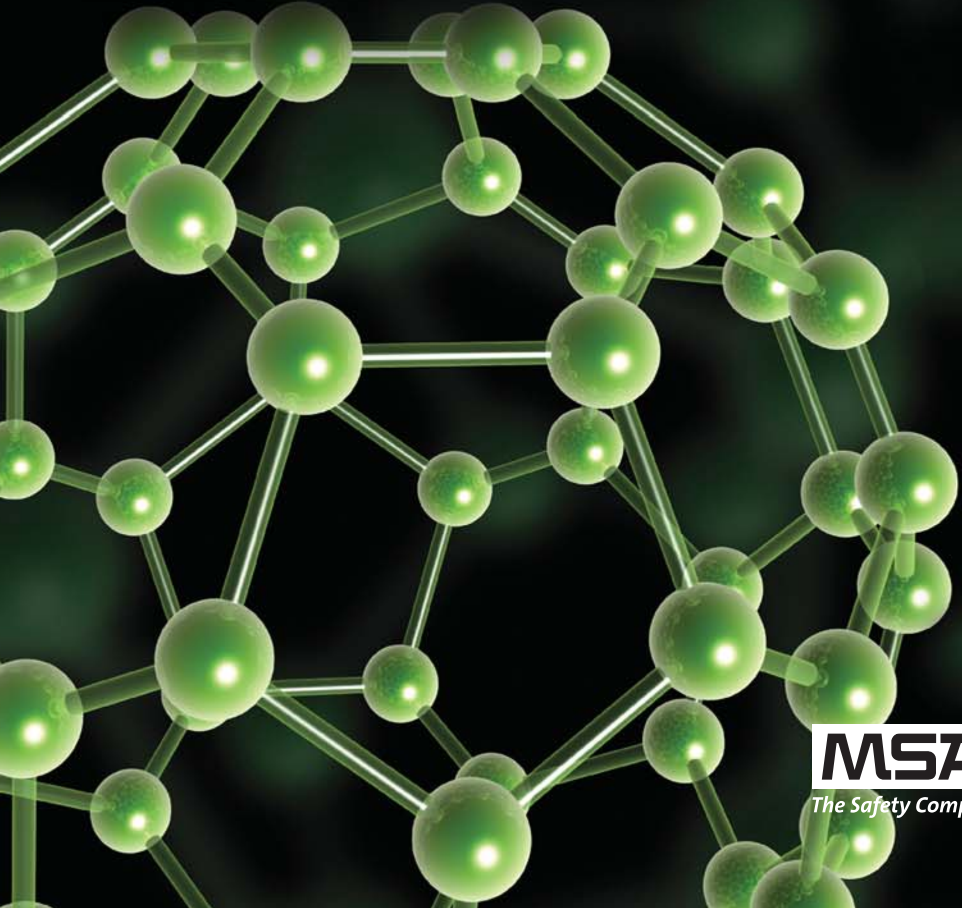
Gas Detection

HANDBOOK

Fifth Edition

Key concepts &
reference material
for permanently installed
gas monitoring systems



MSA
The Safety Company

The MSA Gas Detection Handbook is designed to introduce users to key terms and concepts in gas detection and to serve as a quick reference manual for information such as specific gas properties, exposure limits and other data.

The **Handbook** contains:

- a glossary of essential gas detection terms and abbreviations.
- a summary of key principles in combustible and toxic gas monitoring.
- reference data—including physical properties and exposure limits—for the most commonly monitored gases, in industrial and various other environments.
- a comparison of the most widely-used gas detection technologies.
- a table indicating the gas hazards common to specific applications within major industries.
- a summary of key gas detection instrumentation approvals information, including hazardous locations classification.
- MSA's exclusive Sensor Placement Guide, detailing important factors to take into consideration when determining optimum gas sensor placement.

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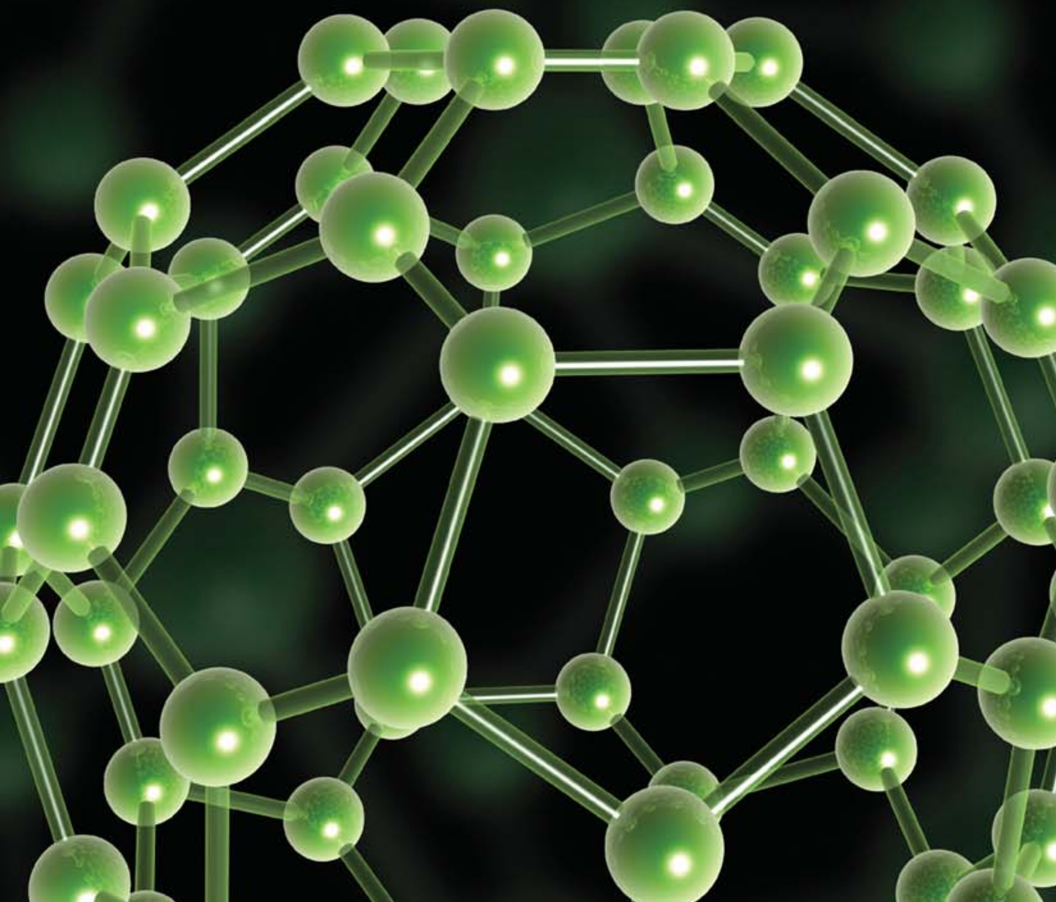
Gas Detection Terms & Abbreviations



Gas Detection Terms & Abbreviations

ACGIH - American Conference of Governmental Industrial Hygienists.

Alarm Set Point - The selected gas concentration level at which an alarm is activated.

Ambient air - Surrounding air to which the sensing element is normally exposed in its installed position.

Asphyxiant - A substance that impairs normal breathing by displacing oxygen.

Atmosphere - The total gases, vapors, mists and fumes present in a specific location.

Autoignition Temperature [also "spontaneous ignition temperature" (SIT) - The minimum temperature at which a combustible substance (gas, vapor, liquid or solid) will ignite and sustain combustion under its own heat energy.

Bump Check (Functional Test) - Procedure used to verify the response of an instrument which does not include actual adjustment. (also known as "Span Check")

Calibration - Procedure by which the performance of a detector is verified to maximize the accuracy of its readings. A calibration is performed by: (1) comparing the instrument with a known standard, and (2) adjusting the instrument reading to match the standard.

Calibration Gas (also "Span Gas") - A known concentration of gas that is used to set instrument accuracy.

Ceiling - The maximum gas concentration to which a worker may be exposed.

Combustible Gas* - A gas that is capable of igniting and burning.

Combustion - The rapid oxidation of a substance involving heat and light.

Confined Space - An area that is large enough for an employee to bodily enter and perform work, has limited or restricted areas of entry or exit, and is not designed for continuous human occupancy.

** Any material that will burn at any temperature is considered to be "combustible", so this term covers all such materials, regardless of how easily they ignite. The term "flammable" specifically refers to those combustible gases that ignite easily and burn rapidly.*

Gas Detection Terms & Abbreviations

Controller - The part of a gas detector that provides centralized processing of the gas signal. The controller receives and responds to the electrical signal from the sensor to output an indication, alarm or other function.

Cross Sensitivity - The predictable response of a detector to compounds other than the target gas.

Dew Point - The temperature at which a gas (air) is saturated with a condensable component.

Diffusion - Process by which particles spread from regions of higher concentration to regions of lesser concentration as a result of random molecular movement. Also used to describe the process by which the atmosphere being monitored is transported to the gas-sensing element by natural random molecular movement.

Electrochemical Sensor - A sensor that uses an electrochemical reaction to provide an electrical output proportional to the measured gas concentration.

Explosion - Rapid uncontrolled combustion process which generates a high temperature, a large volume of gas, and a pressure or shock wave.

Explosionproof (XP) - Method of protection in which an explosion in a hazardous location is prevented by containing any combustion within the device, and thereby, preventing it from spreading into the atmosphere surrounding the enclosure.

Explosive (or "Flammable") Limits - Though a flammable liquid can support combustion at its flash point temperature, to sustain it requires the vapor concentration to be between two specific levels, or "flammable limits", the lower flammable limit and the upper flammable limit. (see below) Any gas or vapor concentration that falls between these two limits is in the flammable range.

- Lower Explosive (or "Flammable") Limit (LEL) - the minimum concentration of a vapor (usually expressed as the percentage of material in air) required to sustain a fire.
- Upper Explosive (or "Flammable") Limit (UEL) - the maximum concentration of a vapor (usually expressed as the percentage of material in air) beyond which a fire cannot be sustained, as the amount of oxygen would be insufficient to continue the fire.

Gas Detection Terms & Abbreviations

Explosive (or "Flammable") Range - The range that encompasses any gas or vapor concentration between the substance's lower explosive limit and upper explosive limit, and is therefore capable of sustaining combustion.

Flammable Gas* - This term applies to a special group of combustible gases that ignite easily and burn rapidly.

Flash Point - The minimum temperature at which a liquid gives off enough vapor to form an ignitable mixture with air (reaching 100% LEL).

Gas - A state of matter characterized by very low density and viscosity (relative to liquids and solids), comparatively great expansion and contraction with changes in pressure and temperature, ability to diffuse readily into other gases, and ability to occupy with almost complete uniformity the whole of any container. (Often used interchangeably with "vapor".)

Gas Detection Instrument - A device composed of electrical, optical, mechanical or chemical components that senses and responds to the presence of gas mixtures.

General Purpose (GP) Enclosure - An enclosure intended for indoor use in non-hazardous rated areas, primarily to prevent accidental contact of personnel with the enclosed equipment in areas where unusual service conditions do not exist.

Hazardous Atmosphere - (As defined by OSHA 29 CFR 1910.146) An atmosphere in which workers are exposed to the risk of death, injury, incapacitation or illness.

Humidity - The amount of water vapor present in the atmosphere.

IDLH (Immediately Dangerous to Life and Health)**
The maximum concentration level of a substance (gas) from which a worker could escape within 30 minutes without developing immediate, severe or irreversible health effects, or other escape-impairing symptoms. IDLH levels are measured in ppm (parts per million).

***As defined by NIOSH (National Institute for Occupational Safety and Health).*

** Any material that will burn at any temperature is considered to be "combustible", so this term covers all such materials, regardless of how easily they ignite. The term "flammable" specifically refers to those combustible gases that ignite easily and burn rapidly.*

Gas Detection Terms & Abbreviations

Interferent - Any gas other than the target gas that will cause a response from a gas sensor.

Intrinsic Safety (IS) - A method of protection in which an explosion is prevented through an electrical design using energy storage devices in which the possibility of ignition is eliminated.

LEL (Lower Explosive Limit) - (see “Explosive Limits”)

Monitor - An instrument used to continuously measure a condition that must be kept within specific limits.

NIOSH - National Institute for Occupational Safety and Health.

OSHA - United States Department of Labor Occupational Safety and Health Administration.

Oxygen Deficient Atmosphere - An atmosphere containing less than 19.5% oxygen by volume. (Possesses a risk of insufficient oxygen for breathing.)

Oxygen Enriched Atmosphere - An atmosphere containing more than 20.8% oxygen by volume. (Possesses an increased risk of explosion.)

PEL (Permissible Exposure Limit) - An airborne concentration of contaminant that most workers can be exposed to repeatedly in a normal 8- hour day, in a 40-hour week, without adverse health effects. PEL levels are measured in ppm (parts per million) and are established by OSHA.

Permanent (or Fixed) Gas Monitor - A gas monitor that is permanently installed in a location.

PPM (Parts Per Million) - The most common unit of measurement for toxic gases. A “10,000 parts per million” gas concentration level equals a 1% by volume exposure.

Relative Density - The density of a gas as compared to that of another gas (typically air). In gas detection, relative density is used to assist in determining optimum sensor placement. If the relative density of the monitored gas is less than 1, then it will tend to rise in air; if the relative density is greater than 1 then it will tend to sink in air and accumulate at ground level.

Gas Detection Terms & Abbreviations

Sensor - The part of a gas detector that converts the presence of a gas or vapor into a measurable signal.

Smart Sensor - Sensor that contains a microprocessor, allowing it to record data, communicate with other devices or control devices such as relays.

Span Check - (see “Bump Check”).

STEL - Short-term exposure limit (See “TLV - STEL”).

TLV® (Threshold Limit Value)* - Refers to the airborne concentration of substances and represents conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.
** As defined by the ACGIH (American Conference of Governmental Industrial Hygienists).*

There are three categories of TLVs:

> **TLV - TWA (Time Weighted Average)** - This is the average amount of gas that a worker can be repeatedly exposed to in a normal 8-hour day, in a 40-hour week, without adverse health effects.
>
> **TLV - STEL (Short Term Exposure Limit)** -The gas concentration that most workers can be continuously exposed to for a 15-minute time period without suffering adverse health affects that would impair self-rescue or worker safety. This limit should not be repeated more than 4 times per day and there should be at least 60 minutes between individual STEL exposure periods.
>
> **TLV - C (Ceiling)** - The highest gas concentration to which workers may be exposed. Ceiling TLVs should never be exceeded and they take precedence over all TWAs and STELs.

Toxic Atmosphere - An atmosphere in which the concentration of gases, dusts, vapors or mists exceeds the permissible exposure limit (PEL).

Toxic Gas or Vapor - Substance that causes illness or death when inhaled or absorbed by the body in relatively small quantities.

Gas Detection Terms & Abbreviations

True Zero - A reading indicating that no amount of target gas is present in the sample. Also known as “baseline”.

TWA - Time-weighted average (see “TLV-TWA”).

UEL (Upper Explosive Limit) - (see “Explosive Limits”).

Vapor - Often used interchangeably with “gas”; vapor is generally used to refer to the gaseous phase of a substance that generally exists as a liquid or solid at room temperature, while “gas” is more commonly used to refer to a substance that generally exists in the gaseous phase at room temperature.

Vapor Density - the weight of a volume of pure gas or vapor compared to that of an equal volume of air at the same temperature and pressure. A vapor density of less than 1 indicates that the gas or vapor is lighter than air and will tend to rise. A vapor density of greater than 1 indicates that the vapor is heavier than air and will tend to accumulate closer to the ground. It may also move a significant distance at these low levels to a source of ignition and then flash back to the original location once ignited. When using vapor density to determine optimum sensor placement, other factors such as air flow patterns and temperature gradients should also be considered.

Vapor Pressure - The pressure exerted when a solid or liquid is in equilibrium with its own vapor. Vapor pressure is directly related to temperature. In gas detection, this is significant because the higher the vapor pressure of a substance, the greater the amount of it that will be present in vapor phase at a given temperature, and thus a greater degree of gas hazard exists.

Zero Check - Check performed to verify that the instrument reads true zero.

Zero Gas - A cylinder of gas that is free of the gas of interest and interferents. It is used to properly zero an instrument’s base line.

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Gas Monitoring Categories
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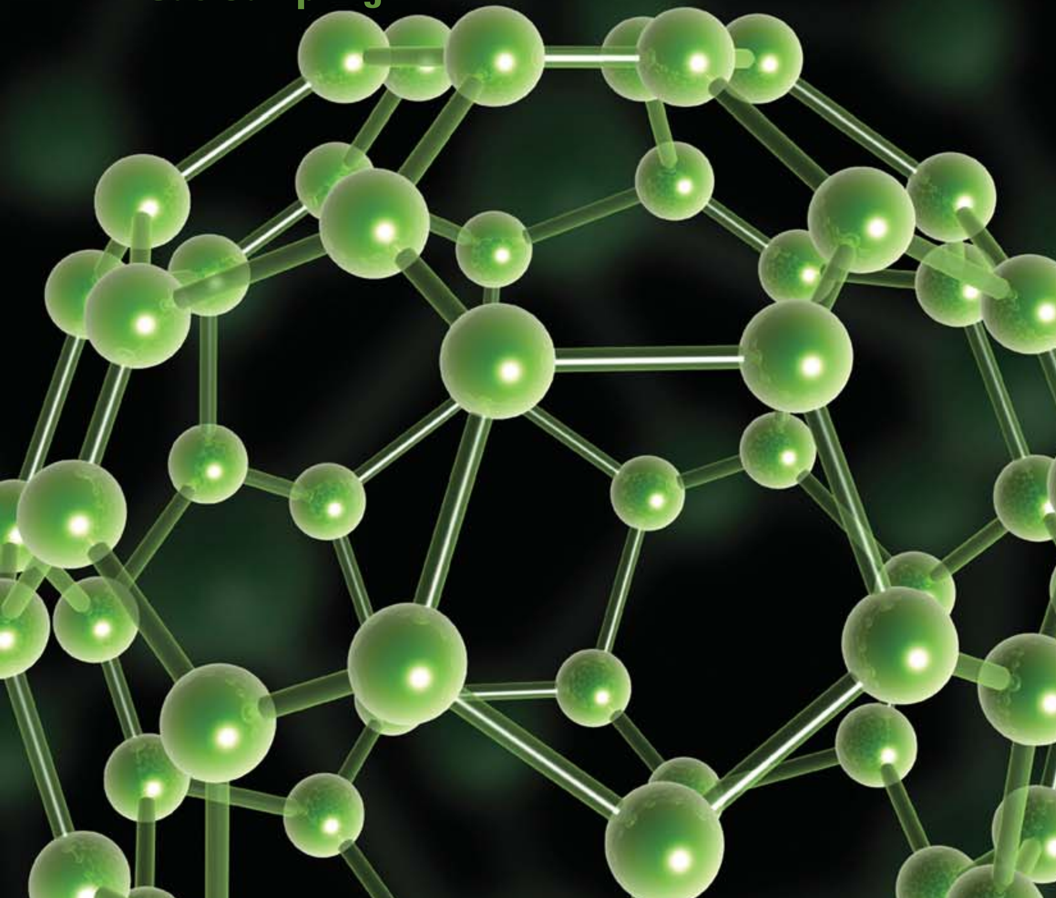


The Four Main Types of Gas Hazards

The following table summarizes the four main reasons why gas monitoring is performed:

Type of Monitoring	The Purpose	The Hazard	Possible Source of Hazard
Personal protection	Worker safety	Toxic gases	Leaks, fugitive emissions, industrial process defects
Explosive	Worker and facility safety	Explosions	Presence of combustible gases/vapors due to leaks, industrial process defects
Environmental	Environmental safety	Environmental degradation	Oil leaks into sewers or lakes, Acid gas emissions
Industrial process	Process control	Malfunction of the process	Possible fault or other process error

Gas Monitoring Categories

Gas Monitoring Categories:

1. Combustible/ Flammable Gas

- Explosive hazard.
- To avoid an explosion, atmospheric levels must be maintained below the lower explosive limit (LEL) for each gas, or purged of oxygen.
- Generally measured as 0-100% of the lower explosive limit or in part per million range.
- Combustible gas monitors are designed to alarm before a potential explosive condition occurs.

2. Toxic/ Irritant Gases

- Hazardous to human health; worker exposure must be monitored.
- Typically measured in the part per million (ppm) range.
- Toxic gas monitors are designed to alert workers before the gas level reaches a harmful concentration.
- Some toxic gas monitors can calculate the average exposure over time, providing short-term exposure limit (STEL) and time-weighted average (TWA) readings.

3. Oxygen

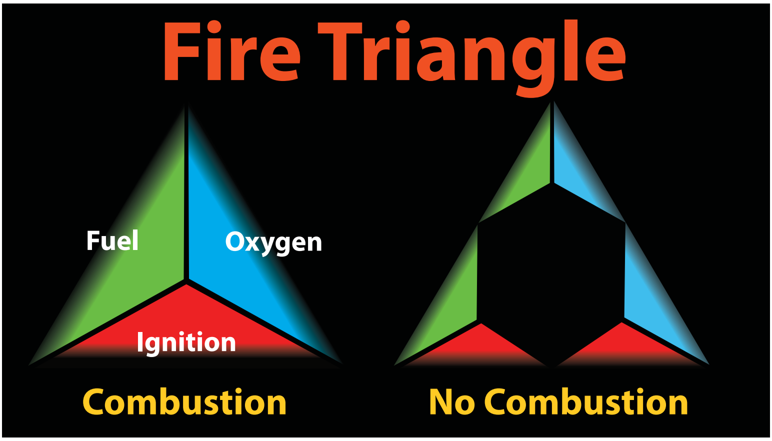
- Atmospheres containing too little oxygen (less than 19.5% oxygen by volume) are considered “oxygen deficient” and interfere with normal human respiration.
- Atmospheres containing too much oxygen (more than 25% oxygen by volume) are considered “oxygen enriched” and possess an increased risk of explosion.
- Measured in the percent volume range (normal oxygen percentage in air is 20.8% by volume at sea level).
- Oxygen monitors are generally set to alarm if the atmosphere contains either too little or too much oxygen.

Combustible Atmospheres

Combustible Atmospheres

In order for a flame to exist, three conditions must be met. There must be:

- A source of fuel (e.g. methane or gasoline vapors).
- Enough oxygen (greater than 10-15%) to oxidize or burn the fuel.
- A source of heat (ignition) to start the process.



Examples of Heat and Ignition Sources

- Open flames such as those from lighters, burners, matches and welding torches are the most common sources of ignition.
- Radiation in the form of sunlight or coming from hot surfaces.
- Sparks from various sources such as the switching on or off of electric appliances, removing plugs, static electricity or switching relays.

Combustible Atmospheres

Combustible Atmosphere Factors

Vapor vs. Gas

Though often used interchangeably, the terms "vapor" and "gas" are not identical. The term "vapor" is used to refer to a substance that, though present in the gaseous phase, generally exists as a liquid or solid at room temperature. When we say that a liquid or solid substance is burning, it is actually its vapors that burn. "Gas" refers to a substance that generally exists in the gaseous phase at room temperature.

Vapor Pressure and Boiling Point

Vapor pressure is the pressure exerted when a solid or liquid is in equilibrium with its own vapor. It is directly related to temperature. An example of vapor pressure is the pressure developed by the vapor of a liquid in a partially-filled closed container. Depending on temperature, the vapor pressure will increase up to a certain threshold. When this threshold is reached, the space is considered to be saturated.

