous Location, Hazardous Area, Hazardous Situation)
An atmosphere that may expose workers to the risk of death, incapacitation, impairment of ability to self-rescue, injury, or acute illness from one or more of the following causes:

1. Flammable gas, vapor, or mist in excess of 10 percent of its LEL
2. Airborne combustible dust at a concentration that meets or exceeds its LEL
3. Atmospheric oxygen concentration below 19.5 percent or above 23.5 percent
4. Atmospheric concentration of any substance for which a PEL is published
5. Any other atmospheric condition that is IDLH.

GLOSSARY OF GAS DETECTION TERMS

IDLH (IMMEDIATELY DANGEROUS TO LIFE OR HEALTH)
Exposure to airborne contaminants that are likely to cause death, immediate or delayed permanent adverse health effects, or prevent escape from such an environment.

IEC
International Electrotechnical Committee.

IECEx
Scheme to standardize international certification.

IGNITION TEMPERATURE
Temperature at which a flammable gas may ignite without a spark or flame source.

INGRESS PROTECTION
A measure of protection against the intrusion of solid objects including dust, water, tools, body parts, etc. as defined by the Standard IEC 60529.

INMETRO
Brazilian conformity mark.

INTRINSICALLY SAFE
Electrical equipment that is incapable of releasing sufficient electrical or thermal energy under normal or abnormal operating conditions to cause ignition of a specific hazardous mixture and air. Equipment must be intrinsically safe to be used in Division 1 environments.

IOHA
International Occupational Hygiene Association.

GLOSSARY OF GAS DETECTION TERMS

ION
An atom or molecule where the total number of electrons is not equal to the total number of protons, giving it a net positive or negative electrical charge.

IP (IONIZATION POTENTIAL)
Amount of energy required to remove an electron from an isolated atom or molecule. Measured in eV.

IR (INFRARED)
A combustible sensor type that measures the absorption of infrared electromagnetic wavelengths as a gas passes through to measure gas levels. In some cases, IR sensors can be used to detect toxic gas concentrations as well or radiation emitted as part of the electromagnetic spectrum with a wavelength longer than visible light.

ISA
International Society of Automation.

ISOLATED 4-20 mA
An analog signal where 4 mA represents a signal equal to 0% of full scale and 20 mA equals 100% full scale. The isolation allows the signal path to be isolated from the power supply to the transmitter or receiver and results in a general insensitivity to electrical noise.

K-FACTOR
A K-factor is used to determine the relative sensor response ratio of the calibration gas to the expected detected gas when the calibration gas is not the same as the detected gas. K-factors are used to allow for the monitoring of a presence of gas, not to achieve accuracy in gas monitoring.
A K-factor can be expressed in the formula:
(K-Factor) (% Cal Gas) = Adjusted Span Output
For example, when calibrating a sensor using 50% LEL propane gas, a K-factor can be applied to achieve readings for butane. Let's assume the K-factor is 0.75. Using 50% LEL propane gas and multiplying by the K-factor of 0.75, the adjusted span calibration should be done to achieve a reading of 37.5%. This will allow a user to monitor for butane. However, it should be noted, to achieve the most accurate readings for the desired targeted gas, the calibration gas should be the same as the target gas.

GLOSSARY OF GAS DETECTION TERMS

LATCHING
Refers to an activated alarm that will remain activated until user acknowledgement occurs regardless of whether the alarm condition clears.

LCO (LOOP CURRENT OFFSET)
Refers to a gas transmitter whose electronics operate at < 4 mA. This is the offset current. The standard 4-20 mA signal, or loop current, is still utilized to produce a gas reading from 0 to full scale.

LEL (LOWER EXPLOSIVE LIMIT)
The Lower Explosive Limit is the percentage of atmosphere below which the concentration of gas mixture to atmosphere is too lean to burn. This is sometimes expressed as Lower Flammable Limit (LFL).

LPM
Liters per minute, a measure of the flow of gas particularly important during calibration of sensors. 1 LPM = 1000 CCM = 2.12 SCFH.

mA
Milliamp is a unit of measure of the current of electricity. 1 mA = 0.001 Amp.

MODBUS®*
A serial communication protocol used to network electronic devices.

MOS
Metal oxide semiconductor.

NEC
National Electric Code.

NEMA
National Electrical Manufacturers Association.