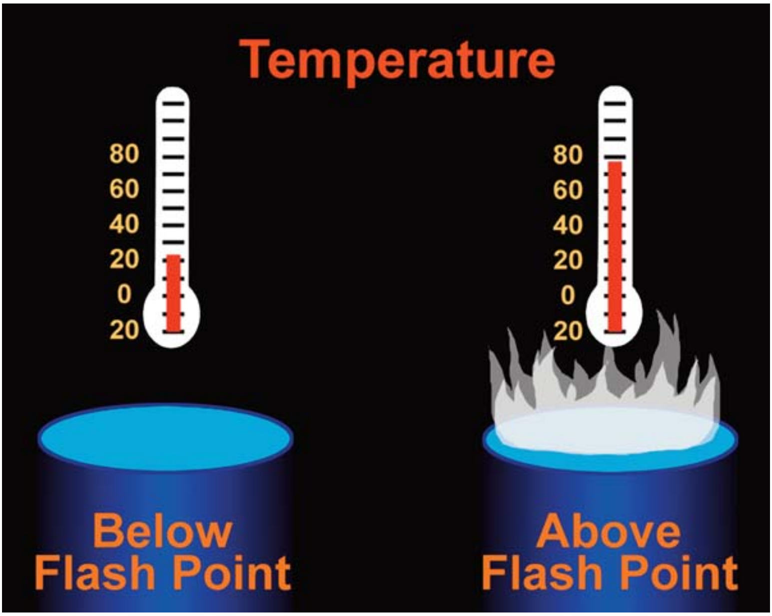
The vapor pressure and boiling point of a chemical determine how much of it is likely to become airborne. Low vapor pressure means there are less molecules of the substance to ignite, so there is generally less of a hazard present. This also means that there are less molecules to sense, which may make detection more challenging and require higher-sensitivity instrumentation. With higher vapor pressure and a lower boiling point, there is a greater likelihood of evaporation. If containers of chemicals with such properties are left open, or if they're allowed to spread over large surfaces, they are likely to cause greater hazards.

Flashpoint

A flammable material will not give off an amount of gas or vapor sufficient to start a fire until it is heated to its flashpoint. Flashpoint is defined as the lowest temperature at which a liquid produces sufficient vapor to produce a flame. If the temperature is below this point, the liquid will not produce enough vapor to ignite. If the flashpoint is reached and an external source of ignition such as a spark is provided, the material will catch fire. The National Fire Protection Agency's NFPA's document NFPA-325M, *Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solvents,* lists the flashpoints of many common substances. See www.nfpa.org.

Combustible Atmospheres

Flash points are significant because they give an indication of the degree of hazard presented by a flammable liquid. Generally, the lower the flash point, the easier it is for flammable fuel-air mixtures to form, and thus the greater hazard.



Autoignition Temperature

If heated to a certain point—the spontaneous ignition (or “autoignition”) temperature—most flammable chemicals can spontaneously ignite under its own heat energy, without an external source of ignition.

Combustible Atmospheres

Vapor Density

Vapor density is the weight ratio of a volume of flammable vapor compared to an equal volume of air. Most flammable vapors are heavier than air so they gravitate toward the ground, settling in low areas. A gas or vapor with a vapor density greater than 1 may travel at low levels to find a source of ignition (e.g. hexane, which has a 3.0 vapor density); a gas or vapor with a vapor density less than 1 will tend to rise (e.g. methane, which has a 0.6 vapor density). Vapor density is important to consider when determining optimum sensor placement because it helps predict where the gas or vapor is most likely to accumulate in a room or area.

Explosive Limits

To produce a flame, a sufficient amount of gas or vapor must exist. But too much gas can displace the oxygen in an area and fail to support combustion. Because of this, there are limits at both low-end and high-end gas concentrations where combustion can occur. These limits are known as the Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL). They are also referred to as the Lower Flammability Limit (LFL) and the Upper Flammability Limit (UFL).

To sustain combustion, the atmosphere must contain the correct mix of fuel and oxygen (air). The LEL indicates the lowest quantity of gas which must be present for combustion and the UEL indicates the maximum quantity of gas. The actual LEL level for different gases may vary widely and are measured as a percent by volume in air. Gas LELs and UELs can be found in NFPA 325.

LELs are typically 1.4% to 5% by volume. As temperature increases, less energy is required to ignite a fire and the percent gas by volume required to reach 100% LEL decreases, increasing the hazard. An environment containing enriched oxygen levels raises the UEL of a gas, as well as its rate and intensity of propagation. Since mixtures of multiple gases add complexity, their exact LEL must be determined by testing.

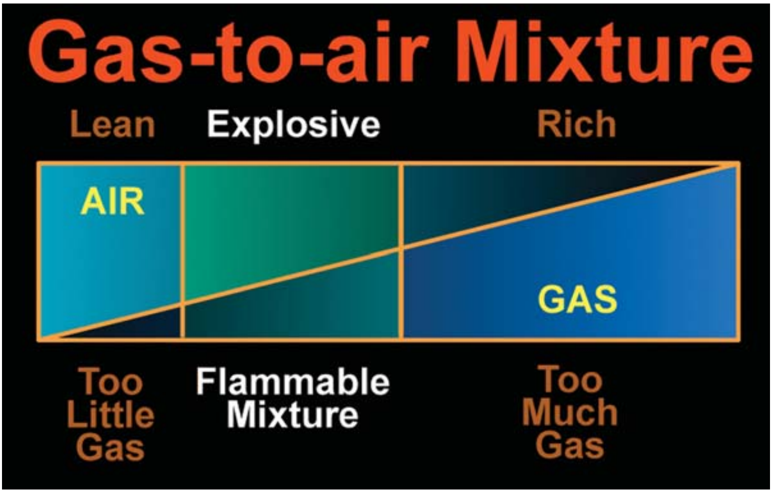
Most combustible gas instruments measure in the LEL range and display gas readings as a percentage of the LEL. For example: a 50% LEL reading means the sampled gas mixture contains one-half of the amount of gas necessary to support combustion.

Combustible Atmospheres

Gas Type	100% LEL	UEL
Methane	5.0% gas by volume	15.0% gas by volume
Hydrogen	4.0% gas by volume	75.0% gas by volume
Propane	2.1% gas by volume	9.5% gas by volume
Acetylene	2.5% gas by volume	100% gas by volume

Any gas or vapor concentration that falls between these two limits is in the flammable (explosive) range. Different substances have different flammable range widths — some are very wide and some are narrower. Those with a wider range are generally more hazardous since a larger amount of concentration levels can be ignited.

Atmospheres in which the gas concentration level is below the LEL (insufficient fuel to ignite) are referred to as too "lean" to burn; those in which the gas level is above the UEL (insufficient oxygen to ignite) are too "rich" to burn.



Toxic Atmospheres

Toxic Gas Monitoring

A toxic gas is one which is capable of causing damage to living tissue, impairment of the central nervous system, severe illness or—in extreme cases—death, when ingested, inhaled or absorbed by the skin or eyes. The amounts required to produce these results vary widely with the nature of the substance and exposure time. "Acute" toxicity refers to exposure of short duration, such as a single brief exposure. "Chronic" toxicity refers to exposure of long duration, such as repeated or prolonged exposures.

Toxic gas monitoring is important because some substances can't be seen or smelled and have no immediate effects. Thus the recognition of a gas hazard via a worker's senses often comes too late, after concentrations have reached harmful levels.

The toxic effects of gases range from generally harmless to highly toxic. Some are life-threatening at even short, low-level exposures, while others are hazardous only upon multiple exposures at higher concentrations. The degree of hazard that a substance poses to a worker depends upon several factors which include the gas concentration level and the duration of exposure.

Exposure Limits

The American Conference of Governmental Industrial Hygienists (ACGIH) publishes an annually revised list of recommended exposure limits for common industrial compounds, titled "TLV"s and BEI"s Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices". (To order a copy, see www.acgih.org). ACGIH developed the concept of Threshold Limit Value" (TLV), which is defined as the airborne concentration of a contaminant to which it is believed that almost all workers may be repeatedly exposed, day after day, over a working lifetime without developing adverse effects. These values are based on a combination of industrial experience and human and animal research.

Time Weighted Averages (TWAs)

TLVs are generally formulated as 8-hour time-weighted averages. The averaging aspect enables excursions above the prescribed limit as long as they are offset by periods of exposure below the TLV.

Toxic Atmospheres

Short-Term Exposure Limits (STELs)

Short-term exposure limits are concentrations above the 8-hour average to which workers may be exposed for short periods of time without harmful effects. (If the concentration is high enough, even a one-time exposure can produce harmful health effects.) STELs are used to govern situations in which a worker is exposed to a high gas concentration, but only for a short period of time. They are defined as 15-minute time-weighted averages that are not to be exceeded even if the 8-hour TWA is below the TLV.

Ceiling Concentrations

For some toxic gases, a single exposure exceeding the TLV may be hazardous to worker health. In these cases, ceiling concentrations are used to indicate levels that are never to be exceeded.

Permissible Exposure Limits (PELs)

PELs are enforced by the Occupational Safety and Health Administration (OSHA). Part 29 of the Code of Federal Regulations (CFR) Section 1910.1000 contains these standards, which are similar to ACGIH TLVs except that they are legally enforceable rather than simply recommendations. However, the most accurate PELs are listed in the associated Material Safety Data Sheets (MSDS).

Immediately Dangerous to Life and Health (IDLH)

The National Institute for Occupational Safety and Health (NIOSH) defines an IDLH exposure condition atmosphere as one that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment. Since IDLH values exist to ensure that a worker can escape from a hazardous environment in the event of failure of respiratory protection equipment, they are primarily used to determine appropriate respiratory selection in compliance with OSHA standards.

Toxic Atmospheres

Web resources:

ACGIH: http://www.acgih.org/TLV

OSHA: http://www.osha.gov

NIOSH: http://www.cdc.gov/niosh/homepage.html

Gas detection systems are used to monitor toxic gases in primarily two types of monitoring applications:

1. Ambient air monitoring (includes leak monitoring)
    - low-level gas detection for worker safety
    - to reduce leakage of expensive compounds (e.g., refrigerants)

2. Process monitoring
    - to monitor levels of compounds used in chemical synthesis processes (e.g., in the plastics, rubber, leather and food industries)
    - from low ppm levels to high % by volume levels

For toxic gas monitoring, electrochemical, metal oxide semiconductor (solid state), infrared and photoionization are the sensing technologies most commonly used.

Oxygen Deficiency/Enrichment

Oxygen Deficiency

Normal ambient air contains an oxygen concentration of 20.8% by volume. When the oxygen level dips below 19.5% of the total atmosphere, the area is considered oxygen deficient. In oxygen-deficient atmospheres, life-supporting oxygen may be displaced by other gases, such as carbon dioxide. This results in an atmosphere that can be dangerous or fatal when inhaled. Oxygen deficiency may also be caused by rust, corrosion, fermentation or other forms of oxidation that consume oxygen. As materials decompose, oxygen is drawn from the atmosphere to fuel the oxidation process.

The impact of oxygen deficiency can be gradual or sudden, depending on the overall oxygen concentration and the concentration levels of other gases in the atmosphere. Typically, decreasing levels of atmospheric oxygen cause the following physiological symptoms:

% Oxygen	Physiological Effect
19.5 - 16	No visible effect.
16 - 12	Increased breathing rate. Accelerated heartbeat. Impaired attention, thinking and coordination.
14 – 10	Faulty judgment and poor muscular coordination. Muscular exertion causing rapid fatigue. Intermittent respiration.
10 – 6	Nausea and vomiting. Inability to perform vigorous movement, or loss of the ability to move. Unconsciousness, followed by death.
Below 6	Difficulty breathing. Convulsive movements. Death in minutes.

Oxygen Enrichment

When the oxygen concentration rises above 20.8% by volume, the atmosphere is considered oxygen-enriched and is prone to becoming unstable. As a result of the higher oxygen level, the likelihood and severity of a flash fire or explosion is significantly increased.

Gas Detection Technologies

Gas Detection Technologies

There are a variety of gas detection technologies in use today. Among the most commonly employed are:

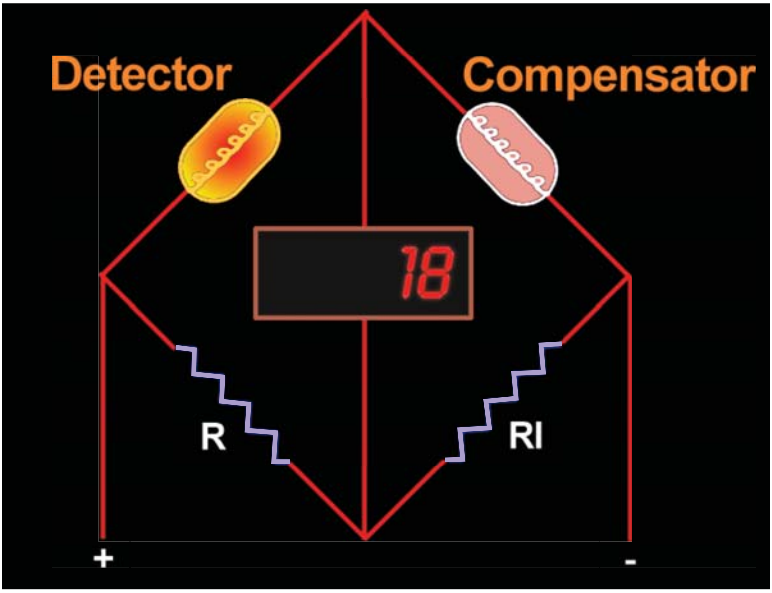
- Catalytic Bead
- Metal Oxide Semiconductor (also known as “solid state”)
- Point Infrared Short Path
- Open (Long Path) Infrared
- Photoacoustic Infrared
- Electrochemical for Toxic Gas Detection
- Electrochemical for Oxygen Detection
- Thermal Conductivity
- Photoionization
- NDIR

The tables and diagrams on the following pages summarize the operation of each technology.

Gas Detection Technologies

Technology	Catalytic bead
Gas Type Detected	Combustible gas
Principle of Operation	Uses a catalytic bead to oxidize combustible gas; a Wheatstone Bridge converts the resulting change in resistance into a corresponding sensor signal.
Description - Detailed	A wire coil is coated with a catalyst-coated glass or ceramic material, and is electrically heated to a temperature that allows it to burn (catalyze) the gas being monitored, releasing heat and increasing the temperature of the wire. As the temperature of the wire increases, so does its electrical resistance. This resistance is measured by a Wheatstone Bridge circuit and the resulting measurement is converted to an electrical signal used by gas detectors. A second sensor, the compensator, is used to compensate for temperature, pressure and humidity.
Readings	% LEL
Pros	Long life, less sensitive to temperature, humidity, condensation and pressure changes; high accuracy; fast response; monitors a wide range of combustible gases and vapors in air.
Cons	Subject to sensor poisoning; requires air or oxygen; shortened life with frequent or continuous exposure to high LELs.

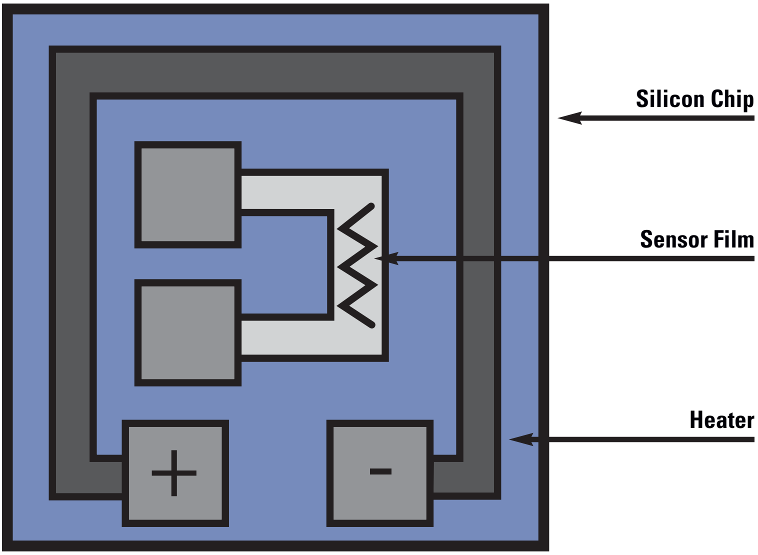
Typical Catalytic Bead Sensor Operation



Gas Detection Technologies

Technology	Metal Oxide Semiconductor
Gas Type Detected	Combustible gas; Toxic gas
Principle of Operation	Made of a metal oxide that changes resistance in response to the presence of a gas; this change is measured and translated into a concentration reading.
Description - Detailed	A semiconducting material (metal oxide) is applied to a non-conducting substance (substrate) between two electrodes. The substrate is heated to a temperature at which the presence of the gas can cause a reversible change in the conductivity of the semi-conducting material. When no gas is present, oxygen is ionized onto the surface and the sensor becomes semi-conductive; when molecules of the gas of interest are present, they replace the oxygen ions, decreasing the resistance between the electrodes. This change is measured electrically and is proportional to the concentration of the gas being measured.
Readings	PPM
Pros	High sensitivity (detects low concentrations); wide operating temperature range; long life.
Cons	Non-specific (cross-sensitive to other compounds); nonlinear output; sensitive to changes in humidity: subject to poisoning.

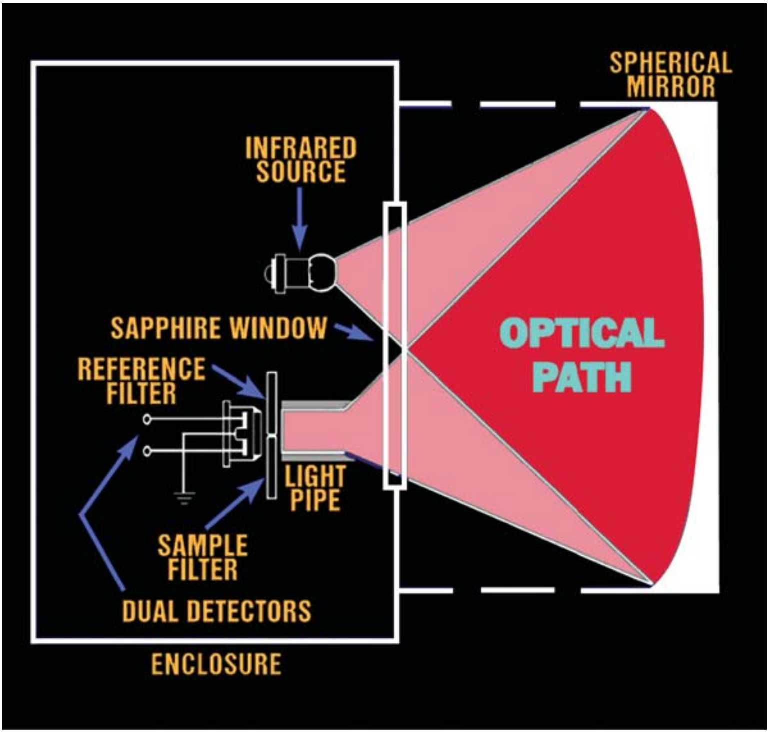
Typical Metal Oxide Semiconductor (Solid State) Sensor Operation



Gas Detection Technologies

Technology	Point Infrared Short Path
Gas Type Detected	Combustible gas
Principle of Operation	[Also referred to as Non-Dispersive Infrared (NDIR)]; Absorptive IR uses a gas ability to absorb IR radiation. Two gas samples--the gas of interest, and an inert reference gas--are exposed to infrared light. The amount of light transmitted through each sample is compared to determine the concentration of the gas of interest.
Description - Detailed	Uses an electrically modulated source of infrared energy and two detectors that convert the infrared energy into electrical signals. Each detector is sensitive to a different range of wavelengths in the infrared portion of the spectrum. The source emission is directed through a window in the main enclosure into an open volume. A mirror may be used at the end of this volume to direct the energy back through the window and onto the detectors. The presence of a combustible gas will reduce the intensity of the source emission reaching the analytical detector, but not the intensity of emission reaching the reference detector. The microprocessor monitors the ratio of these two signals and correlates this to a %LEL reading.
Readings	% LEL
Pros	High accuracy and selectivity; large measurement range; low maintenance; highly resistant to chemical poisons; does not require oxygen or air; span drift potential virtually eliminated (no routine calibration required); fail-to-safe. Compared to open-path IR, provides exact gas level (but at point of detection only).
Cons	Not suitable for hydrogen detection.

Typical Point Infrared Short Path Operation

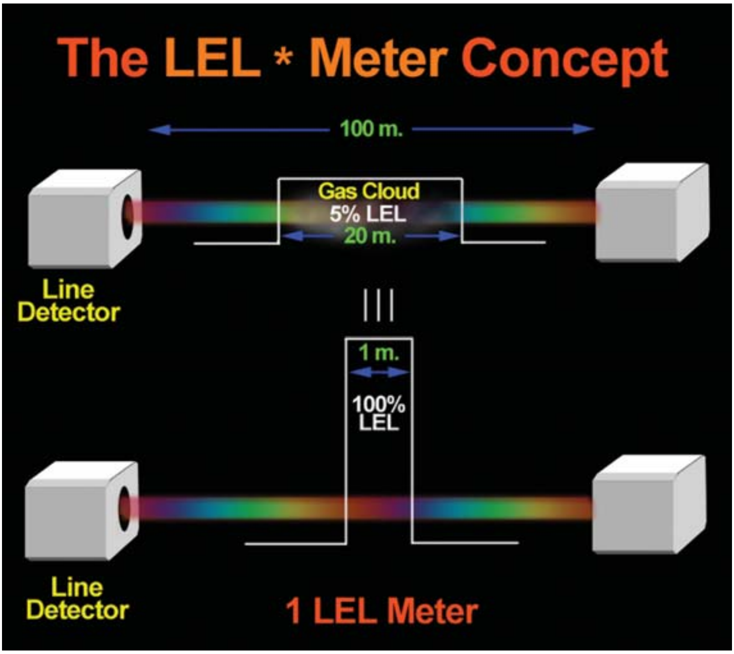


Gas Detection Technologies

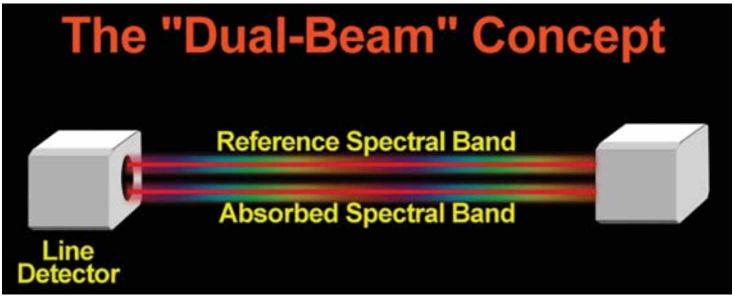
Technology	Open Path Infrared
Gas Type Detected	Combustible gas
Principle of Operation	Operates similarly to point infrared detectors, except that the IR source is separated from the detector.
Description - Detailed	Open-path IR monitors expand the concepts of point IR detection to a gas sampling path of up to 100 meters. Like point IR monitors, they utilize a dual beam concept. The "sample" beam is in the infrared wavelength which absorbs hydrocarbons, while the second "reference" beam is outside this gas absorbing wavelength. The ratio of the two beams is continuously compared. When no gas is present, the signal ratio is constant; when a gas cloud crosses the beam, the sample signal is absorbed or reduced in proportion to the amount of gas present while the reference beam is not. System calculates the product of the average gas concentration and the gas cloud width, and readings are given in %LEL/meter.
Readings	% LEL per meter
Pros	High accuracy and selectivity; large measurement range; low maintenance; highly resistant to chemical poisons; does not require oxygen or air; span drift potential virtually eliminated (no routine calibration required); fail-to-safe.
Cons	Not suitable for hydrogen detection. Compared with point IR detection, is not capable of isolating the leak source. Requires unobstructed path between source and detector.

Gas Detection Technologies

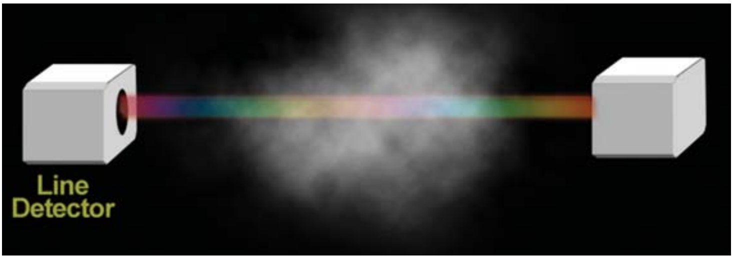
Typical Open Long Path Infrared Operation



The LEL * Meter Concept



The "Dual-Beam" Concept



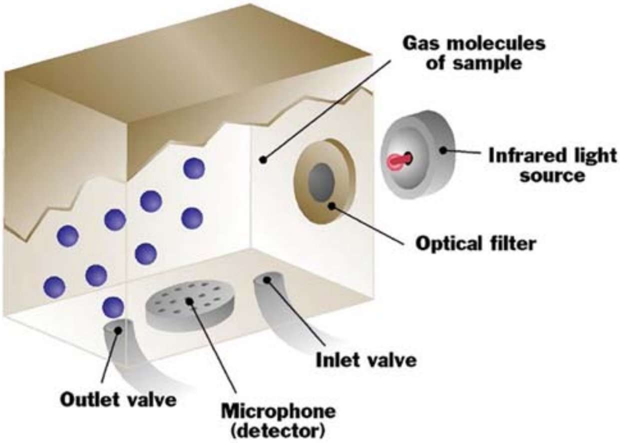
Gas Detection Technologies

Technology	Photoacoustic Infrared
Gas Type Detected	Combustible gas; Toxic gas
Principle of Operation	Uses a gases ability to absorb IR radiation and the resulting change in pressure.
Description - Detailed	The gas sample is exposed to infrared light; as it absorbs light its molecules generate a pressure pulse. The magnitude of the pressure pulse indicates the gas concentration present.
Readings	% LEL, % by volume, PPM, PPB
Pros	High sensitivity; linear output; easy to handle; not subject to poisoning; long-term stability.
Cons	Not suitable for hydrogen detection.

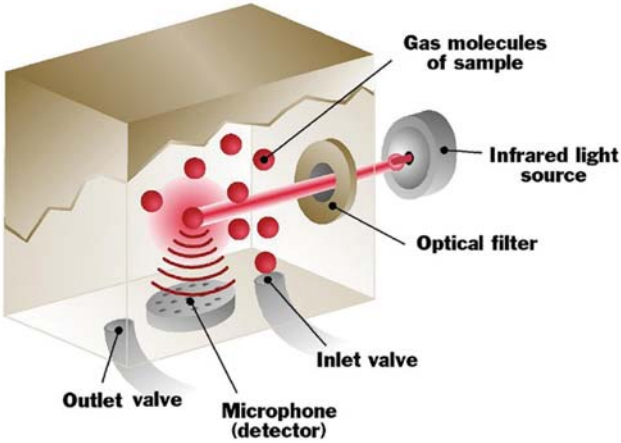
Gas Detection Technologies

Pumped Photoacoustic Infrared Operation

(Diffusion method also available)

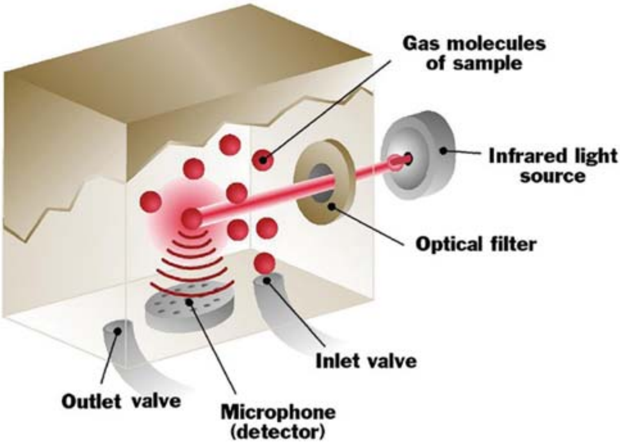


Sample gas enters the measuring cell.

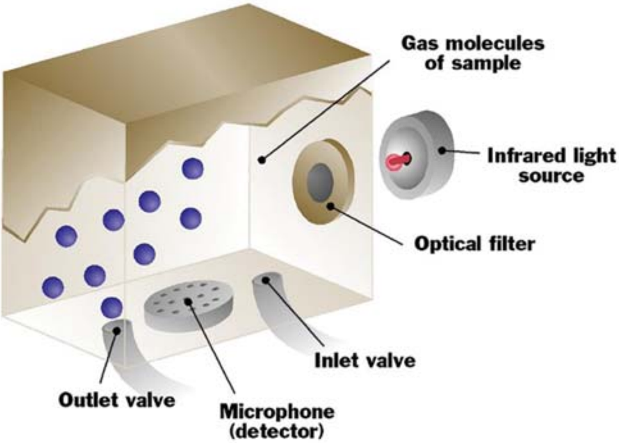


The gas is irradiated with pulsed infrared energy.

Gas Detection Technologies



The gas molecules heat and cool as they absorb the infrared energy. The pressure changes as a result of the heating and cooling of the molecules measured by the detector. This pressure change is converted into a gas reading.

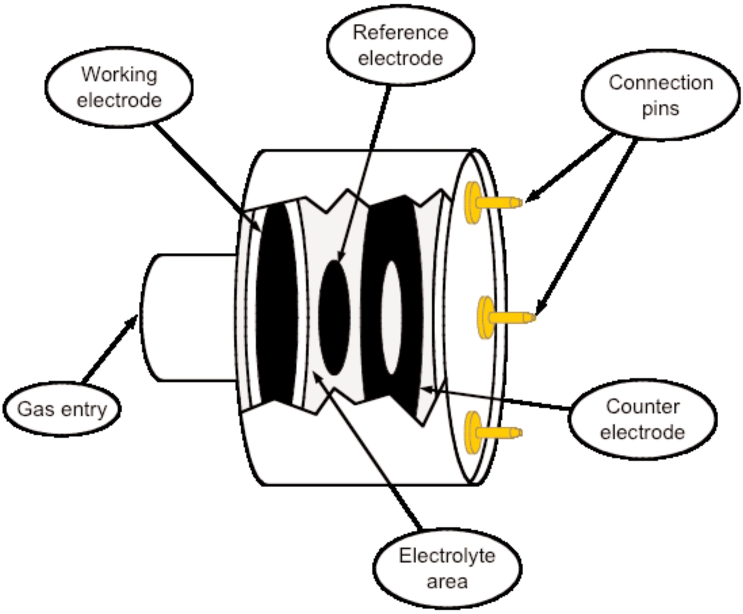


The gas is exhausted and a fresh sample enters the cell. This sampling process is continuously repeated.

Gas Detection Technologies

Technology	Electrochemical Toxic Gases
Gas Type Detected	Toxic gas
Principle of Operation	Uses an electrochemical reaction to generate a current proportional to the gas concentration.
Description - Detailed	Sensor is a chamber containing a gel or electrolyte and two active electrodes--the measuring (sensing/working) electrode (anode) and the counter electrode (cathode). A third electrode (reference) is used to build up a constant voltage between the anode and the cathode. The gas sample enters the casing through a membrane; oxidation occurs at the anode and reduction takes place at the cathode. When the positive ions flow to the cathode and the negative ions flow to the anode, a current proportional to the gas concentration is generated.
Readings	PPM readings for toxic gases
Pros	High sensitivity; linear output; easy to handle.
Cons	Limited shelf life; subject to interferents; sensor lifetime shortened in very dry and very hot environments.

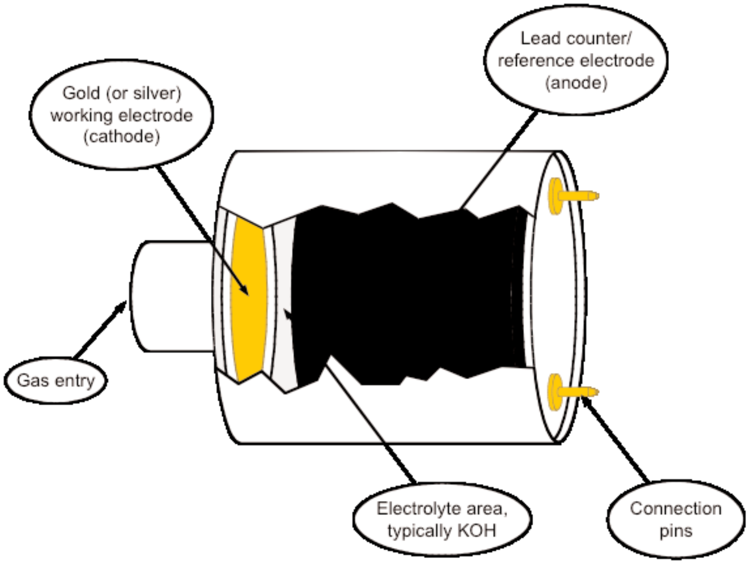
Typical Electrochemical Toxic Sensor



Gas Detection Technologies

Technology	Electrochemical Oxygen
Gas Type Detected	Oxygen deficiency/ enrichment
Principle of Operation	Uses an electrochemical reaction to generate a current proportional to the gas concentration.
Description - Detailed	Sensor is a chamber containing a gel or electrolyte and two electrodes--the measuring (sensing/working) electrode and the (usually lead) counter/reference electrode. The gas sample enters the casing through a membrane; oxidation occurs at the anode and reduction takes place at the cathode. When the positive ions flow to the cathode and the negative ions flow to the anode, a current proportional to the gas concentration is generated.
Readings	Percent volume readings for oxygen
Pros	High sensitivity; linear output; easy to handle; not subject to poisoning.
Cons	Limited shelf life; subject to interferents; sensor life shortened in very dry and very hot environments, or in enriched O2 applications.

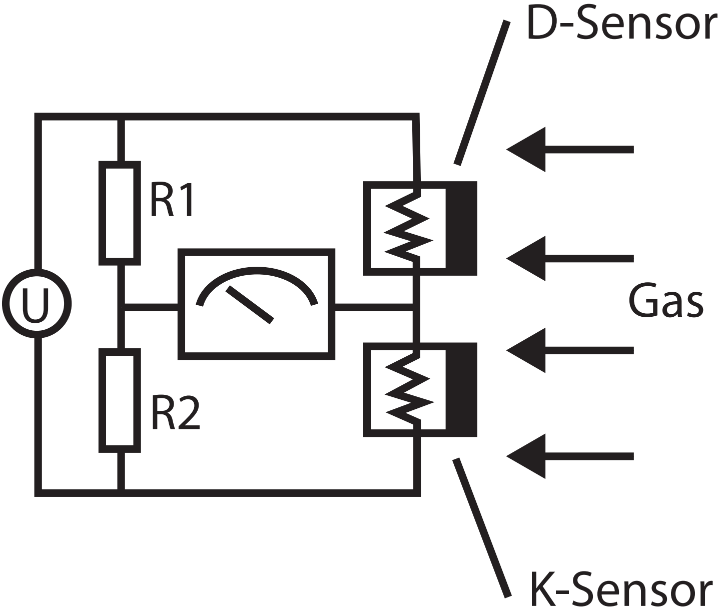
Typical Electrochemical Oxygen Sensor



Gas Detection Technologies

Technology	Thermal Conductivity
Gas Type Detected	Combustible gas; Toxic gases
Principle of Operation	Measures the gas sample's ability to transmit heat by comparing it with a reference gas (usually air).
Description - Detailed	Two sensors (detecting sensor and compensating sensor) are built into a Wheatstone Bridge. The detecting sensor is exposed to the gas of interest; the compensating sensor is enclosed in a sealed compartment filled with clean air. Exposure to the gas sample causes the detecting sensor to cool, changing the electrical resistance. This change is proportional to the gas concentration. The compensating sensor is used to verify that the temperature change is caused by the gas of interest and not by ambient temperature or other factors.
Readings	PPM; up to 100% by volume
Pros	Wide measuring range.
Cons	Non-specific (cross-sensitive to other compounds); does not work with gases with thermal conductivities (TCs) close to one (that of air, NH3, CO, NO, O2, N2); gases with TCs of less than one are more difficult to measure; output signal not always linear.

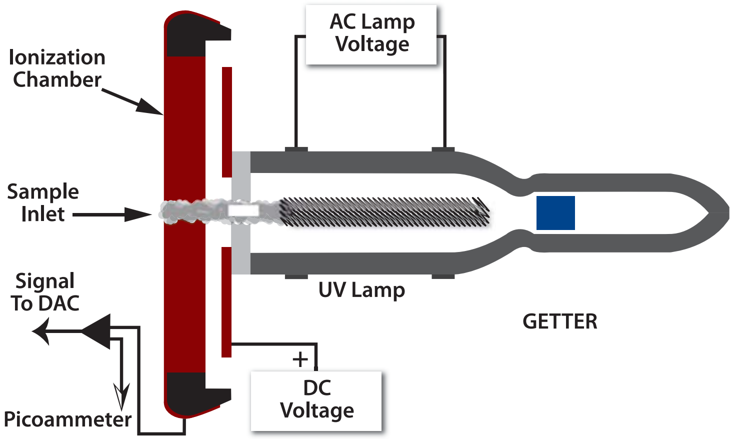
Typical Thermal Conductivity Sensor



Gas Detection Technologies

Technology	Photoionization
Gas Type Detected	Toxic (organic compounds)
Principle of Operation	Uses ionization as the basis of detection.
Description - Detailed	A photoionization detector (PID) uses an ultraviolet lamp to ionize the compound of interest. Ions are collected on a ‘getter’, a current is produced and the concentration of the compound is displayed in parts per million on the instrument meter.
Readings	PPM, sub-ppm
Pros	Fast response speed, very low level detection, detects a large number of substances.
Cons	More expensive, increased maintenance, requires more frequent calibration, non-specific, sensitive to humidity.

Typical Photoionization Sensor Design



Gas Sampling

Gas Sampling

There are three methods of gas sampling:

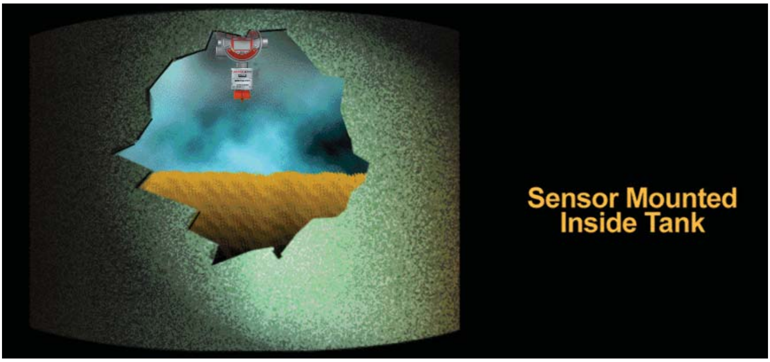
- Diffusion Sampling
- Pumped Sampling
- Aspirated Sampling

Diffusion Sampling

Diffusion is the natural movement of molecules away from an area of high concentration to an area of lower concentration. The term “diffusion” denotes the process by which molecules or other particles intermingle as a result of their random thermal motion. Ambient conditions such as temperature, air currents and other characteristics affect diffusion.

Advantages:

- Most effective placement is at desired sampling point.
- Fast response because no sample transport is required.
- No pumps and/or filters to maintain.



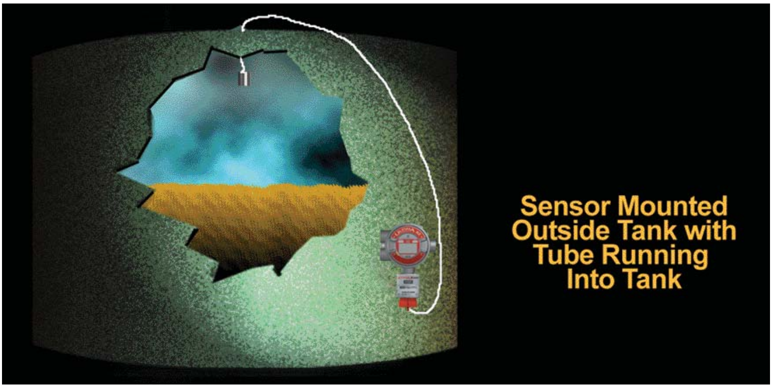
Pumped Sampling

Pumped sampling uses a pump to pull the sample from a remote location into or through the sensor. With pumped sampling, samples can be gathered simultaneously from two or more locations.

Gas Sampling

Conditions Favoring Pumped Sampling:

- Sampling point is too hot/cold.
- Sampling point is difficult to access.
- Heavy vapor present that does not diffuse well by natural forces.
- An application can be converted from an explosionproof (XP) rating to a general purpose (GP) rating through pumped operation. (Flashback arrestors may be necessary between the sample port and the sensor.)
- Confined Spaces



Aspirated Sampling

Aspirated sampling uses suction to draw the sample from a remote location into or through the sensor.

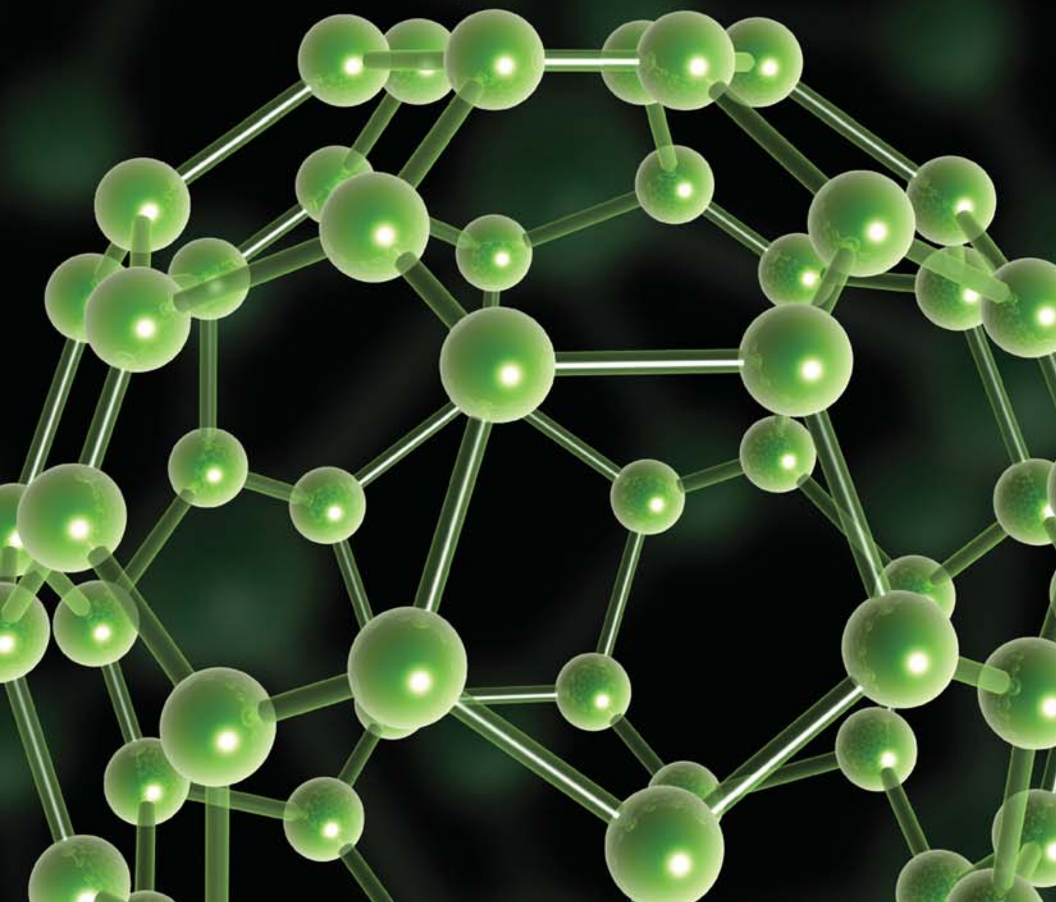
Advantages of Aspirated Sampling Versus Pumped:

- Lower cost
- Reduced maintenance because there are no moving parts

Section 3
Section 3

Section 3

Gas Information Table



Gas Information Table

Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)[1]*	LEL (% by vol)[1]	UEL (% by vol)[1]	ACGIHT LV-TWA (PPM)[2]	ACGIHT LV -STEL (PPM)[2]	OSHA PEL (PPM)[3]	NIOSH IDLH (PPM)[4]	Detection Technologies: Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity	Auto-ignition Temp (°C)*	Boil-ing Point (°C)[1]	Vapor Pressure (mm Hg at 20°C) [1,4]
Acetaldehyde	Acetic aldehyde	C_2H_4O	Heavier	X	-38	4.0	60	-	25 [C]	200	2,000		X	X		X		175	21	750
Acetic Acid		$C_2H_4O_2$	Heavier	X	39	4.0	19.9	10	15	10	50		X	X	X	X		463	118	11
Aceticaldehyde	Acetaldehyde	C_2H_4O	Heavier	X	-38	4.0	60	-	25 [C]	200	2,000		X	X		X		175	21	750
Acetone		C_3H_6O	Heavier	X	-20	2.5	12.8	500	750	1,000	2,500		X	X	X	X		465	56	
Acetonitrile		C_2H_3N	Heavier	X	6	3.0	16	20	-	40	500		X	X	X	X		524	82	73
Acetylene		C_2H_2	Lighter	X	Gas	2.5	100	A	A	-	-		X	X	X	X		305	-83	
Acroleic acid	Acrylic acid	$C_3H_4O_2$	Heavier	X	50	2.0	8	2	-	-	-		X		X	X		438	142	3
Acrolein	Acrylaldehyde	C_3H_4O	Heavier	X	-26	2.8	31	-	0.1 [C]	0.1	2		X	X	X	X		220	52	210
Acrylaldehyde	Acrolein	C_3H_4O	Heavier	X	-26	2.8	31	-	0.1 [C]	0.1	2		X	X	X	X		220	52	210
Acrylic acid	Acroleic acid	$C_3H_4O_2$	Heavier	X	50	2.0	8	2	-	-	-		X		X	X		438	142	3
Acrylonitrile		C_2H_3N	Heavier	X	0	3.0	17	2	-	2	85		X		X	X		481	77	83

Key:
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Gas Information Table

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												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Allyl alcohol	2-propenyl	C_3H_6O	Heavier	X	21	2.5	18	0.5	-	2	20		X	X	X	X		378	97	17
Allyl Chloride		C_3H_5Cl	Heavier	X	-32	2.9	11.1	1	2	1	250		X			X		392	45	295
Ammonia		NH_3	Lighter	X	Gas	15.0	28	25	35	50	300	X	X	X	X			651	-33	400 @ 45°C
Amyl acetate, n-		$C_7H_{14}O_2$	Heavier	X	16	1.1	7.5	-	-	100	1,000		X		X	X		360	149	
Arsine		AsH_3	Heavier	X	Gas	5.1	78	0.05	-	0.05	3	X							-62	>760
Benzene^		C_6H_6	Heavier	X	-11	1.3	7.1	0.5	2.5	10	500		X	X	X	X		498	80	75
Benzene chloride	Chlorobenzene	C_6H_5Cl	Heavier	X	29	1.3	9.6	10	-	75	1,000		X	X	X	X		638	132	12
Bromine		Br_2	Heavier		n/a	n/a	n/a	0.1	0.2	0.1	3	X							59	175
Bromochlorodifluoromethane	Halon 1211	CF_2ClBr	Heavier		n/a	n/a	n/a	-	-	-	-			X	X	X		-	3.3	778
Bromomethane	Methylbromide	CH_3Br	Heavier	X	n/a	10.0	16	1	-	20 [C]	250 [Ca]		X	X	X	X		537	4	1,250
Bromotrifluoromethane	Halon 1301	$CBrF_3$	Heavier		n/a	n/a	n/a	1,000	-	1,000	-			X	X	X		-	-58	12,153 @ 25°C