** Registered trademark of Schneider Electric.*

SCOTT SAFETY

GLOSSARY OF GAS DETECTION TERMS

NIOSH
National Institute for Occupational Safety and Health.

NC (NORMALLY CLOSED
Normally Closed refers to a relay contact that removes circuit continuity when activated.

NO (NORMALLY OPEN)
Normally Open refers to a relay contact that allows circuit continuity when activated.

NON-FAILSAFE
Refers to an electronically activated circuit, such as a relay, that will remain “as is” upon a loss of power.

NON-INCENDIVE
Electrical equipment that is incapable of releasing sufficient electrical or thermal energy to cause ignition of a hazardous mixture and air under normal operating conditions. Equipment must be non-incendive to be used in Division 2 environments.

NON-LATCHING
Refers to an activated alarm that will clear without any user interaction once the alarm condition has cleared.

NRTL
Nationally Recognized Testing Laboratory.

OHM’S LAW
Ohm’s Law defines the relationships between (P) power, (E) voltage, (I) current, and (R) resistance.
P - This is the total power generated in a circuit. It is the product of current and voltage, measured in watts.
E - This is the difference in electrical potential between two points of a circuit, measured in volts. Volts are the muscle to move current.
I - This is the current, or what flows on a wire, measured in amps.
R - This is the resistance of the circuit, or what determines how much electricity can flow in a circuit. As resistance increases, current flow becomes less and vice versa. Measured in ohms.

GLOSSARY OF GAS DETECTION TERMS

OPEN PATH
A type of IR sensor technology that measures gas detection along a line of sight between a transmitter and receiver.

OSHA
Occupational Safety and Health Administration.

OXIDATION
Oxidation is a chemical reaction that results in the loss of electrons. Chemicals that cause the loss of electrons are also called oxidizing agents. The oxidation-reduction reaction is typical in an electrochemical sensor.

PEL (PERMISSIBLE EXPOSURE LEVEL)
Permissible exposure levels are the maximum concentration a worker may be exposed to as defined by OSHA (Occupational Safety and Health Administration). PELs are defined in two ways, TWA and C (C).

PFD
Probability of Failure on Demand; part of a SIL Rating.

PID (PHOTO IONIZATION DETECTOR)
A gas detection technology that uses an ultraviolet lamp to ionize the target gas and measures the ionic current between two electrodes to detect it.

POISON RESISTANT
Catalytic bead sensor's ability to remain resistant to damaging contaminants such as silicone and solvents while still continuing to detect gas.

PORTABLE GAS DETECTION SYSTEM
Typically a handheld gas detector capable of detecting 1-5 gases for use in sewers, tanks, and other locations where a fixed detector is either impractical or unable to account for the necessary space and volume needed by personnel.

GLOSSARY OF GAS DETECTION TERMS

PPB
Parts per billion. Measurement of a concentration of a gas per billion parts. 1 ppb = 0.001 ppm.

PPM
Parts per million. Measurement of a concentration of a gas per million parts. 1 ppm = 1000 ppb or 1 ppm = 0.0001% of sample concentration.

PELLISTOR
See Catalytic Bead.

PROCESS
A series of operations performed in the making, treating, or developing of a product.

PROGRAMMABLE LOGIC CONTROLLER (PLC)
A digital computer used for automation of electromechanical processes. PLCs typically accept numerous inputs and provide multiple outputs.

PROTON
A particle that carries a positive electric charge.

QAR
Quality Assessment Report; part of the IECEx Scheme.

RECEPTOR POINT
Location where hazardous gases cause a threat to personnel, property, or facilities.

RELEASE POINT
Location where hazardous gases can potentially be released.

RELATIVE DENSITY
Ratio of the density of gas compared with ambient atmosphere. Greater than 1.0 indicates the gas is heavier than air.

GLOSSARY OF GAS DETECTION TERMS

REMOTE ALARM RESET
An option sometimes available on either a fixed gas detector or controller that allows users to acknowledge an alarm or deactivate a relay switch from a remote location.

RFI (RADIO FREQUENCY INTERFERENCE
Electrical interference from unwanted reception of radio signals originating from any number of wireless communication devices. RFI can be a particular problem in circuits with low current such as 4-20 mA or in relay protection circuits as the signal noise generated from RFI can cause false readings, alarms, or relay activation.