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												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Butadienes		C_4H_{10}	Heavier	X	-76	2.0	11.5	2	(-)	1	2,000		X	X	X	X		420	-4	Gas
Butane, n-		C_4H_{10}	Heavier	X	Gas	1.5	8.5	800	-	-	-		X	X	X	X		287	-1	
Butanol, *n-*	Butyl alcohol	$C_4H_{10}O$	Heavier	X	29	1.4	11.2	20	-	100	1,400		X	X	X	X		343	117	
Butanol, *sec-*	Butyl alcohol	$C_4H_{10}O$	Heavier	X	24	1.7	9.8	100	-	150	2,000		X	X	X	X		405	94	
Butanone, 2-	Methylethylketone	C_4H_8O	Heavier	X	-9	1.4	11.4	200	300	200	3,000		X	X	X	X		404	80	
Butyl acetate, *n-*		$C_6H_{12}O_2$	Heavier	X	22	1.3	7.6	150	200	150	1,700		X	X	X	X		420	127	
Butyl acetate, sec-		$C_6H_{12}O_2$	Heavier	X	17	1.7	9.8	200	-	200	1,700		X	X	X	X		-	112	
Butyl acetate, *tert*		$C_6H_{12}O_2$	Heavier	X	22	1.5	-	200	-	200	1,500		X	X	X	X		-		
Butyl acrylate, *n-*		$C_6H_{12}O_2$	Heavier	X	29	1.5	9.9	2	-	-	-		X	X	X	X		267	127	
Butyl alcohol, n-	Butanol, n-	C_4H_{10}	Heavier	X	29	1.4	11.2	20	-	100	1,400		X	X	X	X		343	117	
Butyl ethylene hexylene	Hexene, 1-	C_6H_{12}	Heavier	X	-26	1.2	6.9	50	-	-	-		X	X	X			253	63	308 @ 38°C

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Gas Information Table

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												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Butyraldehyde	Butylaldehyde: butanal	C_4H_8O	Heavier	X	-22	1.9	12.5	-	-	-	-		X	X	X	X		218	76	
Carbon dioxide		CO_2	Heavier		n/a	n/a	n/a	5,000	30,000	5,000	40,000			X	X		X	-		
Carbon disulfide		CS_2	Heavier	X	-30	1.3	50	10	-	20	500				X			90	46	300
Carbon monoxide		CO	Slightly lighter	X	Gas	12.0	75	25	-	50	1,200	X	X	X	X	X		609	-192	>760
Carbon tetrachloride	Tetrachloromethane	CCl_4	Heavier		n/a	n/a	n/a	5	10	10	200			X	X			-	77	91
Carbonyl chloride	Phosgene	$COCl_2$	Heavier		n/a	n/a	n/a	0.1	-	0	2			X	X			-	8	568 @ 0°C
Chlorine		Cl_2	Heavier		Gas	-	n/a	0.5	1	1 [C]	10	X						-	-34	Gas
Chlorine dioxide		ClO_2	Heavier		n/a	n/a	n/a	0.1	0.3	0.1	5	X						-		
Chlorobenzene	Benzene chloride	C_6H_5Cl	Heavier	X	29	1.3	9.6	10	-	75	1,000		X	X	X			638	132	12
Chloroethane	Ethyl chloride	C_2H_5Cl	Heavier	X	-50	3.8	15.4	100	-	1,000	3,800		X	X	X			519	12	

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												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Chloroform	Trichloromethane	$CHCl_3$	Heavier		n/a	n/a	n/a	10	-	50 [C]	500			X	X			-	62	160
Chloromethane	Methyl chloride	CH_3Cl	Heavier	X	Gas	-50	17.4	50	100	100	2,000		X	X	X			632	-24	
Cumene	Isopropylenzene	C_9H_{12}	Heavier	X	33	0.9	6.5	50	-	50	500		X	X	X	X		425	152	3.2
Cyclohexane		C_6H_{12}	Heavier	X	-20	1.3	8	100	-	300	1,300		X	X	X	X		245	82	
Cyclohexanone		$C_6H_{10}O$	Heavier	X	43	1.1	9.4	25	-	50	700		X	X	X	X		420	156	
Cyclopetane		C_5H_{10}	Heavier	X	-37	1.1	8.7	600	-	-	-		X	X	X	X		361	49	
Diacetone alcohol	Diacetone	$C_6H_{12}O_2$	Heavier	X	58	1.8	6.9	50	-	50	1,800		X	X	X	X		603	164	
Diborane	Boroethane	B_2H_6	Slightly heavier	X	-90	0.8	98	0.1	-	0.1	15	X						38-52	-93	224 @ 112°C
Dichlorobenzene, *o*-		$C_6H_4Cl_2$	Heavier	X	66	2.2	9.2	25	50	50 [C]	200		X	X	X	X		648	180	1.2
Dichloroethane *.1,1*-	Ethylidene dichloride	$C_2H_4Cl_2$	Heavier	X	-17	5.4	11.4	100	-	100	3,000		X	X	X	X		458	57-59	
Dichloroethane *.1,2*-	Ethylen dichloride	$C_2H_4Cl_2$	Heavier	X	13	6.2	15.9	10	-	50	50 [C]		X	X	X	X		413	84	100 @ 29°C
Diethyl ether	Ethyl ether	$C_4H_{10}O$	Heavier	X	-45	1.9	36	400	500	400	1,900		X	X	X	X		160	35	442

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												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Diethyl ketone	DEK	$C_5H_{10}O$	Heavier	X	12	1.6	6.4	200	300	-	-		X	X	X	X		450	103	
Diethylamine	Diethamine	$C_4H_{11}N$	Heavier	X	-28	1.8	10.1	5	15	25	200		X	X	X	X		312	56	194
Diethylbenzene	Dowtherm J	$C_{10}H_{14}$	Heavier	X	55	-	-	-	-	-	-			X	X			380	181	0.75
Diisopropylamine		$C_6H_{15}N$	Heavier	X	-6	0.8	7.1	5	-	5	200		X	X	X	X		316	84	60
Difluoromethane	HFC-32	CH_2F_2	Heavier	X	n/a	12.7	33.4	-	-	-	-			X	X	X		647	-52	11,377 @ 21°C
Dimethyl acetamide		C_4H_9NO	Heavier	X	70	1.8	11.5	10	-	10	300		X	X	X	X		490	165	
Dimethyl ether	DME	C_2H_6O	Heavier	X	Gas	3.4	27	-	-	-	-		X	X	X	X		350	-24	1, 4
Dimethylamine	DMA	C_2H_7N	Heavier	X	Gas	2.8	14.4	5	15	10	500		X	X	X	X		430	7	1500 @ 25°C
Dimethylethylamine		$C_2H_{11}N$	Heavier	X	-45	0.9	11.2	-	-	-	-		X	X	X			190	36	-
Dimethylformamide	DMF	C_3H_7NO	Heavier	X	57	2.2	15.2	10	-	10	500			X	X	X		445	153	

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Gas Information Table

Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)^1*	LEL (% by vol)^1	UEL (% by vol)^1	ACGIHT LV-TWA (PPM)^2	ACGIHT LV-STEL (PPM)^2	OSHA PEL (PPM)^3	NIOSH IDLH (PPM)^4	Detection Technologies						Auto-ignition Temp (°C)*	Boil-ing Point (°C)^1	Vapor Pressure (mm Hg at 20°C) ^{1,4}
												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Dimethylsulfoxide		C_2H_6SO			94	2.6	42	-	-	-	-			X	X	X		215	189	
Dioxane	Diethylene dioxide	$C_4H_8O_2$	Heavier	X	12	2.0	22	-	-	100	500		X	X	X	X		180	101	29
Dowtherm J	Diethylbenzene	$C_{10}H_{14}$	Heavier	X	55	-	-	-	-	-	-			X	X			380	181	0.75
Epichlorohydrin		C_3H_5OCl	Heavier	X	31	3.8	21	0.5	-	5	75		X	X	X	X		411	116	13
Ethane		C_2H_6	Slightly heavier	X	Gas	3.0	12.5 (15.5)	A	A	-	A		X	X	X	X		472	-89	
Ethene	Ethylene	C_2H_4	Slightly lighter	X	Gas	2.7	3.6	A	A	-	-		X	X	X	X		490	-104	
Ethoxyethanol, *2-*	Cellosolve	$C_4H_{10}O_2$	Heavier	X	43	1.7	15.6	5	-	200	500		X	X	X	X		235	135	
Ethyl acetate		$C_4H_8O_2$	Heavier	X	-4	2.0	11.5	400	-	400	2,000		X	X	X	X		427	77	
Ethyl acrylate		$C_5H_8O_2$	Heavier	X	9	1.4	14	5	15	25	300 [Ca]		X	X	X	X		372	100	31
Ethyl alcohol	Ethanol	C_2H_6O	Heavier	X	12	3.3	19	1,000	-	1,000	3,300		X	X	X	X		363	78	
Ethylbenzene		C_8H_{10}	Heavier	X	21	1.0	6.7	100	125	100	800		X	X	X	X		432	136	7

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Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)[1]*	LEL (% by vol)[1]	UEL (% by vol)[1]	ACGIHT LV-TWA (PPM)[2]	ACGIHT LV -STEL (PPM)[2]	OSHA PEL (PPM)[3]	NIOSH IDLH (PPM)[4]	Detection Technologies						Auto-ignition Temp (°C)*	Boil-ing Point (°C)[1]	Vapor Pressure (mm Hg at 20°C) [1,4]
												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Ethyl chloride	Chloroethane	C_2H_5Cl	Heavier	X	-50	3.8	15.4	100	-	1,000	3,800		X	X	X	X		519	12	
Ethyl ether	Diethyl ether	$C_4H_{10}O$	Heavier	X	-45	1.9	36	400	500	400	1,900		X	X	X	X		160	35	442
Ethylene	Ethene	C_2H_4	Slightly lighter	X	Gas	2.7	3.6	A	A	-	-		X	X	X	X		490	-104	
Ethylene dichloride	1,2 dichloroethylene	$C_2H_4Cl_2$	Heavier	X	13	6.2	15.9	10	-	50	50 [Ca]		X	X	X	X		413	84	100 @ 29°C
Ethylene glycol		$C_2H_6O_2$	Heavier	X	111	3.2	15.3	-	100 mg/m3	-	-					X		398	197	
Ethylene oxide	EtO	C_2H_4O	Heavier	X	-20	3.0	100	1	-	1	800 [Ca]	X	X	X	X			429	11	1,095
Ethylidene dichloride	Dichloroethane, 1, 1-	$C_2H_3Cl_2$	Heavier	X	-17	5.4	11.4	100	-	100	3,000		X	X	X	X		458	57-59	
Fluorine		F_2	Heavier		n/a	n/a	n/a	1	2	0.1	25	X			X	X		429	-188	
Furfural	Furfurol	$C_5H_4O_2$	Heavier	X	60	2.1	19.3	2	-	5	100			X	X	X		316	162	2
Gasoline	Heptane, Hexane	-		X	-42	1.4	7.6	300	500	-	[Ca]		X	X	X	X				

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Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)[1]*	LEL (% by vol)[1]	UEL (% by vol)[1]	ACGIHT LV-TWA (PPM)[2]	ACGIHT LV -STEL (PPM)[2]	OSHA PEL (PPM)[3]	NIOSH IDLH (PPM)[4]	Detection Technologies						Auto-ignition Temp (°C)*	Boil-ing Point (°C)[1]	Vapor Pressure (mm Hg at 20°C) [1,4]
												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Halon 1211	Bromochlorodi-fluoromethane	CF_2ClBr	Heavier		n/a	n/a	n/a	-	-	-	-			X	X	X			-3.3	778
Halon 1301	Bromotrifluoro-methane	$CBrF_3$	Heavier		n/a	n/a	n/a	1,000	-	1,000	-			X	X	X			-58	12,153 @ 25°C
Heptane, n-		C_7H_{16}	Heavier	X	-4	1.1	6.7	400	500	500	750		X	X	X	X		204	98	1,293
Hexafluoro 1,3 butadiene		C_4F_6	Heavier	X	-	7	73	-	-	-	-			X	X	X		-	6	4,800
Hexafluoropropene	Hexafluoro-propylene	C_3F_6	Heavier		n/a	n/a	n/a	-	-	-	-			X	X	X		-	-30	4,800
Hesafluoropropylene	Hexafluoro-propene	C_3F_6	Heavier		n/a	n/a	n/a	-	-	-	-			X	X	X		-	-30	
Hexanone, 2-	Methyl butyl ketone	$C_6H_{12}O$	Heavier	X	25	1.2	8	5	10	100	1,600		X	X	X			423	128	
Hexene, 1-	Butyl ethylene hexylene	C_6H_{12}	Heavier	X	-26	1.2	6.9	50	-	-	-		X	X	X			253	63	308 @ 38°C

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Gas Information Table

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												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Hexane, 2-		C_6H_{12}	Heavier	X	<-7	-	-	-	-	-	-		X	X	X			245	67	310 @ 38°C
HFC - 32	Difluoromethane	CH_2F_2		X	n/a	12.7	33.4	-	-	-	-			X	X			647	-52	11,377 @ 21°C
HFE 347E		$C_4F_7OH_3$	Heavier		-	n/a	n/a	-	-	-	-			X	X	X		n/a	36	500 @ 22°C
HFE 7100			Heavier		-	-	-	-	-	-	-			X	X	X		405	61	202 @ 25°C
Hydrobromic acid	Hydrogen bromide	HBr	Heavier		n/a	n/a	n/a	-	3 [C]	3	30	X							74	
Hydrocarbons (see specific)																				
Hydrogen		H_2	Lighter	X	Gas	4.0	75	A	A	-	-	X	X			X	X	400-253		Gas
Hydrogen bromide	Hydrobromic acid	HBr	Heavier		n/a	n/a	n/a	-	3 [C]	3	30	X						s	74	

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Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)[1]*	LEL (% by vol)[1]	UEL (% by vol)[1]	ACGIHT LV-TWA (PPM)[2]	ACGIHT LV -STEL (PPM)[2]	OSHA PEL (PPM)[3]	NIOSH IDLH (PPM)[4]	Detection Technologies						Auto-ignition Temp (°C)*	Boil-ing Point (°C)[1]	Vapor Pressure (mm Hg at 20°C) [1,4]
												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Hydrogen chloride	Hydrochloric acid	HCl	Heavier		n/a	n/a	n/a	-	5 [C]	5 [C]	50	X						-	-85	Gas
Hydrogen cyanide		HCN	Lighter	X	-18	5.6	40	-	4.7 [C]	10	50	X			X			540	26	
Hydrogen fluoride		HF	Lighter		n/a	n/a	n/a	-	3 [C]	3	30							-	20	760
Hydrogen sulfide		H_2S	Heavier	X	Gas	4.3	46	10	15	20 [C]	100	X				X		260	-60	14,060
Isoamyl alcohol		$C_5H_{12}O$	Heavier	X	43	1.2	9	50	-	100	500				X	X		350	132	
Isobutane		C_4H_{10}	Heavier	X	Gas	1.8	8.4	-	-	-	-		X	X	X	X		460	-12	
Isobutyl acetate		$C_6H_{12}O_2$	Heavier		17	1.3	10.5	150	-	150	1,300		X	X	X	X		421	118	
Isopar G	Isoparaffinic hydrocarbon		Heavier	X	38	1.2	9.6						X	X	X				>160	2.3
Isophorone		$C_9H_{14}O$	Heavier	X	84	0.8	3.8	-	5 [C]	25	200		X	X	X	X		460	215	<1
Isoprene		C_5H_8	Heavier	X	-54	2.0	9	-	-	-	-		X	X	X	X		220	34	400 @ 15°C

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												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Isopropanol	Isoropyl alcohol	C_3H_8O	Heavier	X	11	2.0	12.7	400	500	400	2,000		X	X	X	X		399	83	
Isopropyl acetate		$C_5H_{10}O_2$	Heavier	X	2	1.8	8	250	310	250	1,800		X	X	X	X		460	90	
Isoproryl alcohol	Isopropanol	C_3H_8O	Heavier	X	11	2.0	12.7	400	500	400	2,000		X	X	X	X		399	83	
Isopropyl benzene	Cumene	C_9H_{12}	Heavier	X	33	0.9	6.5	50	-	50	900		X	X	X	X		425	152	3.2
Isopropyl ether	Diisopropyl ether	$C_6H_{14}O$	Heavier	X	-28	1.4	7.9	250	310	500	1,400		X	X	X	X		443	69	
Kerosene/JP-1 Jet fuel	Fuel oil no. 1		Heavier	X	37-72	0.7	5	-	-	-	-			X	X	X		210	151-301	
Methane		CH_4	Lighter	X	Gas	5.0	15	A	A	-	A		X	X	X	X	X	537	-162	
Methanol	Methyl alcohol	CH_4O	Heavier	X	11	6.0	36	200	250	200	6,000			X	X	X		464	64	
Methoxyethanol, 2-	Methyl cellosolve	$C_3H_8O_2$	Heavier	X	39	1.8	14	5	-	25	200			X	X	X		285	124	
Methyl acetate		$C_3H_6O_2$	Heavier	X	-10	3.1	16	200	250	200	3,100		X	X	X	X		454	60	

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												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Methyl alcohol	Methanol	CH_4O	Heavier	X	11	6.0	36	200	250	200	6,000		X	X	X	X		464	64	
Methyl bromide	Bromomethane	CH_3Br	Heavier	X	n/a	10.0	16	1	-	20 [C]	250 [Ca]		X	X	X	X		537	4	
Methyl butyl ketone	Hexanone, 2-	$C_6H_{12}O$	Heavier	X	25	1.2	8	5	10	100	1,600	X						423	128	
Methyl cellosolve	2-methoxyethanol	$C_3H_8O_2$	Heavier	X	39	1.8	14	5	-	25	200			X	X	X		285	124	
Methyl chloride	Chloromethane	CH_3Cl	Heavier	X	-50	8.1	17.4	50	100	100	2,000		X	X	X	X		632	-24	
Methylchloroform	Trichloroethane, 1,1,1-	$C_2H_3Cl_3$	Heavier	X		7	16.0	350	450	350	700		X	X	X	X		500	74	
Methyl ethyl ketone (MEK)	Butanone, 2	C_4H_8O	Heavier	X	-9	1.4	11.4	200	300	200	3,000		X	X	X	X		404	80	
Methyl fluoride		CH_3F	Heavier	X										X	X	X			-78	28,577 @ 21.1°C
Methylformate		$C_2H_4O_2$	Heavier	X	-19	5.0	23	100	150	100	4,500		X	X	X	X		456	32	476

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Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)[1]*	LEL (% by vol)[1]	UEL (% by vol)[1]	ACGIHT LV-TWA (PPM)[2]	ACGIHT LV -STEL (PPM)[2]	OSHA PEL (PPM)[3]	NIOSH IDLH (PPM)[4]	Detection Technologies						Auto-ignition Temp (°C)*	Boiling Point (°C)[1]	Vapor Pressure (mm Hg at 20°C) [1,4]
												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Methyl iodide		CH_3I	Heavier		n/a	n/a	n/a	2	-	5	100 [Ca]		X	X	X	X		-		
Methyl isoamyl ketone		$C_7H_{14}O$	Heavier	X	36	1.0	8.2	50	-	100	-		X	X	X	X		191	146	
Methyl isobutyl carbinol	Methylamyl alcohol	$C_6H_{14}O$	Heavier	X	48	1.0	5.5	25	40	25	400		X	X	X	X		-		
Methyl isobutyl ketone (MIBK)		$C_6H_{12}O$		X	18	1.2	8	50	75	100	-		X	X	X	X		448	117	16
Methyl methacrylate		$C_5H_8O_2$	Heavier	X	10	1.7	8.2	50	100	100	1,000		X	X	X	X		435	100	29
Methylamine	Monomethylamine	CH_5N	Slightly heavier	X	Gas	4.9	20.7	5	15	10	100		X	X	X	X		430	-6	2,622 @ 25°C
Methylene chloride	Dichloromethane	CH_2Cl_2	Heavier	X	-	13.0	23	50	-	25	2300 [Ca]		X	X	X	X		556	40	350
Mono chloro-benzene	(Benezene chloride)	C_6H_5Cl	Heavier	X	29	1.3	9.6	10	-	75	1,000		X	X	X	X		638	132	12
Monomethlamine	Methylamine	CH_5N	Slightly heavier	X	Gas	4.9	20.7	5	15	10	100		X	X	X	X		430	-6	2,622 @ 25°C

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Gas Information Table

												Detection Technologies								
Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)^{1}*	LEL (% by vol)^{1}	UEL (% by vol)^{1}	ACGIHT LV-TWA (PPM)^{2}	ACGIHT LV-STEL (PPM)^{2}	OSHA PEL (PPM)^{3}	NIOSH IDLH (PPM)^{4}	Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity	Auto-ignition Temp (°C)*	Boiling Point (°C)^{1}	Vapor Pressure (mm Hg at 20°C)^{1,4}
Naphtha	Coal Tar	-	Heavier	X	-2	0.9	6	-	-	100	1,000		X	X	X	X				
Napthalene		$C_{10}H_8$	Heavier	X	79	0.9	5.9	10	15	10	250		X	X	X	X		526	218	1.0 @ 53°C
Nitric oxide		NO	Same		n/a	n/a	n/a	25	-	25	100	X			X				-52	
Nitrobenzene		$C_6H_5NO_2$	Heavier	X	87	1.8	-	1	-	1	200		X	X	X	X		480	211	1,4
Nitrogen dioxide		NO_2	Heavier		Gas		n/a	3	5	5 [C]	20	X			X				15	
Nitrogen trifluoride		NF_3	-			n/a	n/a	10	-	10	1,000			X	X					
Nitropropane, 1-		$C_3H_7NO_2$	Heavier	X	36	2.2	-	25	-	25	1,000		X	X	X	X		421	120-132	13
Nitropropane, 2-		$C_3H_7NO_2$	Heavier	X	24	2.2	11	10	-	25	100 [Ca]		X	X	X	X		428	120-132	13
Nitrous oxide		N_2O	Heavier			n/a	n/a	50	-	-	-			X	X					
Octafluorocyclo-butane		C_4F_8	Heavier		-	-	-	-	-	-	-			X	X	X			-6	2,052 @ 21.1°C
Octafluorocyclo-propene														X	X	X				

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Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)[1]*	LEL (% by vol)[1]	UEL (% by vol)[1]	ACGIHT LV-TWA (PPM)[2]	ACGIHT LV -STEL (PPM)[2]	OSHA PEL (PPM)[3]	NIOSH IDLH (PPM)[4]	Detection Technologies						Auto-ignition Temp (°C)*	Boil-ing Point (°C)[1]	Vapor Pressure (mm Hg at 20°C)[1,4]
												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Octane, n-		CH_8H_{18}	Heavier	X	13	1.0	6.5	300	-	500	1,000		X	X	X			206	126	
Oxygen		O_2	Same		Gas	-	n/a	n/a	n/a	n/a	n/a	X							-183	
Pentane		C_5H_{12}	Heavier	X	<-40	1.5	7.8	600	-	1,000	1,500		X	X	X	X		260	36	
Perchloroethlyene	Tetrachloroethylene	C_2Cl_4	Heavier		n/a	n/a	n/a	25	100	100	150 [Ca]			X	X	X		-	121	13
Perfluorohexane			-		-	n/a	n/a	-	-	-	-			X	X	X			>58	-
Perfluoromethyl-vinyl ether	PMVE													X	X					
Phosgene	Carbony chloride	$COCl_2$	Heavier		n/a	n/a	n/a	0.1	-	0	2			X	X			-	8	568 @ 0°C
Phosphine		PH_3	Heavier	X	Gas	1.6	98	0.3	1	0	50	X						38	-88	>760
Propane		C_3H_8	Heavier	X	Gas	2.1	9.5	2,500	-	1,000	2,100		X	X	X	X		450	-42	
Propanol, 2-	Allyl alcohol	C_3H_6O	Heavier	X	21	2.5	18	0.5	-	2	20		X	X	X	X		378	97	17

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Gas Information Table

Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)[1]*	LEL (% by vol)[1]	UEL (% by vol)[1]	ACGIHT LV-TWA (PPM)[2]	ACGIHT LV -STEL (PPM)[2]	OSHA PEL (PPM)[3]	NIOSH IDLH (PPM)[4]	Detection Technologies						Auto-ignition Temp (°C)*	Boil-ing Point (°C)[1]	Vapor Pressure (mm Hg at 20°C) [1,4]
												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Propanol, n-	Propyl alcohol, n-	C_3H_8O	Heavier	X	23	2.2	13.7	200	250	200	800		X	X	X	X		371	97	
Propyl acetate, n-		$C_5H_{10}O_2$	Heavier	X	13	1.7	8	200	250	200	1,700		X	X	X	X		450	102	
Propyl alcohol, n-	Propanol, n	C_3H_8O	Heavier	X	23	2.2	13.7	200	250	200	800		X	X	X	X		371	97	
Propylene		C_3H_6	Heavier	X	Gas	2.0	11.7	A	A	-	-		X	X	X	X		455	-47	
Propylene dichloride		$C_3H_6Cl_2$	Heavier	X	16	3.2	14.5	75	110	75	400 [Ca]		X	X	X	X		557	96	40
Propylene oxide		C_3H_6O	Heavier	X	-37	2.1	37	2	-	100	400 [Ca]		X	X	X			465	34	442
Propyleneglycol dimethyl acetate			Heavier																	
Silane		SiH_4	Heavier	X	-	1.4	96	-	-	-	-	X						-	-112	
Stoddard solvent			Heavier	X	21	0.9	6	100	-	500	2,000 mg/m3							229	149-204	
Styrene		C_8H_8	Heavier	X	31	1.1	7	20	40	100	700		X			X		490	145	5

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Gas Information Table

Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)^{1}*	LEL (% by vol)^{1}	UEL (% by vol)^{1}	ACGIHT LV-TWA (PPM)^{2}	ACGIHT LV -STEL (PPM)^{2}	OSHA PEL (PPM)^{3}	NIOSH IDLH (PPM)^{4}	Detection Technologies						Auto-ignition Temp (°C)*	Boil-ing Point (°C)^{1}	Vapor Pressure (mm Hg at 20°C) ^{1,4}
												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Sulfur dioxide		SO_2	Heavier		Gas	n/a	n/a	2	5	5	100	X			X			-	-10	
Sulfur hexafluoride		SF_6	Heavier		n/a	n/a	n/a	1,000	-	1,000	-			X	X					
Tetrachloroethylene	Perchloroethylene	C_2Cl_4	Heavier		n/a	n/a	n/a	25	100	100	150 [Ca]			X	X	X		-	121	13
Tetrachloromethane	Carbon Tetrachloride	CCl_4	Heavier		n/a	n/a	n/a	5	10	10	200			X	X			-	77	91
Tetrafluoroethylene		C_2F_4	Heavier	X	<0	11.0	60	2	-	-	-			X	X	X		188	-78	
Tetrahydrofuran		C_4H_8O	Heavier	X	-14	2.0	11.8	200	250	200	2,000		X	X		X		321	66	145
Toluene		C_7H_8	Heavier	X	4	1/2	7.1	50	-	200	500		X	X	X	X		480	111	22
Trichloroethane, 1, 1, 1-	Methyl chloroform	$C_2H_3Cl_3$	Heavier	X		7	16.0	350	450	350	700		X	X	X	X		500	74	100
Trichloroethane, 1, 2, 2-		$C_2H_3Cl_3$	Heavier	X	4	6.0	15.5	10	-	10	100 [Ca]		X	X	X	X		-	113	19
Trichloroethylene		C_2HCl_3	Heavier	X	-	8.0	10.5	50	100	100	1,000 [Ca]		X	X	X	X		420	87	58

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Gas Information Table

Gas or Vapor	Synonym	Chemical Formula	Relative Density (vs.Air)+	Combustible	Flash Point (°C)[1]*	LEL (% by vol)[1]	UEL (% by vol)[1]	ACGIHT LV-TWA (PPM)[2]	ACGIHT LV -STEL (PPM)[2]	OSHA PEL (PPM)[3]	NIOSH IDLH (PPM)[4]	Detection Technologies						Auto-ignition Temp (°C)*	Boil-ing Point (°C)[1]	Vapor Pressure (mm Hg at 20°C) [1,4]
												Electrochemical	Catalytic	Photoacoustic IR	Absorptive IR	Semiconductor	Thermal Conductivity			
Trichloromethane	Chloroform	$CHCl_3$	Heavier		n/a	n/a	n/a	10	-	50 [C]	500			X	X			-	62	160
Triethylamine		$C_6H_{15}N$	Heavier	X	-9	1.2	8	1	3	25	200		X	X		X		249	89	54
Turpentine		$C_{10}H_{16}$	-	X	35	0.8	-	100	-	100	800			X	X	X		220	149	
Vinyl acetate		$C_4H_6O_2$	Heavier	X	-6	2.6	13.4	10	15	-	-		X	X	X	X		402	73	88
Vinyl chloride		C_2H_3Cl	Heavier	X	-78	3.6	33	1	-	1	Ca		X	X	X	X		472	-14	2,524
Vinyl fluoride		C_2H_3F	Heavier	X	Gas	2.6	21.7	-	-	-	-			X	X	X		385	-72	25.2 atm
Vinylidene chloride		$C_2H_2Cl_2$	Heavier	X	-18	7.3	16	5	-	-	Ca			X	X	X		570	32	400 @ 15°C
Xylenes		C_8H_{10}	Heavier	X	27-30	1.1	6.7	100	150	100	900		X	X	X	X		463-528	137-144	

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GAS INFORMATION TABLE

[1] Data obtained from the National Fire Protection Association (NFPA) Fire Protection Guide to Hazardous Materials, 13th ed., 2002, National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards, 1995, and material safety data sheets.

[2] Data obtained from American Conference of Governmental Industrial Hygienists (ACGIH) 2002 Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs), and material safety data sheets.

[3] The PELs are the maximum 8-hour time weighted average concentrations to which a worker may be exposed, per 29 CFR 1910.1000 Table Z-1; [C] denotes a ceiling limit, the maximum concentration to which a worker may be exposed. They are to be determined from breathing-zone air samples. Data obtained from National Institute for Occupational Safety and Health (NIOSH) Documentation for Immediately Dangerous to Life or Health Concentrations, 1995, and material safety data sheets.

[4] Data obtained from U.S. Department of Labor Occupational Safety and Health Administration (OSHA) 29 CFR 1910.1000 Table Z-1 Limits for Air Contaminants, and material safety data sheets.

^ See 29 CFR 1910.1028 for specific circumstantial exceptions.

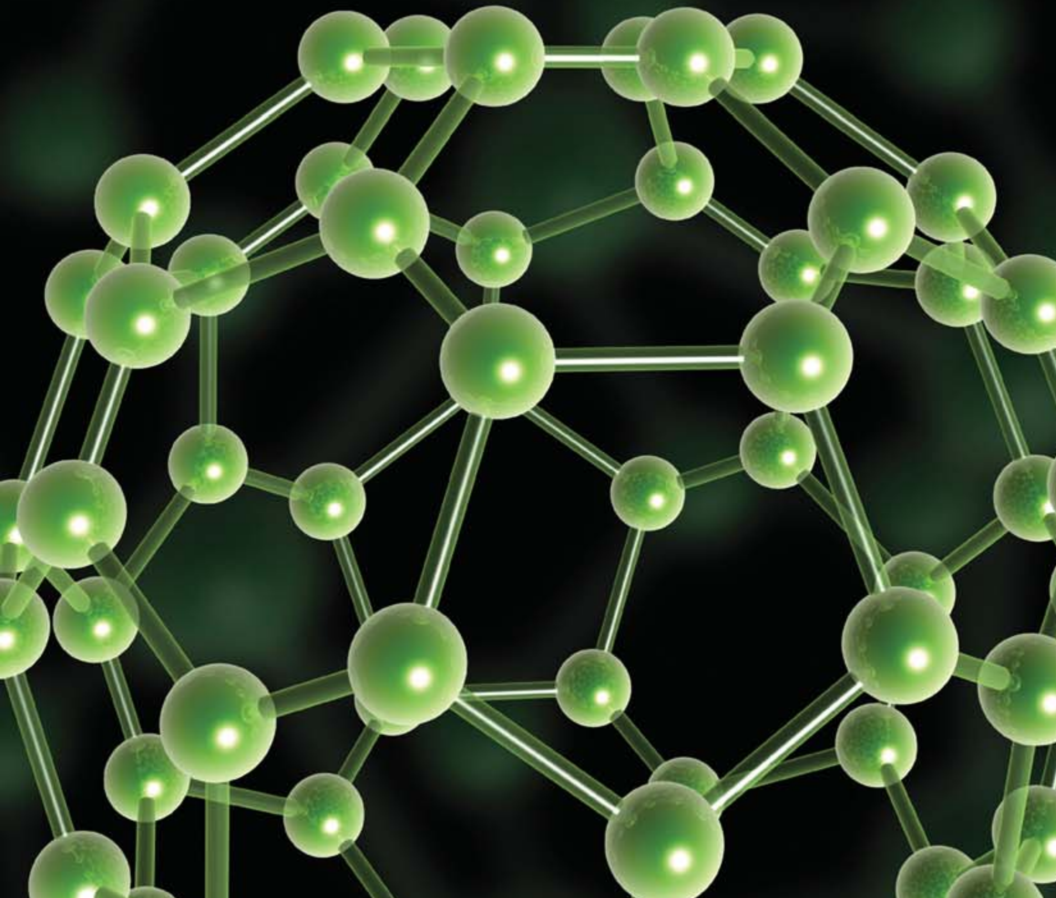
+ Density of gas at 1 atmosphere.

* ‘Gas’ indicates substance is a gas at normal ambient temperature.

Section 4
Section 4

Section 4

A Selection of Gases Typically Associated with Various Industries



A Selection of Gases Typically Associated with Various Industries

Industry	**Aerospace/Defense**			
	Test cambers/labs	Plant facilities	Heat treating	Launch pads
Combustible Gases	**X**	**X**	**X**	**X**
Ammonia				**X**
Carbon dioxide	**X**		**X**	
Carbon monoxide	**X**		**X**	
Chlorine				
Chlorine dioxide				
Ethylene				
Ethylene oxide				
Hydrogen chloride				
Hydrogen cyanide				
Hydrogen sulfide				
Nitric oxide	**X**			
Nitrogen dioxide				
O_2 deficiency/enrichment	**X**	**X**	**X**	**X**
Phosphine				
Refrigerants	**X**	**X**		**X**
Toluene	**X**			
VOC's				

A Selection of Gases Typically Associated with Various Industries

Industry	**Agriculture**									
	Chillers	Fruit storage areas	Greenhouses, silos & storage areas	Forklift operation	Confined spaces (silos)	Grain storage & processing	Poultry houses	Fumigation	Livestock, oil extraction process	Soil fertilization
Combustible Gases				X	X				X	
Ammonia	X	X					X		X	X
Carbon dioxide	X	X	X		X		X	X		
Carbon monoxide				X	X				X	
Chlorine										
Chlorine dioxide										
Ethylene		X	X		X					
Ethylene oxide								X		
Hydrogen chloride										
Hydrogen cyanide								X		
Hydrogen sulfide								X		
Nitric oxide				X	X					
Nitrogen dioxide				X	X					
O_2 deficiency/enrichment		X	X		X					
Phosphine						X		X		
Refrigerants	X	X								
Sulfar Dioxide							X	X		
VOC's		X								

A Selection of Gases Typically Associated with Various Industries

Industry	**Automotive**		
	Research & development labs	Engine testing	Environmental chambers
Combustible Gases	X	X	X
Ammonia			
Carbon dioxide	X	X	X
Carbon monoxide	X	X	X
Chlorine			
Chlorine dioxide			
Ethylene			
Ethylene oxide			X
Hydrogen chloride			
Hydrogen cyanide			
Hydrogen sulfide			
Nitric oxide	X	X	
Nitrogen dioxide	X	X	
O_2 deficiency/enrichment	X	X	X
Phosphine			
Refrigerants	X	X	X
Sulfur dioxide	X		
VOC's	X		

A Selection of Gases Typically Associated with Various Industries

Industry	Aviation				
	Body & engine repair & maintenance	Aircraft hanger facilities, fuel & hydraulic fluid storage and pumping facilities	Confined space (wing) tank maintenance	Jet fuel vapors, solvents	Aircraft parts mfg.
Combustible Gases	X	X	X	X	
Ammonia					
Carbon dioxide			X		
Carbon monoxide	X		X		
Chlorine					
Chlorine dioxide					
Ethylene					
Ethylene oxide					
Hydrogen chloride					
Hydrogen cyanide	X				X
Hydrogen sulfide					
Nitric oxide	X				
Nitrogen dioxide	X			X	
O_2 deficiency/enrichment			X		X
Phosphine					
Refrigerants					
Sulfur dioxide					
VOC's	X	X		X	X

A Selection of Gases Typically Associated with Various Industries

Industry	**Chemical**						
	General leak detection process manufacturing	Confined space (liquid nitrogen carriers/storage tank maintenance, reactor work, tunnels)	Labs, fine chemical manufacturing	Manufacturing, polymers/plastics, process manufacturing for leaks	Organic synthesis operations, liquid-solid separation, cleaning agents	General leak detection, organic synthesis	Textiles
Combustible Gases	X	X	X	X	X	X	
Ammonia	X		X	X	X	X	X
Carbon dioxide	X	X					
Carbon monoxide	X	X	X	X	X	X	
Chlorine	X		X		X	X	X
Chlorine dioxide	X		X		X	X	
Ethylene	X		X	X	X	X	X
Ethylene oxide	X		X	X	X	X	
Hydrogen chloride	X				X		
Hydrogen cyanide	X		X	X		X	X
Hydrogen sulfide	X	X			X		X
Nitric oxide	X		X			X	X
Nitrogen dioxide	X		X	X		X	
O_2 deficiency/enrichment	X	X		X			X
Phosphine	X		X	X			
Refrigerants			X				
Sulfur dioxide	X						X
VOC’s	X		X	X	X	X	

A Selection of Gases Typically Associated with Various Industries

Industry	**Chemical**			
	Rubber	Storage warehouses	Solvent recovery	Holding tanks, transfer areas, loading & unloading areas
Combustible Gases	X	X	X	X
Ammonia	X	X		X
Carbon dioxide		X		X
Carbon monoxide		X		X
Chlorine		X		X
Chlorine dioxide		X		X
Ethylene		X		X
Ethylene oxide		X		
Hydrogen chloride		X		
Hydrogen cyanide	X	X		
Hydrogen sulfide	X	X		
Nitric oxide		X		
Nitrogen dioxide		X		
O_2 deficiency/enrichment		X		X
Phosphine		X		
Refrigerants		X		
Sulfar Dioxide		X		
VOC’s	X	X	X	X

A Selection of Gases Typically Associated with Various Industries

Industry	**Coatings & Printing Adhesives**	
	Manufacturing floor, outside of press	Press processes
Combustible Gases	X	X
Ammonia		
Carbon dioxide		
Carbon monoxide		
Chlorine		
Chlorine dioxide		
Ethylene		
Ethylene oxide		
Hydrogen chloride		
Hydrogen cyanide		
Hydrogen sulfide		
Nitric oxide		
Nitrogen dioxide		
O_2 deficiency/enrichment	X	X
Phosphine		
Refrigerants		
Sulfar Dioxide		
VOC's	X	X

A Selection of Gases Typically Associated with Various Industries

Industry	**Food & Beverage**						
	Refrigeration facilities & cold storage	Fruit storage areas	Grain processing	Edible oil processing	Breweries & wineries, beverage bottling, fermentation tanks, refrigeration facilities, meat packing, food processing	Heaters & boilers, gasoline-powered equipment, vehicles & forklifts baking facilities	Coolers, confined spaces
Combustible Gases			**X**	**X**		**X**	**X**
Ammonia	**X**	**X**			**X**		**X**
Carbon dioxide	**X**	**X**			**X**		
Carbon monoxide			**X**			**X**	**X**
Chlorine							
Chlorine dioxide							
Ethylene	**X**	**X**					
Ethylene oxide							
Hydrogen chloride							
Hydrogen cyanide							
Hydrogen sulfide							
Nitric oxide						**X**	
Nitrogen dioxide						**X**	
O_2 deficiency/enrichment	**X**	**X**					**X**
Phosphine							
Refrigerants	**X**	**X**			**X**		**X**
Sulfur dioxide	**X**		**X**		**X**		
VOC's							

A Selection of Gases Typically Associated with Various Industries

Industry	**Food & Beverage**				
	Wastewater tanks, drainage & sewage areas	Drainage & sewage areas, boilers & heaters, food packaging	Fermentation process, packaging or gassing foods, confined space	Fumigation of yeast & mold spores, sterilization	Disinfecting equipment & utensils
Combustible Gases	X	X			
Ammonia			X		
Carbon dioxide			X	X	
Carbon monoxide		X	X		
Chlorine				X	X
Chlorine dioxide				X	X
Ethylene			X		
Ethylene oxide				X	X
Hydrogen chloride					
Hydrogen cyanide					
Hydrogen sulfide	X	X			
Nitric oxide					
Nitrogen dioxide					
O_2 deficiency/enrichment	X		X		
Phosphine					
Refrigerants					
Sulfur dioxide			X	X	
VOC's	X	X			

A Selection of Gases Typically Associated with Various Industries

Industry	Food & Beverage	
	Cold storage & transport facilities, meat packing plants, supermarkets, refrigerator & storage locations, food storage systems monitoring	Food packaging (solvent vapor process monitoring)
Combustible Gases		X
Ammonia	X	
Carbon dioxide	X	X
Carbon monoxide		X
Chlorine		
Chlorine dioxide		
Ethylene		
Ethylene oxide		
Hydrogen chloride		
Hydrogen cyanide		
Hydrogen sulfide		
Nitric oxide		
Nitrogen dioxide		
O_2 deficiency/enrichment	X	X
Phosphine		
Refrigerants	X	
Sulfur dioxide	X	
VOC's		X

A Selection of Gases Typically Associated with Various Industries

Industry	**Foundries**					**Fuel cell Manufacturing**
	Furnace operation, coremaking, metal preparation & pouring	Metal-mining, finishing work	Coremaking	Heat-treating processes	Confined space	Manufacturing floor, fuel cells
Combustible Gases		X	X	X	X	X
Ammonia						
Carbon dioxide				X	X	X
Carbon monoxide	X		X	X	X	X
Chlorine						
Chlorine dioxide						
Ethylene						
Ethylene oxide						
Hydrogen chloride						
Hydrogen cyanide		X				
Hydrogen sulfide		X	X			X
Nitric oxide			X			
Nitrogen dioxide			X			
O_2 deficiency/enrichment					X	X
Phosphine						
Refrigerants						
Sulfur dioxide			X			
VOC's						

A Selection of Gases Typically Associated with Various Industries

Industry	HAZMAT				
	HazMat applications	Flammable liquid/ gas storage & pumping facilities	Confined space	Underground construciton	Storage, transfer and treatment
Combustible Gases	X	X	X	X	X
Ammonia	X				
Carbon dioxide		X	X		
Carbon monoxide	X		X	X	X
Chlorine	X				
Chlorine dioxide	X				
Ethylene					
Ethylene oxide					
Hydrogen chloride					
Hydrogen cyanide					
Hydrogen sulfide	X				
Nitric oxide					
Nitrogen dioxide					
O_2 deficiency/enrichment			X	X	
Phosphine	X				
Refrigerants					
Sulfur dioxide	X				
VOC's	X	X	X		X

A Selection of Gases Typically Associated with Various Industries

Industry	Heavy Manufacturing					
	Vehicle manufacturing plants	Heat-transfer fluids	Vehicle emissions	Metal-plating	Manufacturing process emissions	Forklift & crane operations
Combustible Gases	X				X	X
Ammonia				X		
Carbon dioxide			X		X	
Carbon monoxide	X		X			X
Chlorine						
Chlorine dioxide						
Ethylene						
Ethylene oxide						
Hydrogen chloride				X		
Hydrogen cyanide				X		
Hydrogen sulfide					X	
Nitric oxide			X		X	
Nitrogen dioxide	X		X		X	X
O_2 deficiency/enrichment						
Phosphine						
Refrigerants	X	X				
Sulfur dioxide			X		X	
VOC’s	X	X	X		X	

A Selection of Gases Typically Associated with Various Industries

Industry	**Heavy Manufacturing**			
	Chemical loading/ off-loading	Paint booths	Degreasers	Mechanical equipment rooms
Combustible Gases	**X**	**X**	**X**	**X**
Ammonia	**X**			**X**
Carbon dioxide				
Carbon monoxide		**X**		
Chlorine	**X**			
Chlorine dioxide				
Ethylene				
Ethylene oxide				
Hydrogen chloride				
Hydrogen cyanide				
Hydrogen sulfide				
Nitric oxide				
Nitrogen dioxide				
O_2 deficiency/enrichment		**X**		**X**
Phosphine				
Refrigerants				**X**
Sulfur dioxide				
VOC's	**X**	**X**	**X**	

A Selection of Gases Typically Associated with Various Industries

Industry	**HVAC**						
	Heating boilers or ducting, general office applications	Parking garages, warehouses	Occupied buildings, office buildings, research labs	Parking garages, tunnels, furnace rooms, maintenance garages	Ventilation ducts	Cold storage & transport facilities, meat packing plants, supermarkets, refrigerator storage locations, food storage system monitoring	Mechanical rooms
Combustible Gases	X		X	X	X		X
Ammonia		X	X	X		X	X
Carbon dioxide	X		X		X	X	
Carbon monoxide	X	X		X	X		
Chlorine							
Chlorine dioxide							
Ethylene							
Ethylene oxide		X				X	
Hydrogen chloride							
Hydrogen cyanide							
Hydrogen sulfide							
Nitric oxide							
Nitrogen dioxide		X		X	X		
O_2 deficiency/enrichment			X	X		X	X
Phosphine							
Refrigerants			X	X		X	X
Sulfur dioxide							
VOC's			X		X		

A Selection of Gases Typically Associated with Various Industries

Industry	**Indoor air quality**	
	Occupied buildings (industrial, commercial, residential), office buildings, research labs	Parking garages, tunnels, furnace rooms, maintenance garages, crawl spaces
Combustible Gases	X	X
Ammonia		
Carbon dioxide	X	X
Carbon monoxide	X	X
Chlorine		
Chlorine dioxide		
Ethylene		
Ethylene oxide		
Hydrogen chloride		
Hydrogen cyanide		
Hydrogen sulfide		
Nitric oxide		
Nitrogen dioxide		X
O_2 deficiency/enrichment	X	X
Phosphine		
Refrigerants	X	X
Sulfur dioxide		
VOC's	X	