RRF
Risk reduction factor; part of a SIL rating.

RS-232
A digital form of communication over a networked interface. Allows for a single point to point communication over a distance of 50 or less feet.

RS-485
A digital form of communication over a networked interface. Allows for multiple point to point communications of up to 32 devices over a distance of up to 4000 feet.

SCC
Standards Counsel of Canada.

SCFH
Standard cubic feet per hour, a measure of the flow of gas particularly important during calibration of sensors and determining the applicability of duct mounted gas detection. 2.12 SCFH = 1000 CCM = LPM.

SENSOR HEAD
A part of a fixed gas detection system that facilitates the electrical interface of the sensor with the transmitter or controller. May be mounted remotely or affixed to a transmitter.

GLOSSARY OF GAS DETECTION TERMS

SIL (RATING)
Safety Integrity Level, a safety level rating as defined by the standard IEC 61511 or EN 61511. The level is determined by analyzing the safety function of separate and combination gas detection systems and the risk reduction they create to the safety hazards.

STEL (SHORT TERM EXPOSURE LIMIT)
Short term exposure limit is defined by ACGIH (American Conference of Governmental Industrial Hygienists) as the concentration to which workers can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage, or narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or reduce work efficiency.

T90
Time it takes a sensor to respond to 90% of full reading when exposed to target gas.

TLV (THRESHOLD LIMIT VALUE)
Threshold limit values are established by the ACGIH (American Conference of Governmental Industrial Hygienists). They are the levels to which a worker can be exposed to a chemical each day for a working lifetime without adverse health concerns. These limits are guidelines and not regulated by law.

TOXIC
Refers to a gas whose primary hazard is as a breathing contaminant or poison. It is important to note many gases have both combustible and toxic properties.

TRANSMITTANCE
Measurement of the intensity of infrared radiation that has passed through gas molecule.

TRANSMITTER
A device that receives, displays, and transmits the electronic signals from gas sensors.

TRIP HIGH
A set point that causes the activation of an alarm or relay when a gas reading exceeds a certain value.

GLOSSARY OF GAS DETECTION TERMS

TRIP LOW
A set point that causes the activation of an alarm or relay when a gas reading falls below a certain value.

TWA (TIME WEIGHTED AVERAGE)
Time weighted average is an average value of exposure over the course of an 8 hour work shift.

UEL (UPPER EXPLOSIVE LIMIT)
The Upper Explosive Limit is the percentage of atmosphere at which the concentration of gas mixture to atmosphere is too rich to burn. This is sometimes expressed as UFL (Upper Flammable Limit).

UL
Underwriters Laboratories, a certifying agency for the electrical safety of devices; including those used in hazardous atmospheres.

ULTRAVIOLET
Radiation emitted as part of the electromagnetic spectrum with a wavelength shorter than visible light.

VAPOR
A gaseous compound in equilibrium with its liquid or solid phase.

VAPOR DENSITY
A measure of the density of a gas or vapor relative to ambient air (Vapor Density 1.0) Those gases or vapors with densities > 1.0 will settle at lower elevations. Those gases or vapors with densities < 1.0 will settle at higher elevations.

VAPOR PRESSURE
The pressure of the vapor in equilibrium with its liquid or solid phase at the given temperature. As temperature increases, the vapor pressure increases nearly exponentially with temperature.

GLOSSARY OF GAS DETECTION TERMS

VOC
Volatile organic compound.

VOTING CONFIGURATION
A fixed gas detection system set up to activate alarm functions only when a preconfigured set of values has been reached on multiple points of detection; helps to reduce false alarm conditions.

ZONED CONFIGURATION
A fixed gas detection system set up to cover a large surface area with multiple points of detection; useful when release points cannot be easily predicted.

ZONE
Zone is the international method of specifying the probability that a location is made hazardous by the presence, or potential presence, of flammable concentrations of gases and vapors.

Scott Safety continues to build and forge sustained partnerships with our customers to understand and meet their individual needs. We recognize the importance of industry best practices and certify our products through intensive testing to be of the highest quality. We are focused on developing new technologies to make workers safer each and every day, and we take pride in doing it.

Visit our website at **www.scottsafety.com** or contact us at 1.800.247.7257 to learn more about the products and services we offer. Scott Safety is ready to share our experience and provide solutions to our customers.

SCOTT SAFETY

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