A Selection of Gases Typically Associated with Various Industries

Industry	**Iron & Steel**						
	Blast furnance operation & maintenance, converter operation, furnace & gas pipeline leaks	Metal-mining, finishing work, fuel storage	Coking operations	Welding	Confined space	Maintenance rooms (chillers)	Motor maintenance & cleaning, coke oven emissions
Combustible Gases	X	X	X	X	X		X
Ammonia		X		X		X	
Carbon dioxide		X					X
Carbon monoxide	X		X		X		X
Chlorine							
Chlorine dioxide							
Ethylene							
Ethylene oxide							
Hydrogen chloride							
Hydrogen cyanide							
Hydrogen sulfide		X	X		X		
Nitric oxide				X			
Nitrogen dioxide				X			X
O_2 deficiency/enrichment	X				X		
Phosphine							
Refrigerants						X	
Sulfur dioxide			X				X
VOC's					X		X

A Selection of Gases Typically Associated with Various Industries

Industry	**Medical**						
	Operating rooms, occupied areas	Alcohol’s, “sick building syndrome”	Central supply, sterilization areas	MRI	Parking garages	Decontamination areas	Mechanical equipment rooms
Combustible Gases							**X**
Ammonia							**X**
Carbon dioxide	**X**	**X**					
Carbon monoxide					**X**		**X**
Chlorine							
Chlorine dioxide							
Ethylene	**X**	**X**					
Ethylene oxide	**X**	**X**	**X**				
Hydrogen chloride							
Hydrogen cyanide							
Hydrogen sulfide							
Nitric oxide							
Nitrogen dioxide							
O_2 deficiency/enrichment	**X**			**X**			
Phosphine							
Refrigerants							**X**
Sulfur dioxide							
VOC’s		**X**	**X**			**X**	

A Selection of Gases Typically Associated with Various Industries

Industry	**Mining**						
	Confined space	Mechanized coal cutting	Mining process	Result of combustion (fire), diesel-powered machinery exhaust, confined space blasting	Metal mining	Diesel exhaust	Diesel-powered machinery, blasting
Combustible Gases	**X**	**X**	**X**	**X**			
Ammonia					**X**		
Carbon dioxide	**X**		**X**		**X**		
Carbon monoxide	**X**			**X**	**X**	**X**	**X**
Chlorine							
Chlorine dioxide							
Ethylene							
Ethylene oxide							
Hydrogen chloride							
Hydrogen cyanide					**X**		
Hydrogen sulfide			**X**		**X**		
Nitric oxide						**X**	**X**
Nitrogen dioxide				**X**		**X**	**X**
O_2 deficiency/enrichment	**X**				**X**		
Phosphine							
Refrigerants					**X**		
Sulfur dioxide							
VOC's							

A Selection of Gases Typically Associated with Various Industries

Industry	**Oil & Gas**					
	Petroleum refining	Pipeline compressor stations & pumping stations	Refineries	Refineries, petrochemical facilities, perimeter monitoring	Incomplete combustion, conversion, coking, general processing, leak detection	Conversion processes, isomerization, catalytic reforming, treatment processes, leak detection, storage vessels, perimeter monitoring
Combustible Gases	X	X	X	X	X	X
Ammonia	X		X			
Carbon dioxide						
Carbon monoxide			X		X	
Chlorine						
Chlorine dioxide						
Ethylene						
Ethylene oxide						
Hydrogen chloride	X		X			X
Hydrogen cyanide						
Hydrogen sulfide	X		X	X	X	X
Nitric oxide						
Nitrogen dioxide					X	
O_2 deficiency/enrichment						X
Phosphine						
Refrigerants						
Sulfur dioxide	X		X	X		
VOC's	X		X	X		X

A Selection of Gases Typically Associated with Various Industries

Industry	**Oil & Gas**						
	Refining process, general leak detection, treatment processes, crude separation, drilling rigs	Confined space (tank cleaning operations, enclosed bldgs or structures)	Natural gas lines	Offshore drilling platforms-storage & processing areas, control rooms, living spaces, power generation rooms	Refining process, process stream sample collection, general plant operations	Mechanical equipment rooms	Thermal oxidizers
Combustible Gases	X	X	X	X	X	X	X
Ammonia							
Carbon dioxide	X				X		
Carbon monoxide							
Chlorine							
Chlorine dioxide							
Ethylene							
Ethylene oxide							
Hydrogen chloride							
Hydrogen cyanide							
Hydrogen sulfide	X		X	X	X		
Nitric oxide							
Nitrogen dioxide							
O_2 deficiency/enrichment		X					
Phosphine							
Refrigerants						X	
Sulfur dioxide	X				X		
VOC's	X	X			X		

A Selection of Gases Typically Associated with Various Industries

Industry	**Paper & Pulp**				
	Paper production (bleaching)	Chemical pulping, Kraft pulping	Confined spaces (tanks, pits, sumps, vats)	Paper production (coating & dying)	Mechanical equipment rooms
Combustible Gases			**X**	**X**	**X**
Ammonia		**X**			**X**
Carbon dioxide					
Carbon monoxide					
Chlorine	**X**		**X**		
Chlorine dioxide	**X**				
Ethylene					
Ethylene oxide					
Hydrogen chloride					
Hydrogen cyanide					
Hydrogen sulfide		**X**	**X**	**X**	
Nitric oxide					
Nitrogen dioxide	**X**			**X**	
O_2 deficiency/enrichment			**X**		
Phosphine					
Refrigerants	**X**				**X**
Sulfur dioxide	**X**	**X**			
VOC’s				**X**	

A Selection of Gases Typically Associated with Various Industries

Industry	**Pharmaceutical**				
	Manufacturing, gas leaks	Solvent vapor process monitoring	Chemical synthesis operations	Labs, fine chemical manufacturing	Labs, organic synthesis, liquid-solid separation, compounding, granulating & tablet-coating operations, drying & packaging, fine chemical manufacturing
Combustible Gases	**X**	**X**	**X**	**X**	**X**
Ammonia	**X**	**X**	**X**	**X**	**X**
Carbon dioxide		**X**			**X**
Carbon monoxide				**X**	
Chlorine	**X**			**X**	**X**
Chlorine dioxide	**X**				
Ethylene		**X**			
Ethylene oxide	**X**		**X**	**X**	**X**
Hydrogen chloride					
Hydrogen cyanide	**X**		**X**	**X**	**X**
Hydrogen sulfide					
Nitric oxide					
Nitrogen dioxide					
O_2 deficiency/enrichment			**X**		
Phosphine					
Refrigerants					**X**
Sulfur dioxide	**X**				
VOC’s		**X**	**X**		**X**

A Selection of Gases Typically Associated with Various Industries

Industry	**Pharmaceutical**		
	Nitrogen blanketing of storage vessels, reactors and centrifuges	Compressed breathing air	Utilities
Combustible Gases			**X**
Ammonia			
Carbon dioxide		**X**	
Carbon monoxide	**X**	**X**	**X**
Chlorine			
Chlorine dioxide			
Ethylene			
Ethylene oxide			
Hydrogen chloride			
Hydrogen cyanide			
Hydrogen sulfide			
Nitric oxide			
Nitrogen dioxide			
O_2 deficiency/enrichment	**X**	**X**	
Phosphine			
Refrigerants			**X**
Sulfur dioxide			
VOC's			

A Selection of Gases Typically Associated with Various Industries

Industry	**Power generation**							
	Home furnace leaks	Transformer insulation	Power generation plants	Fuel storage	Fuel transportL loading & unloading	Fossil fuel power plants	Confined space	Coal & fuel oil oxidization in combustion process (emissions)
Combustible Gases	**X**		**X**	**X**	**X**	**X**	**X**	
Ammonia			**X**			**X**		**X**
Carbon dioxide			**X**				**X**	**X**
Carbon monoxide	**X**		**X**		**X**	**X**	**X**	**X**
Chlorine			**X**					
Chlorine dioxide								
Ethylene								
Ethylene oxide								
Hydrogen chloride			**X**					**X**
Hydrogen cyanide								
Hydrogen sulfide								
Nitric oxide						**X**		
Nitrogen dioxide			**X**			**X**		**X**
O_2 deficiency/enrichment			**X**				**X**	
Phosphine								
Refrigerants								
Sulfur dioxide			**X**			**X**		**X**
Sulfur hexafluoride		**X**						
VOC’s					**X**		**X**	

A Selection of Gases Typically Associated with Various Industries

Industry	**Semiconductor fabs**					
	Manufacturing, processing	As doping agent in manufacturing, diffusion and ion implementation, checmcal vapor deposition	Cleaning agents, fluorinated compounds	Lithography, etching, oxidation, metalization, assembly & testing	Chiller plant	Compressed breathing air
Combustible Gases	X		X			
Ammonia					X	
Arsine	X					
Bromine	X					
Carbon monoxide	X					X
Chlorine	X					
Chlorine dioxide	X					
Diborane	X					
Germane	X					
Hydrogen chloride	X			X		
Hydrogen cyanide						
Nitric oxide	X					
Nitrogen dioxide	X					
O_2 deficiency/enrichment						X
Phosphine		X				
Refrigerants			X		X	
Silane	X					
VOC's			X	X		

A Selection of Gases Typically Associated with Various Industries

Industry	**Shipyard/marine**								
	Confined space (storage holds)	Fuel storage & pumping facilities	Engine room	Waste treatment	Chillers	LNG transport	Oil tanker pumps	U.S. Navy ships	Ferry boats
Combustible Gases	X	X	X	X		X	X	X	X
Ammonia			X		X			X	X
Carbon dioxide		X							
Carbon monoxide	X		X					X	X
Chlorine									
Chlorine dioxide	X								
Ethylene									
Ethylene oxide									
Hydrogen chloride									
Hydrogen cyanide									
Hydrogen sulfide				X				X	
Nitric oxide									
Nitrogen dioxide									
O_2 deficiency/enrichment	X			X					
Phosphine									
Refrigerants			X		X			X	X
Sulfur dioxide									
VOC's	X							X	

A Selection of Gases Typically Associated with Various Industries

Industry	**Water & Wastewater**									
	Processing; storage tanks, rooms & pipes	Digesters, digester gas storage	Stagnant gas, incinerators	Plant pumps, plant sewage basin monitoring for solvent leaks or dumping	General processes	Sewer work	Confined space	Dechlorinization, storage tanks	Wet well influent	Pump stations
Combustible Gases	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**
Ammonia	**X**									
Carbon dioxide		**X**	**X**				**X**			
Carbon monoxide									**X**	**X**
Chlorine	**X**						**X**	**X**		
Chlorine dioxide	**X**						**X**	**X**		
Ethylene										
Ethylene oxide										
Hydrogen chloride										
Hydrogen cyanide										
Hydrogen sulfide	**X**	**X**			**X**	**X**	**X**		**X**	**X**
Nitric oxide										
Nitrogen dioxide										
O_2 deficiency/enrichment					**X**	**X**	**X**			**X**
Phosphine										
Refrigerants										
Sulfur dioxide								**X**		
VOC's	**X**						**X**			

A Selection of Gases Typically Associated with Various Industries

Industry	**Welding** Confined space, arc air cutting, flux-shielded & gas shielded arc welding, metal cutting & flame gouging, gas pressure welding	General operations	Thermite and stud welding, laser welding & chilling, arc air cutting, arc welding, electric resistance & gas pressure welding, metal cutting & flame gouging, brazing
Combustible Gases	**X**		**X**
Ammonia	**X**		
Carbon dioxide	**X**		
Carbon monoxide	**X**		**X**
Chlorine			
Chlorine dioxide			
Ethylene	**X**		
Ethylene oxide			
Hydrogen chloride			
Hydrogen cyanide			
Hydrogen sulfide			
Nitric oxide			
Nitrogen dioxide			
O_2 deficiency/enrichment	**X**		**X**
Phosphine			
Refrigerants			
Sulfur dioxide			
VOC's			

A Selection of Gases Typically Associated with Various Industries

Industry	**Welding**	
	Arc welding & cutting, stud welding, arc + air cutting, gas pressure welding, metal cutting & flame gouging	Confined space welding, electron beam welding
Combustible Gases	**X**	**X**
Ammonia		
Carbon dioxide		
Carbon monoxide		**X**
Chlorine		
Chlorine dioxide		
Ethylene		
Ethylene oxide		
Hydrogen chloride		
Hydrogen cyanide		
Hydrogen sulfide		
Nitric oxide		
Nitrogen dioxide	**X**	
O_2 deficiency/enrichment	**X**	**X**
Phosphine		
Refrigerants		
Sulfur dioxide		
VOC's		

Section 5
Section 5

Section 5

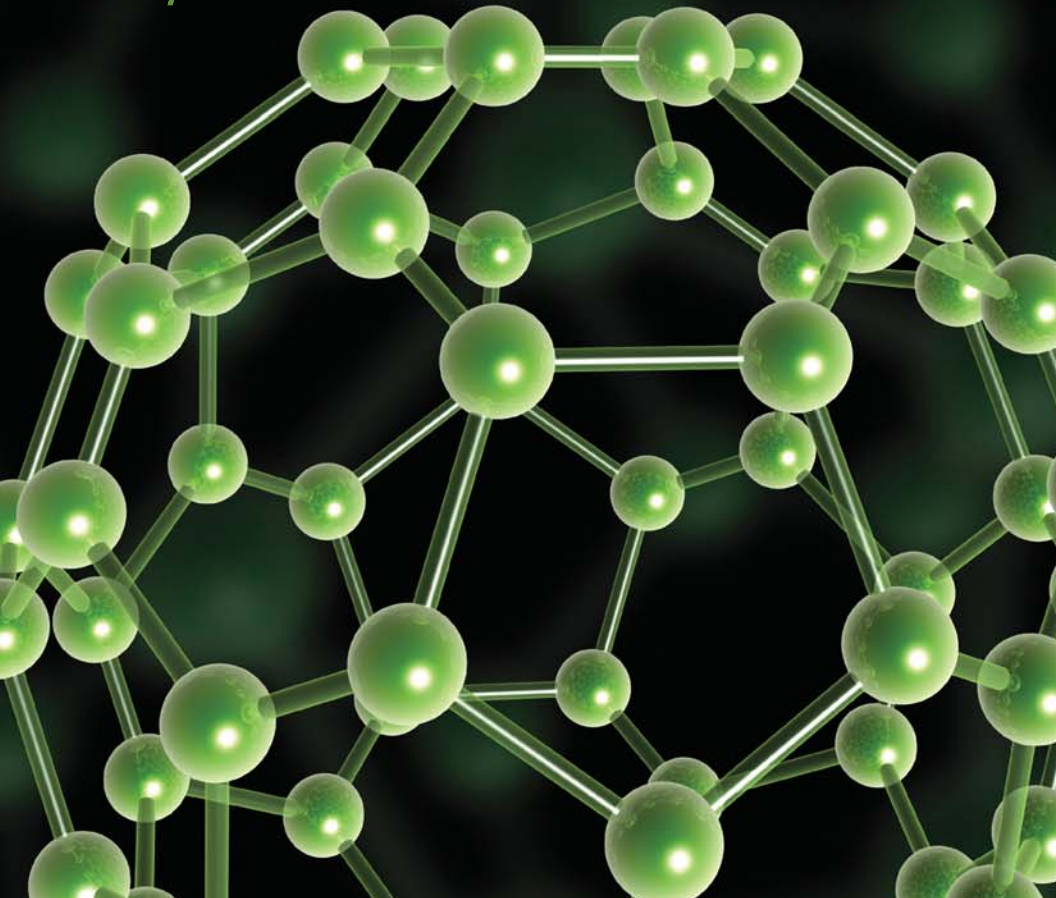
Hazardous Locations Classification

Class I: Flammable Gasses, Vapors or Liquids
Class II: Combustible Dusts
Class III Ignitable Fibers & Flyings

ATEX - Explosive Atmospheres

A Selection of Recognized Testing Laboratories

System Installation



Hazardous Locations Classification

The hazardous location classification system was designed to promote the safe use of electrical equipment in environments defined as “hazardous areas”. A hazardous area is a location in which the potential presence of a flammable gas/ air mixture requires special precautions to reduce the possibility of any electronics in the hazardous area becoming a source of ignition.

In the gas detection applications, hazardous areas are generally defined by two factors: the type of gas that may be present, and the degree of probability that it will be present at any given instant. Hazardous areas are defined slightly differently in various countries, but essentially the same result is achieved.

Areas are classified according to the likelihood that they will produce a combustion hazard for the electronic device. In a hazardous area each apparatus must possess the appropriate approvals for safe operation in that area (i.e., to ensure that it does not become a source of ignition). Various methods of protection are used to meet this need.

Area Classification

Each area is classified according to the likelihood that the hazard will be present at any given instant. There are two major hazardous location classifications:

- Classification 1: Used in North American installations (US National Electric Code“ and Canadian Electric Code). Areas are subdivided into “Classes” and “Divisions”.
- Classification 2: Used in European (CENEL EC) and International Electrotechnical Committee- (IEC) aligned countries such as Australia; also used in some North American installations. Areas are categorized into “Zones”.

Gas Groups

Gases are grouped according to their ignition energies which are produced from spark sources (from most easily ignited to least easily ignited).

Hazardous Locations Classification

Temperature Class

Gases are also grouped according to their ignition temperature. This is the maximum surface temperature that can be attained by an apparatus or component at maximum-rated ambient temperature. Six basic temperature classes are used to categorize this factor (T1 through T6). The higher the temperature class, the lower the maximum surface temperature and thus the wider the range of gases for which the apparatus is suitable.

Protection Methods

Various forms of ignition protection are used, such as intrinsic safety, explosionproof, flameproof, purging/ pressurization, hermetic sealing and non-sparking design.

Environmental Protection

Environmental protection refers to design methods used to minimize equipment exposure to invasive environmental conditions such as water, ice, dust and corrosion. As with Hazardous Area Classifications, equipment environmental protection ratings vary somewhat within and outside of North America. As seen in the following two tables, National Electrical Manufacturers Association (NEMA) and Ingress Protection (IP) Codes provide similar information regarding instrument protection against various environmental conditions.

Attaining one rating does not imply that the other ratings have also been met.

Hazardous Locations Classification

INGRESS PROTECTION (IP) CODES
(IEC/EN 60529)

FIRST NUMERAL Protection against solid bodies			**SECOND NUMERAL** Protection against liquids
No Protection	**0**	**0**	**No Protection**
Objects Greater Than 50mm	**1**	**1**	**Vertically Dripping Water**
Objects Greater Than 12mm	**2**	**2**	**Angled Dripping Water - 75° to 90°**
Objects Greater Than 2.5mm	**3**	**3**	**Sprayed Water**
Objects Greater Than 1.0mm	**4**	**4**	**Splashed Water**
Dust-Protected	**5**	**5**	**Water Jets**
Dust-Tight	**6**	**6**	**Heavy Seas**
		7	**Effects of Immersion**
		8	**Indefinite Immersion**

Example: IP65 equipment is dust-tight and protected against water jets

Hazardous Locations Classification

Enclosure Ratings		
NEMA, UL, & CSA Type Rating	**Approximate IEC/IP classification**	**Abbreviated protection description**
1	IP30	Indoor, from contact with contents
2	IP31	Indoor, limited, from dirt & water
3	IP64	Outdoor, from rain, sleet, windblown dust & ice damage
3R	IP32	Outdoor, from rain, sleet & ice damage
4	IP66	Indoor & outdoor, from windblown dust, rain, splashing & hose directed water & ice damage
4X	IP66	Indoor & outdoor, from corrosion, windblown dust, rain, splashing & hose directed water & ice damage
6	IP67	Indoor & outdoor, from hose-directed water, water entry during submersion & ice damage
12	IP55	Indoor, from dust, falling dirt & dripping non-corrosive liquids
13	IP65	Indoor, from dust, spraying water, oil & non-corrosive liquids

Hazardous Locations Classification

Class I: Flammable Gases, Vapors or Liquids

Class I Area Classification

Division 1:

Where ignitable concentrations of flammable gases, vapors or liquids can exist all of the time or some of the time under normal operating conditions.

Division 2:

Where ignitable concentrations of flammable gases, vapors or liquids are not likely to exist under normal operating conditions.

Zone 0:

Where ignitable concentrations of flammable gases, vapors or liquids are present continuously or for long periods of time under normal operating conditions.

Zone 1:

Where ignitable concentrations of flammable gases, vapors or liquids are likely to exist under normal operating conditions.

Zone 2:

Where ignitable concentrations of flammable gases, vapors or liquids are not likely to exist under normal operating conditions.

Class I Groups
Division 1 and 2

A acetylene

B hydrogen, fuel and combustible process gases containing more than 30% hydrogen by volume, or gases or vapors of equivalent hazard such as butadiene, ethylene oxide, propylene oxide and acrolein

C cyclopropane, ethyl ether, ethylene, or gases or vapors of equivalent hazard

D acetone, ammonia, benzene, butane, ethanol, gasoline, hexane, methane, natural gas, naptha, propane, or gases or vapors of equivalent hazard

Zone 0, 1 and 2

IIC acetylene and hydrogen, fuel and combustible process gases containing more than 30% hydrogen by volume, or gases or vapors of equivalent hazard such as butadiene, ethylene oxide, propylene oxide and acrolein

IIB cyclopropane, ethyl ether, ethylene, or gases or vapors of equivalent hazard

IIA acetone, ammonia, benzene, butane, ethanol, gasoline, hexane, methane, natural gas, naptha, propane, or gases or vapors of equivalent hazard

Hazardous Locations Classification

Class I: Flammable Gases, Vapors or Liquids

Class I Temperature Codes

(Maximum surface temperature of apparatus)

Division 1 and 2
T1 (≤450°C)
T2 (≤300°C)
T2A, T2B,T2C,T2D (≤280°C, ≤260°C, ≤230°C, ≤215°C)
T3 (≤200°C)
T3A, T3B, T3C (≤180°C, ≤165°C, ≤160°C)
T4 (≤135°C)
T4A (≤120°C)
T5 (≤100°C)
T6 (≤85°C)

Zone 0, 1, and 2
T1 (≤450°C)
T2 (≤300°C)
-
T3 (≤200°C)
-
T4 (≤135°C)
T5 (≤100°C)
T6 (≤85°C)

Hazardous Locations Classification

Class I: Flammable Gases, Vapors or Liquids

Class I, Division 1 and 2 Protection Methods			
		Applicable Certification Documents	
Area	Protection Methods	USA	Canada
Div. 1	• Explosionproof • Intrinsic safety (2 fault) • Purged/pressurized (Type X or Y)	UL 1203 UL 913 NFPA 496	CSA-30 CSA-157 NFPA 496
Div. 2	• Hermetically sealed • Nonincendive • Non-Sparking • Purged/Pressurized (Type Z) • Any Class I, Div. 1 method • Any Class I, Zone 0, 1 or 2 method	UL 1604 UL 1604 UL 1604 NFPA 496 — UL 2279	CSA-213 CSA-213 CSA-213 NFPA 496 — CSA-E79 Series

Hazardous Locations Classification

Class I: Flammable Gases, Vapors or Liquids

Class I, Zone 0, 1 and 2 Protection Methods

		Applicable Certification Documents			
Area	***Protection Methods***	***USA***	***Canada***	***IECEx Scheme†***	***Europe***
Zone 0	• Intrinsic safety, 'ia' (2 fault)	UL 60079-11	E60079-11	IEC 60079-11	EN 60079-11
	• Special requirements	Pending	No	IEC 60079-26	EN 60079-26
Zone 1	• Encapsulation, 'm'	UL 60079-18	CSA-E79-18	IEC 60079-18	EN 60079-18
	• Flameproof, 'd'	UL 60079-1	E60079-1	IEC 60079-1	EN 60079-1
	• Increased safety, 'e'	UL 60079-7	E60079-7	IEC 60079-7	EN 60079-7
	• Intrinsic safety, 'ib' (1 fault)	UL 60079-11	E60079-11	IEC 60079-11	EN 60079-11
	• Oil immersion, 'o'	UL 60079-6	E60079-6	IEC 60079-6	EN 50015
	• Powder filling, 'q'	UL 60079-5	E60079-5	IEC 60079-5	EN 50017
	• Pressurization, 'px' or 'py'	ISA 12.04.01	E60079-2	IEC 60079-2	EN 60079-2
	• Any Class I, Zone 0	Yes	Yes	Yes	Yes
	• Any Class I, Div. 1	Yes	Yes	No	No
Zone 2	• Non-sparking, 'nA'	UL 60079-15	E60079-15	IEC 60079-15	EN 60079-15
	• Enclosed break, 'nC'	UL 60079-15	E60079-15	IEC 60079-15	EN 60079-15
	• Energy limited, 'nL'	UL 60079-15	E60079-15	IEC 60079-15	EN 60079-15
	• Restricted breathing, 'nR'	UL 60079-15	E60079-15	IEC 60079-15	EN 60079-15
	• Pressurization, 'pz'	ISA 12.04.01*	E60079-2	IEC 60079-2	EN 60079-2
	• Any Class I, Zone 0 or 1 method	Yes	Yes	Yes	Yes
	• Any Class I, Div. 1 or 2 method	Yes	Yes	No	No

Note: 60079-0 General requirements used in conjunction with 60079-xx. UL 60079-xx equivalents are available as ANSI/ISA 60079-xx.

Note 2: UL 60079-xx equivalents are available as ANSI/ISA 60079-xx.

Note 3: Requirements subject to change without notice. Check your local authorithy having jurisdiction for current requirements.

* See NFPA 496 for Type X, Y, and Z.

Hazardous Locations Classification

Class II: Combustible Dusts

Class II Area Classification

Division 1:

Where ignitable concentrations of combustible dusts can exist all of the time or some of the time under normal operating conditions.

Division 2:

Where ignitable concentrations of combustible dusts are not likely to exist under normal operating conditions.

Class II Groups

Division 1 and 2

E (metals – Div. 1 only)

F (coal)

G (grain)

Class II Temperature Codes

Division 1 and 2

T1 (≤450°C)

T2 (≤300°C)

T2A, T2B,T2C,T2D
(≤280°C, ≤260°C, ≤230°C, ≤215°C)

T3 (≤200°C)

T3A, T3B, T3C
(≤180°C, ≤165°C, ≤160°C)

T4 (≤135°C)

T4A (≤120°C)

T5 (≤100°C)

T6 (≤85°C)

Hazardous Locations Classification

Class II: Combustible Dusts

Class II, Division 1 and 2 Protection Methods			
Applicable Certification Documents			
Area	Protection Methods	USA	Canada
Div. 1	• Dust-ignitionproof	UL 1203	CSA-25 or CSA-E1241-1-1
	• Intrinsic safety	UL 913	CSA-157
	• Pressurized	NFPA 496	NFPA 496
Div. 2	• Dusttight	UL 1604	CSA-157 or CSA-E1241-1-1
	• Hermetically sealed	UL 1604	—
	• Nonincendive	UL 1604	—
	• Pressurized	NFPA 496	NFPA 496
	• Any class II, Div. 1 method	—	—

Hazardous Locations Classification

Hazardous Locations Markings

Class I, II & III, Division 1 & 2 (USA & Canada) – This marking would include:
Class(es), Division(s), Gas/Dust Group(s), Temperature Code
Example: Class I, Division 1, Group C & D, T4A

Class I, Zone 0, 1 & 2 (USA) – This marking would include:
For Zone Listings based on 60079-xx Class, Zone, AEx, Protection Method(s), Gas Group, Temperature Code
Example: Class I, Zone 1, AEx de IIB T4

Class I, Zone 0, 1 & 2 (Canada) – This marking would include:
For Zone Listings based on Canadian Zone Certification Documents Class, Zone, Ex, Protection Method(s), Gas Group, Temperature Code
*Example:*Class I, Zone 1, Ex de IIB T4

Zone 0, 1 & 2 (IECEx Scheme) – This marking would include:
Ex, Protection Method(s), Gas Group, Temperature Code
Example: Ex de IIB T4

Zone 0, 1 & 2 (Europe) – This marking would include:
EEx, Protection Method(s), Gas Group, Temperature Code
Example: Ex de IIB T4

ATEX Directive (Europe) – In addition to the European Ex marking string noted above, this marking would include:

Non-mining: CE, Notified Body (NB) Identifier, ⟨Ex⟩, Equipment Group & Category, G (gas)/D (dust)
Example: (for DEMKO): CE 0539 ⟨Ex⟩ II 2

Mining: CE, Notified Body (NB) Identifier, ⟨Ex⟩, Equipment Group & Category
Example: (for DEMKO): CE 0539 ⟨Ex⟩ I 2

Hazardous Locations Classification

Class III: Ignitable Fibers & Flyings

Class III Area Classification
Division 1:

Where easily ignitable fibers or materials producing combustible flyings are handled, manufactured or used.

Division 2:

Where easily ignitable fibers are stored or handled.

Class III Groups
Division 1 and 2

None

Class III Temperature Codes

Division 1 and 2

None
Note: *Article 503 of the NEC limits the maximum temperature for Class III equipment to 165ºC for equipment not subject to overloading and to 120ºC for equipment that may be overloaded.*

Hazardous Locations Classification

Class III: Ignitable Fibers & Flyings

Class III, Division 1 and 2 Protection Methods			
Applicable Certification Documents			
Area	Protection Methods	USA	Canada
Div. 1	• Dusttight	UL 1604	CSA--157
	• Hermetically sealed	UL 1604	—
	• Intrinsic safety	UL 913	CSA-157
Div. 2	• Nonincendive	UL 1604	—
	• Any Class III, Div. 1 method		—

Hazardous Locations Classification

UL's Hazardous Locations Standards

UL 515	Electrical Resistance Heat Tracing for Commercial and Industrial Applications
ANSI/UL 583	Electric-Battery-Powered Industrial Trucks
ANSI/UL 674	Electric Motors and Generators for Use in Division 1 Hazardous (Classified) Locations
ANSI/UL 698	Industrial Control Equipment for Use in Hazardous (Classified) Locations
ANSI/UL 698A	Industrial Control Panels Relating to Hazardous (Classified) Locations
ANSI/UL 781	Portable Electric Lighting Units for Use in Hazardous (Classified) Locations
ANSI/UL 783	Electric Flashlights and Lanterns for Use in Hazardous (Classified) Locations
ANSI/UL 823	Electric Heaters for Use in Hazardous (Classified) Locations
ANSI/UL 844	Electric Lighting Fixtures for Use in Hazardous (Classified) Locations
ANSI/UL 877	Circuit Breakers and Circuit-Breaker Enclosures for Use in Hazardous (Classified) Locations
ANSI/UL 886	Outlet Boxes and Fittings for Use in Hazardous (Classified) Locations
ANSI/UL 894	Switches for Use in Hazardous (Classified) Locations
ANSI/UL 913	Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division I, Hazardous (Classified) Locations

Hazardous Locations Classification

UL's Hazardous Locations Standards

ANSI/UL 1002	Electrically Operated Valves for Use in Hazardous (Classified) Locations
ANSI/UL 1010	Receptacle-Plug Combinations for Use in Hazardous (Classified) Locations
ANSI/UL 1067	Electrically Conductive Equipment and Materials for Use in Flammable Anesthetizing Locations
ANSI/UL 1203	Explosionproof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations
ANSI/UL 1207	Sewage Pumps for Use in Hazardous (Classified) Locations
UL 1604	Electrical Equipment for Use in Class I and II, Division 2, and Class III Hazardous (Classified) Locations
ANSI/UL 2208	Solvent Distillation Units
UL 2225	Metal-Clad Cables and Cable-Sealing Fittings for Use in Hazardous (Classified) Locations
ANSI/UL 2279	Electrical Equipment for Use in Class I, Zone 0, 1 and 2 Hazardous (Classified) Locations

CE Approval

CE is a labeling system required by some European countries to identify those products which are permitted to be sold in EU (European Union) member states. CE approval is used to verify compliance with certain European health and safety rules known as “Directives”. The Directives relevant to permanent gas detection instrumentation are the Electromagnetic Compatibility (EMC) Directive, Low Voltage Directive and ATEX Directive.

EMC Directive

The Electromagnetic Compatibility Directive 89/336/EEC is designed to limit the effects that one piece of equipment may have on another piece of equipment due to the electrical interference it produces. The effects of such interference can be severe enough to cause a device to shut down when another one is switched on. Electrical signals called EMI (Electromagnetic Interference) are the main cause of these effects. Most of the interference is in the form of radio waves (electromagnetic radiation, also called “emissions”) that are produced inside electrical equipment as a result of high speed communications involving the switching of high speed currents. The EMC Directive requires that equipment emissions be minimized and that the device be rendered immune to the emissions of other equipment. This is accomplished by designing the unit to meet the requirements set forth in European standard EN 50270, which sets limits on the amount of emissions permitted and susceptibility levels (immunity) for equipment. Electrostatic Discharge (ESD), another form of electrical interference that can disrupt equipment functions, is also addressed in EN 50270.

Low Voltage Directive

The Low Voltage Directive (LVD) is a European personal safety Directive that is comparable to a US/Canadian fire/shock and safety approval. It applies to AC line powered devices and high voltage DC equipment. Specifically, the Directive applies to any equipment powered from a 50 VAC or 75 VDC or higher power source. The standard used for designing to compliance is EN/IEC 61010.

ATEX – Explosive Atmospheres

ATEX is the term used for the European Union's Directive 94/9/EC which concerns equipment and protective systems intended for use in potentially explosive atmospheres. The purpose of the directive is to facilitate trade within the EU by aligning the laws of the Member States in Europe regarding safety requirements for hazardous area products.

ATEX approval requires that the following issues be met:

1. Safety requirements
The product must meet the applicable hazardous location requirements.

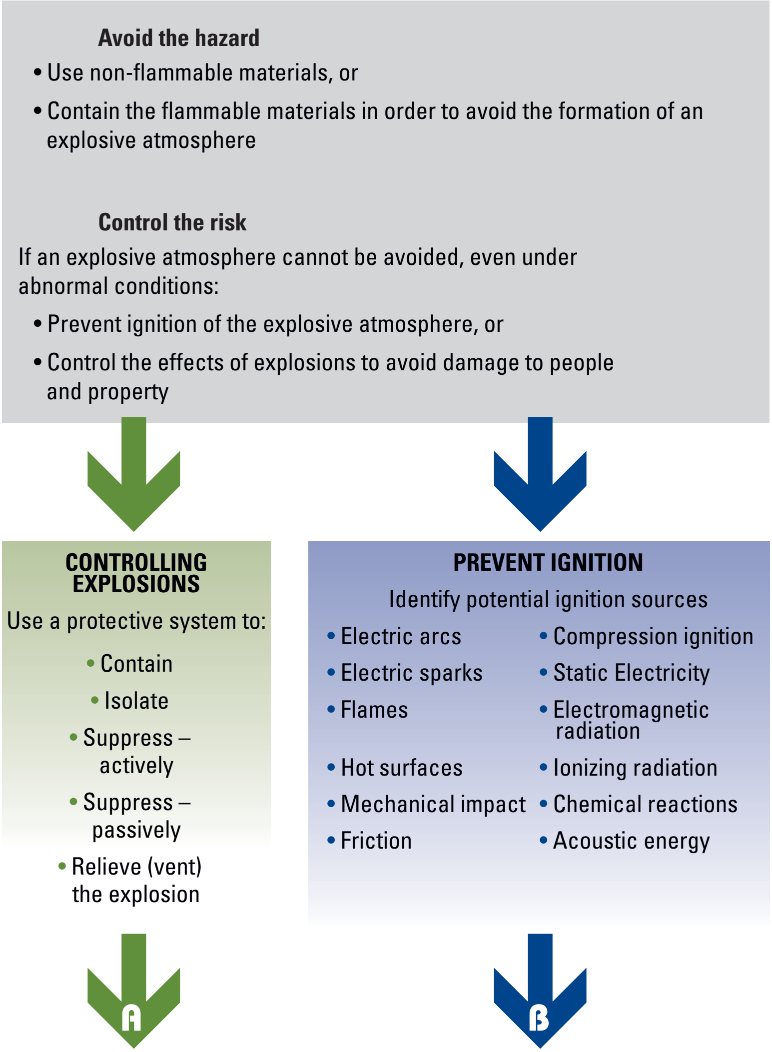
2. Performance requirements
If the product is designed to monitor combustible gas and/or oxygen, then it must meet certain performance criteria in fields such as response time, accuracy and linearity.

3. Quality management certification
The manufacturer must have an approved quality management system.

ATEX Explosive Atmospheres

EXPLOSION SAFETY HIERARCHY

(European Standard EN 1127-1)



Avoid the hazard

- Use non-flammable materials, or
- Contain the flammable materials in order to avoid the formation of an explosive atmosphere

Control the risk

If an explosive atmosphere cannot be avoided, even under abnormal conditions:

- Prevent ignition of the explosive atmosphere, or
- Control the effects of explosions to avoid damage to people and property

CONTROLLING EXPLOSIONS

Use a protective system to:

- Contain
- Isolate
- Suppress – actively
- Suppress – passively
- Relieve (vent) the explosion

A

PREVENT IGNITION

Identify potential ignition sources

- Electric arcs
- Electric sparks
- Flames
- Hot surfaces
- Mechanical impact
- Friction
- Compression ignition
- Static Electricity
- Electromagnetic radiation
- Ionizing radiation
- Chemical reactions
- Acoustic energy

B

PROTECTIVE SYSTEMS

Explosion suppression systems

Explosionproof equipment

Flame arresters

Explosion venting devices

Inerting

Limitation of concentration of combustibles

Dust explosion venting systems

Gas explosion venting systems

Explosion suppression devices

Active explosion extinguishing barriers

Explosion barriers for mines

Mechanical explosion barriers

PROTECT IGNITION SOURCES

Category of protection
(EU Directive 94/9/EC – ATEX)

Mining equipment –
Group I Category M1
Very high level of protection. Equipment can be operated in presence of explosive atmosphere

Category M2
High level of protection. Equipment to be de-energized in presence of explosive atmosphere

Non-mining equipment –
Group II

Category 1
Very high level of protection. Used where explosive atmosphere is present continuously or for long periods of time (Zone 0, 20)*

Category 2
High level of protection. Used where explosive atmosphere is likely to occur in normal service (Zone 1, 21)*

Category 3
Normal level of protection. Used where explosive atmosphere is unlikely to occur and would be infrequent and for short time (Zone 2,22)*

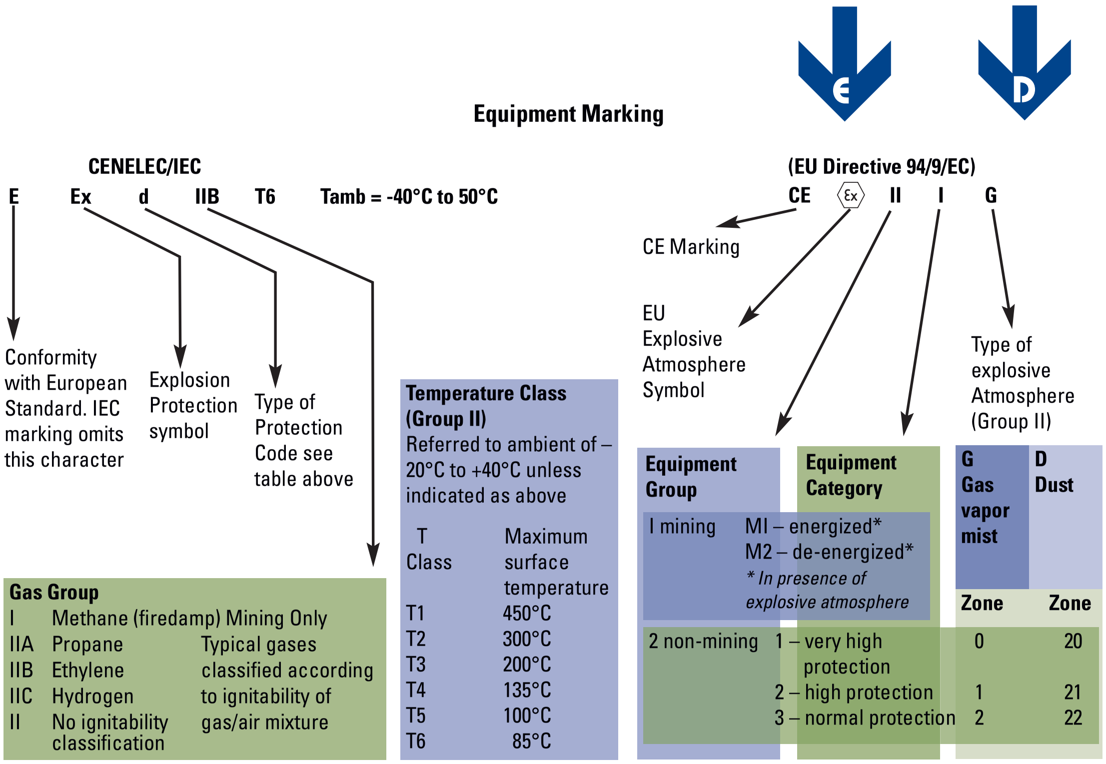
* EN 1127-1:1997. Clause 6.3

ATEX Explosive Atmospheres

Methods Of Protection: Standards								
Electrical equipment for ses, vapors and mists (G)				**Category**				
	Code	**Cenelec EN**	**IEC**	**M1**	**M2**	**1**	**2**	**3**
General requirements		50014	79-0					
Oil immersion	o	50015	79-6				+	
Pressurized	p	50016	79-2				+	
Powder filled	q	50017	79-5				+	
Flameproof enclosure	d	50018	79-1		+		+	
Increased safety	e	50019	79-7		+		+	
Intrinsic safety	ia	50020	79-11	+		+		
Intrinsic safety	ib	50020	79-11		+		+	
Encapsulated	m	50028	79-18				+	
Type of protection ‘n’	n	50021	79-15					+
Category I G		50284*	-			+		
Category MI		50303*	-	+				
Electrical equipment for flammable dusts (D)								
Construction and testing		50281-1-1				+	+	+
Non-electrical equipment		**CEN EN**						
General requirements		xxxx Pt 1*						
Restrictive breathing enclosure		xxxx Pt 2*						
Flameproof enclosure		xxxx Pt 3*						
Inherent safety		xxxx Pt 4*						
Constructional safety		xxxx Pt 5*						
Control of ignition sources		xxxx Pt 6*						

**Standards in preparation*

Note for reference only, ATEX now supercedes Cenelec
ATEX Explosive Atmospheres



Equipment Marking

(EU Directive 94/9/EC)

CE Ⓔx **II** **I** **G**

- CE → CE Marking
- Ⓔx → EU Explosive Atmosphere Symbol
- II → Equipment Group
- I → Equipment Category
- G → Type of explosive Atmosphere (Group II)

Equipment Group	**Equipment Category**
I mining	MI – energized* M2 – de-energized* ** In presence of explosive atmosphere*
2 non-mining	1 – very high protection 2 – high protection 3 – normal protection

G Gas vapor mist	**D Dust**
Zone	**Zone**
0	20
1	21
2	22

CENELEC/IEC

E **Ex** **d** **IIB** **T6** **Tamb = -40°C to 50°C**

- E → Conformity with European Standard. IEC marking omits this character
- Ex → Explosion Protection symbol
- d → Type of Protection Code see table above
- IIB → Gas Group

Temperature Class (Group II)
Referred to ambient of –20°C to +40°C unless indicated as above

T Class	Maximum surface temperature
T1	450°C
T2	300°C
T3	200°C
T4	135°C
T5	100°C
T6	85°C

Gas Group

I	Methane (firedamp) Mining Only	
IIA	Propane	Typical gases classified according to ignitability of gas/air mixture
IIB	Ethylene	
IIC	Hydrogen	
II	No ignitability classification	

A Selection of Recognized Testing Laboratories

North America	
CSA	Canadian Standards Association
ENT	Entela, Inc.
ETL	ETL SEMKO, Intertek Testing Service
FMGT	FM Global Technologies LLC
MET	MET Laboratories, Inc.
MSHA	Mine Safety and Health Administration
UL	Underwriters Laboratories Inc.
Australia	
TestSafe	TestSafe Australia Safety Engineering, Testing and Certification Services
Brazil	
CEPEL	Centro De Pesquisas De Enrgia Electrica
France	
INERIS	Institut National De L'Environnemant Industriel Et Des
Germany	
DMT	Deutsche Montan Technologie GmbH
TUV	TUV Product Services GmbH
KEMA	KEMA Registered Quality, Inc.
Russia	
GOSSTAND ART	Gosstandart of Russia

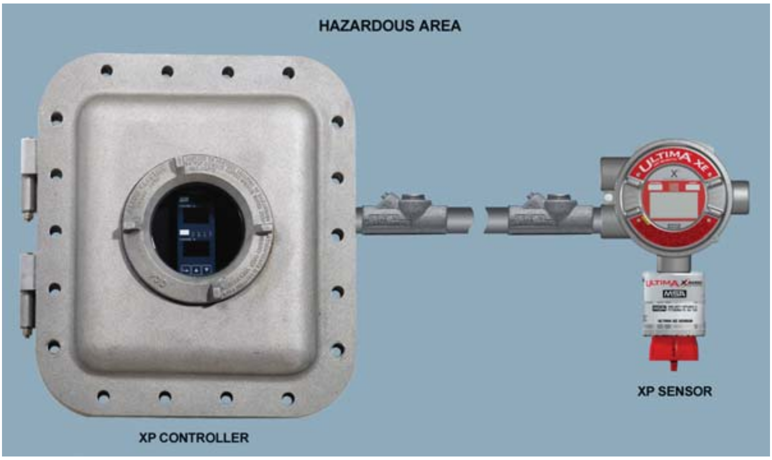
Approvals

System Installation

Permanent gas detection systems can be used in both hazardous and non-hazardous rated locations. In North America, if a monitoring system is located in a hazardous area then it must carry the appropriate approvals for that area, (Class, Division and Group). (See “Hazardous Location Classification” earlier in this section for descriptions of hazardous area classifications.) Most hazardous area monitoring applications require Class 1, Division 1 approval, which means that ignitable atmospheres are likely to be present, and thus protection from ignition sources is required to reduce the possibility of an explosion. The three protection methods approved for electrical equipment in this type of area are explosionproof, intrinsically safe and purged/pressurized.

I. Explosionproof

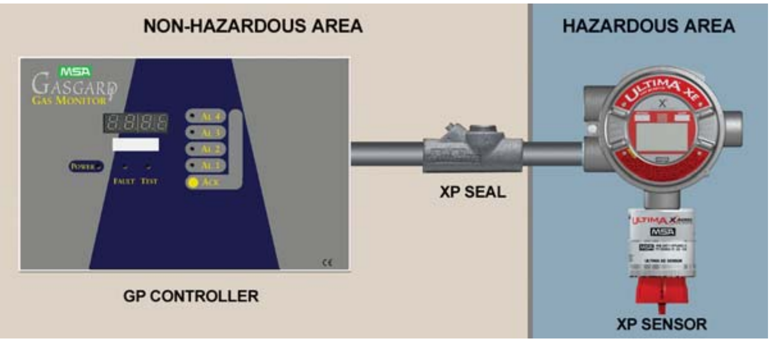
The device prevents an explosion in a hazardous location by containing any combustion within the device, and thereby preventing it from spreading into the atmosphere surrounding the enclosure. (**Note:** *wires connected to explosionproof classified devices must be contained in an explosionproof classified conduit.)*



Approvals

Instead of having both the sensor and the controller rated explosionproof (XP), explosionproof sensor housings are sometimes used with general purpose (GP) controllers that are located in non-hazardous locations.

- Widely used in US
- More costly to install and maintain
- Requires conduit and seals
- Non-intrusive calibration enhances installation
- If atmosphere ignites, it remains inside enclosure



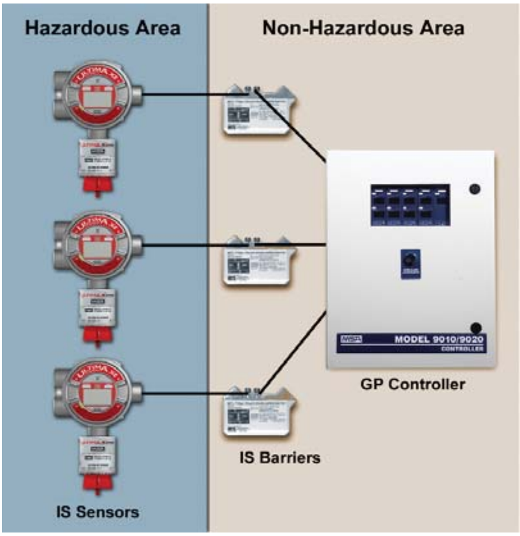
II. Intrinsically Safe

The device prevents explosions in hazardous locations through an electrical design in which the possibility of ignition is eliminated. To achieve this, protective components are often added in series with energy storage devices. The protective components eliminate the risk of ignition from sparks or an increased component surface temperature.

In this situation, an intrinsically safe sensor assembly is located in the hazardous area and an intrinsically safe barrier is installed in the non-hazardous area to reduce the chance of an electrical spark reaching the hazardous area. If multiple sensors are required, then multiple barriers are used.

Approvals

- Eliminates explosion proof conduit for electrical safety
- Requires electrical barriers to limit energy to sensor
- Both heat and electrical energy are kept below ignition thresholds



III. Purged/ Pressurized

Purged/ pressurized equipment cabinets containing spark-producing devices exclude flammable atmospheres. This is done by using compressed air or an inert gas such as nitrogen to pressurize the cabinet's interior. The unit is also designed to turn off the spark-producing device and trigger an alarm in the event of a pressurization failure. NFPA-496 contains specific design requirements for purged/ pressurized equipment.

There are three types of purging:

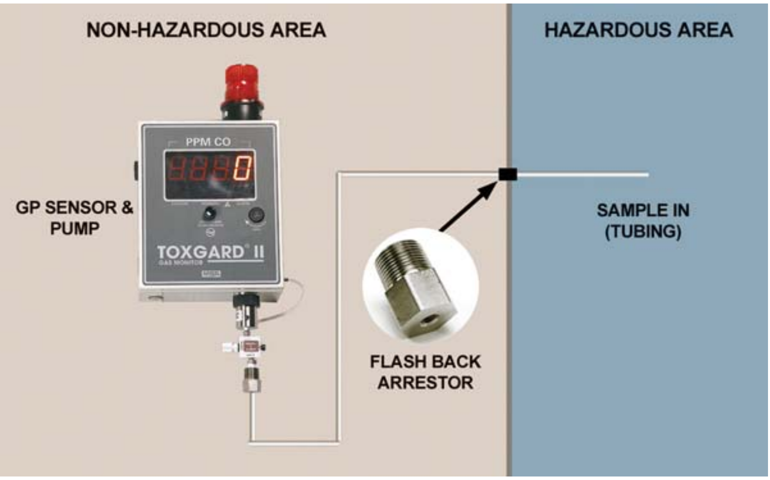
- Type X purging – reduces the classification within an enclosure from Division 1 to nonhazardous
- Type Y purging – reduces the classification within an enclosure from Division 1 to Division 2
- Type Z purging – reduces the classification within an enclosure from Division 2 to nonhazardous

When a purged/pressurized system is used, the unit is located in the hazardous area. Purging/ pressurization works in one of two ways: by either preventing outside atmospheres from entering the enclosed unit, or by removing flammable gases from the enclosure by flushing it with inert gas and maintaining internal pressure on the unit.

Approvals

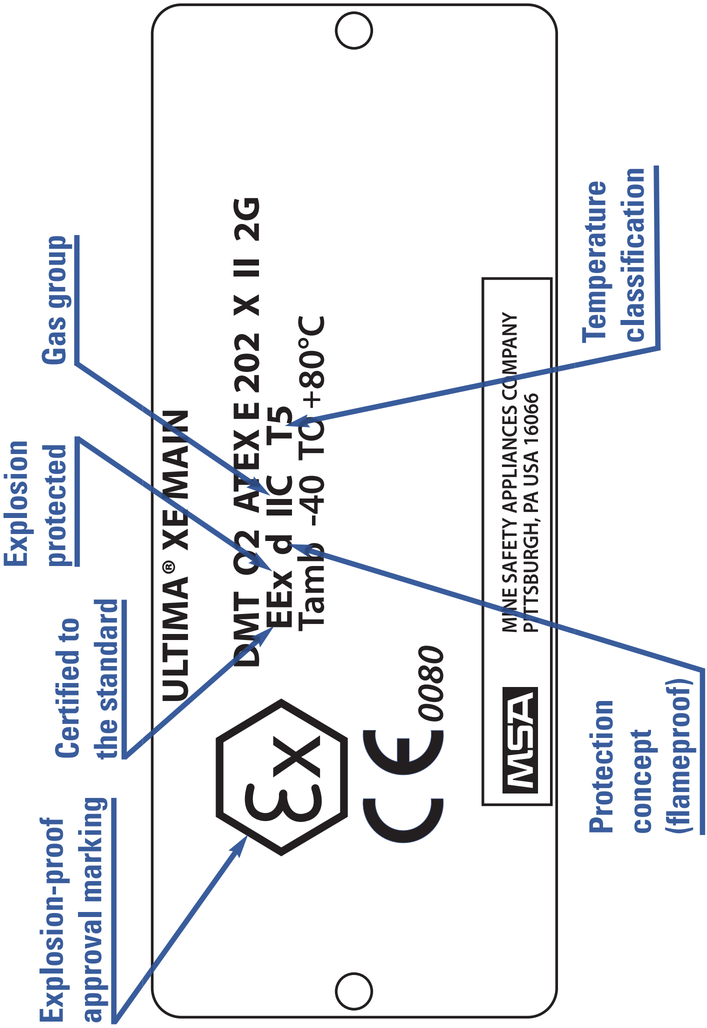
IV. Flameproof

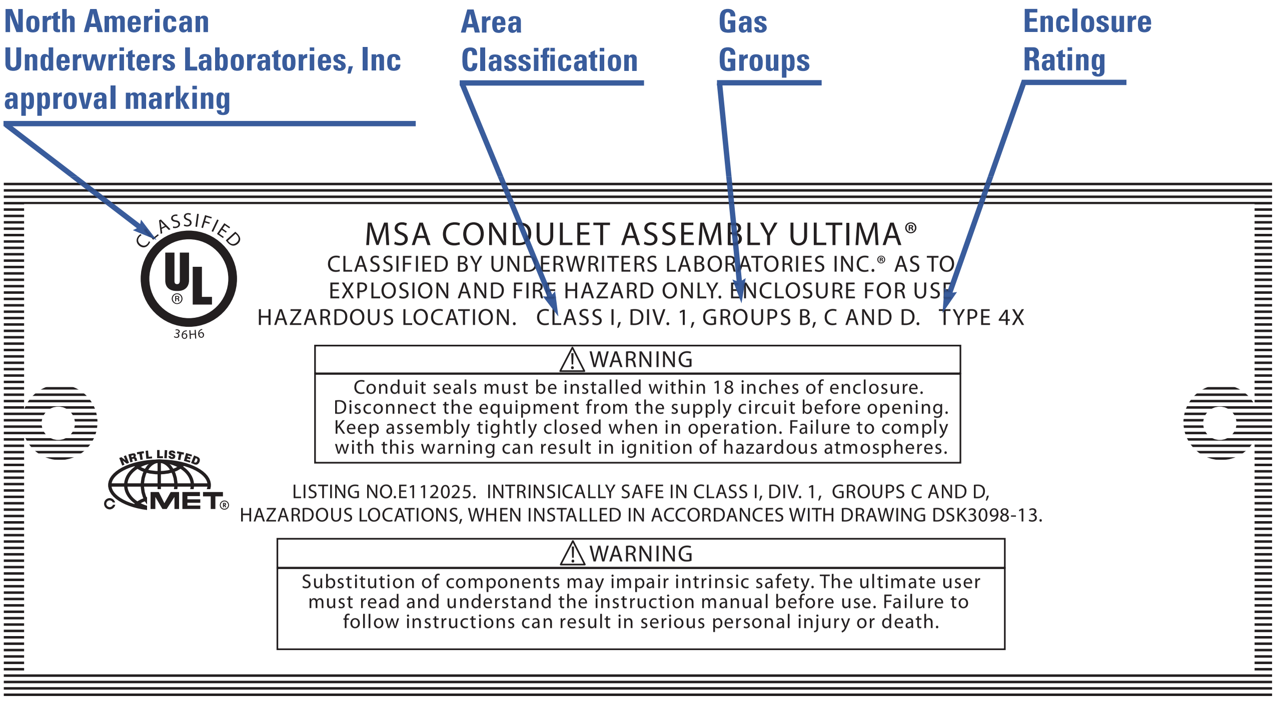
With the flameproof method of protection, the sample is pumped from the hazardous area to the GP sensor, which is located in the non-hazardous area. Flashback arrestors are installed at the hazardous area barrier to reduce the chance of an ignition source entering the hazardous area.



For each of the preceding circumstances, the detection system components should have a label similar to those shown below, indicating that they have received the approvals appropriate to the environment in which they are to be installed.

NOTE: *When installing a gas detection system, always follow National Electric Code (NEC) installation requirements and check the manufacturer's guidelines for calibration.*


Explosion-proof approval marking
Certified to the standard
Explosion protected
Gas group
ULTIMA® XE MAIN
DMT 02 ATEX E 202 X II 2G
EEx d IIC T5
Tamb -40 TO +80°C
0080
MINE SAFETY APPLIANCES COMPANY
PITTSBURGH, PA USA 16066
MSA
Temperature classification
Protection concept (flameproof)



MSA CONDULET ASSEMBLY ULTIMA®
CLASSIFIED BY UNDERWRITERS LABORATORIES INC.® AS TO
EXPLOSION AND FIRE HAZARD ONLY. ENCLOSURE FOR USE
HAZARDOUS LOCATION. CLASS I, DIV. 1, GROUPS B, C AND D. TYPE 4X

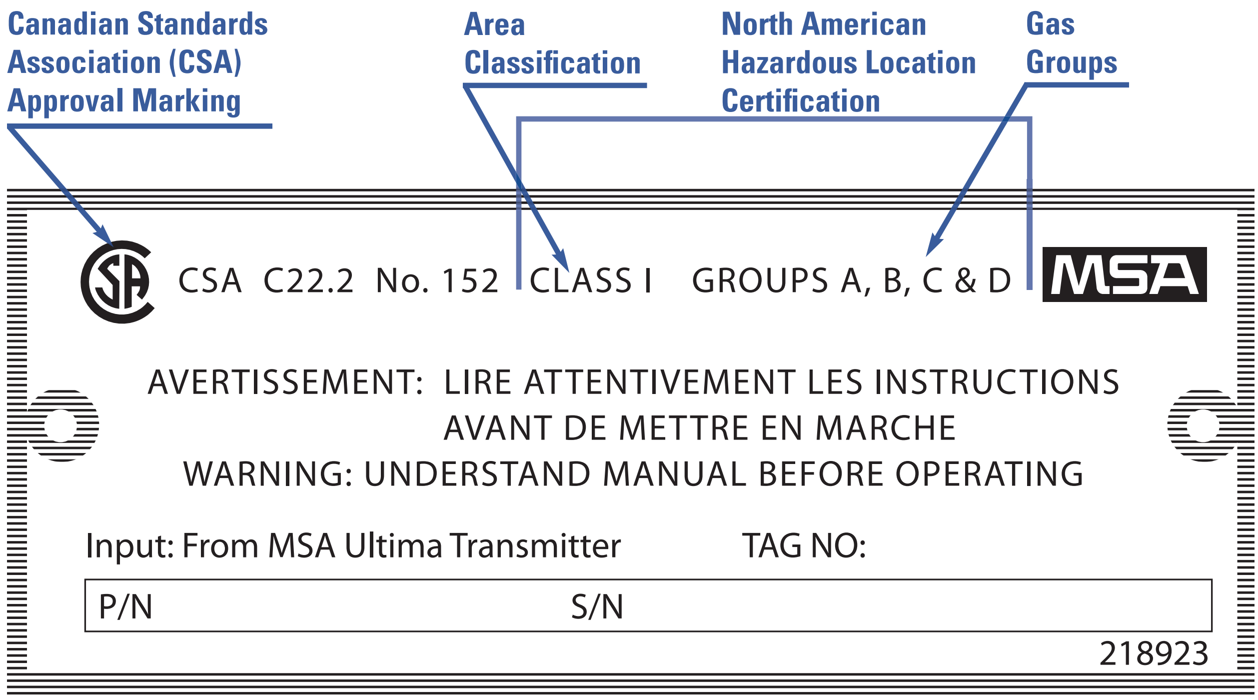
⚠ WARNING

Conduit seals must be installed within 18 inches of enclosure.
Disconnect the equipment from the supply circuit before opening.
Keep assembly tightly closed when in operation. Failure to comply
with this warning can result in ignition of hazardous atmospheres.

LISTING NO.E112025. INTRINSICALLY SAFE IN CLASS I, DIV. 1, GROUPS C AND D,
HAZARDOUS LOCATIONS, WHEN INSTALLED IN ACCORDANCES WITH DRAWING DSK3098-13.

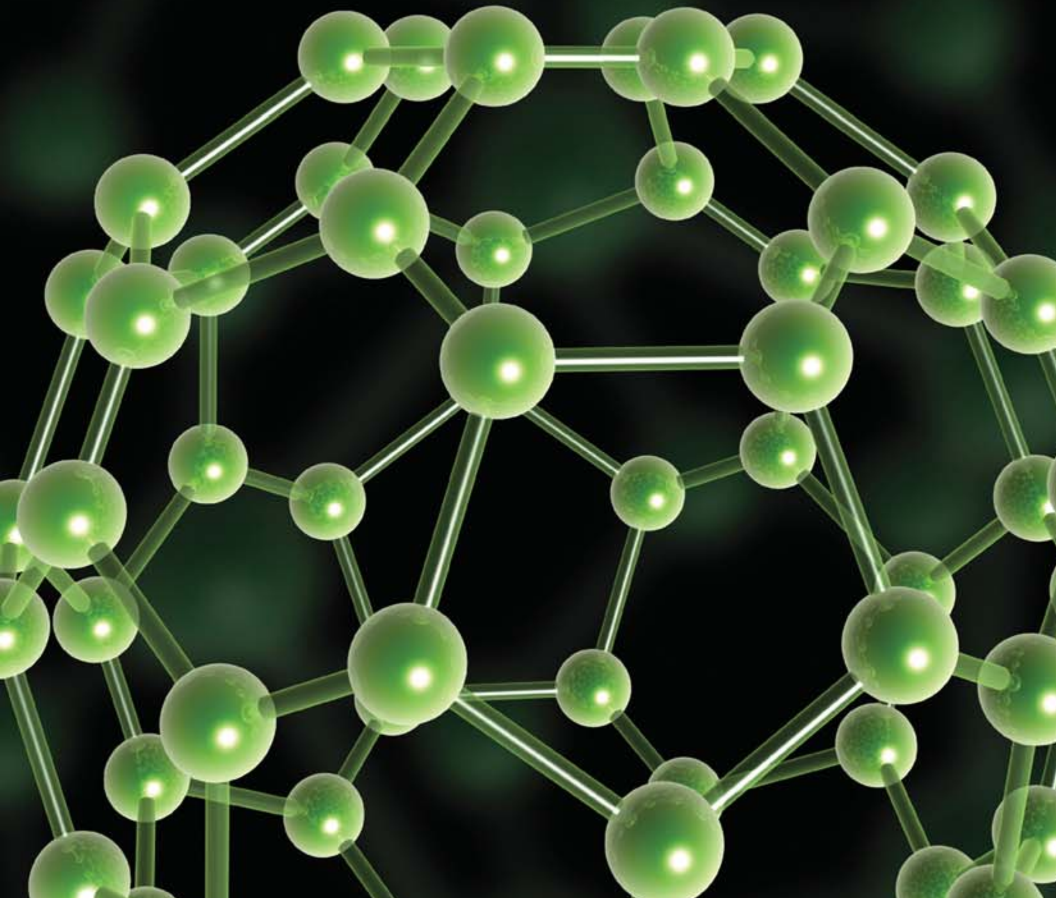
⚠ WARNING

Substitution of components may impair intrinsic safety. The ultimate user
must read and understand the instruction manual before use. Failure to
follow instructions can result in serious personal injury or death.


Canadian Standards Association (CSA) Approval Marking
Area Classification
North American Hazardous Location Certification
Gas Groups
CSA C22.2 No. 152 CLASS I GROUPS A, B, C & D
MSA
AVERTISSEMENT: LIRE ATTENTIVEMENT LES INSTRUCTIONS AVANT DE METTRE EN MARCHE
WARNING: UNDERSTAND MANUAL BEFORE OPERATING
Input: From MSA Ultima Transmitter
TAG NO:
P/N
S/N
218923

Section 6

Sensor Placement Guide



Quantity and Placement of Sensors

MSA gas detection systems monitor the concentration of specified gases at the immediate location of the sensor. The installation instructions and other information from MSA provide only basic guidance on the properties of the gas in question as well as the effects of certain environmental conditions on the function of the sensor. While this information may be used to help determine the number of sensors needed and the optimum sensor placement, do not rely on this information alone to determine the appropriate quantity and placement of the sensors for any particular site or area to be monitored. It is recommended that the user consult with appropriate industrial hygiene, environmental, and/or health professionals when determining the quantity and placement of sensors to adequately monitor the specific area in question.

WARNING

MSA gas detection systems monitor the gas concentration only at the immediate location of the sensor. The user must perform an appropriate environmental analysis on the specific installation site to determine the preferred quantity of sensors and optimum sensor placement. Improper installation can cause a gas release to be undetected and result in serious personal injury or loss of life.

Sensor Placement Guide

MSA Guide to Gas Sensor Selection and Placement

STEP 1: To determine where to place sensors, perform an analysis of the potential gas hazards in your facility

STEP 2: Create drawings indicating all potential leak sites, as well as the severity of each site's hazard potential

There are two main categories of hazardous locations:

A. Potential gas discharge points. These are places where hazardous gases may be released, such as valve stem seals, gaskets, compression fittings and expansion joints.

B. Potential contact areas. These are places where hazardous gases may endanger workers or damage equipment or property. Examples include populated areas, confined spaces, pits, stairwells, crawl spaces, shelters, and residential, business and industrial environments located nearby.

STEP 3: Since gases do not always behave in the same way, take air flow conditions, as well as potential gas pockets, into consideration before placing sensors. MSA smoke tubes (P/N 458481) can be useful in measuring the direction and rate of air flow to determine areas where gases may accumulate.

Sensor Placement Guide

In general, when placing sensors the following principles should be considered:

- Place sensors in areas where the air currents are likely to produce the highest gas concentration, including areas where gas buildup is likely, such as corners or stopping points of moving devices that release gas.
- If you are attempting to take a representative room sample, do not place sensors near entrances or fresh air vents (because sample concentration will be diluted by incoming air) unless there is a need to sample that specific area of the room.
- Place sensors close to the possible gas/leak source.
- Place combustible gas sensors between the potential leak and the ignition source.
- Place toxic (and oxygen deficiency) sensors between the potential leak and the populated area, and in the workers' breathing zone.
- Consider ease of access to the sensor for maintenance requirements, such as periodic calibration. Use a remote sensor for high or inaccessible locations.
- Avoid mounting sensors near radio transmitters or other RFI-producing sources (e.g., welding activity and induction heaters), to reduce possible RFI interference.
- Avoid locations where airborne particles may coat or contaminate the sensor, such as paint booths.
- Install in a position that prevents water or dust accumulation on the sensor head (which may impede the diffusion of gas into the sensor). Preferred position is facing downward; horizontal placement is also acceptable.
- Facility air intakes are generally good locations for sensors.
- Ensure that the entire area in question is sufficiently monitored, including little-used areas such as closets, warehouses and other storage areas.
- Factor in the vapor density of the monitored gases, when compared to air.

Sensor Placement Guide

Gases	Gas Density	Sensor Placement
carbon dioxide, heavy hydrocarbons	greater than air	closer to the ground
hydrogen, methane	less than air	near the ceiling
carbon monoxide, nitrogen	similar to air	according to air current path, at or near breathing level (usually 4 to 6 ft. from floor)

Combustible Gas Sensors

- Hydrogen and methane are lighter than air, so place sensors near the ceiling, and in ceiling corners where pockets of air may collect.
- For electric motor monitoring, place sensors near the ignition source.
- Gasoline is heavier than air, so place sensors near—but not directly on—the floor.
- When monitoring multiple combustible gases, calibrate the instrument for the least sensitive gas.

Toxic & Oxygen Gas Sensors

- Place carbon monoxide and carbon dioxide sensors for indoor air quality monitoring near air intake ducts.
- In general, in occupied areas (e.g., confined spaces), monitor for oxygen and toxic gases in the workers' breathing zone (4-6 feet). This will vary, depending on whether the density of the gas is heavier, the same as, or lighter than, air or oxygen.

Toxic & Combustible Sensors

- Place sensors near the potential release source for process monitoring applications (e.g., pipelines, valves).
- Gas cylinder storage areas: If they are ventilated, place sensor near the return air vent.
- Acid/ solvent drum storage areas: These gases are heavier than air (e.g., heavy hydrocarbons) so place sensors close to the ground and in corners where air may collect in pockets.
- If the hazard is outside, place sensors near the air intake for both combustible and toxic gas monitoring; if the hazard is inside, place sensors near the exhaust.

Sensor Placement Guide

- Some gases may collect in pockets in room corners, at both floor and ceiling levels. Place sensors in these areas if necessary.

Referigerant Monitor Placement

- ASHRAE 15 states that a refrigerant monitor capable of detecting the TLV for a refrigerant gas must be installed in a mechanical equipment room.
- Place the end of the sample line in the location most likely to develop a refrigerant gas leak or spill. Such areas include valves, fittings and the chiller itself. Also, monitor any refrigerant storage location. It is good practice to keep all sampling lines as short as possible when an aspirated or pumped sampling system is used.
- Since most refrigerant gases are heavier than air, monitor these gases close to the floor. Any pits, stairwells or trenches are likely to fill with refrigerant gas before the main area. It may be necessary to monitor these locations for refrigerant gas.
- If ventilation exists in the chiller room, MSA smoke tubes (P/N 458481) will help to determine the most appropriate gas monitoring locations.
- Monitor displays can be placed just outside the doorway of the monitored area. Personnel can check the status of the instrument before entering the area.
- ASHRAE Standard 147P states the following;

  > 4.8 Refrigerant Monitor. On Large refrigerating systems for which a refrigerant monitor is required per ASHRAE 15, a refrigerant monitor capable of detecting refrigerant concentrations of 1 ppm by volume or less shall be used to provide early warning of leaks.

Guideline for Sensor Placement

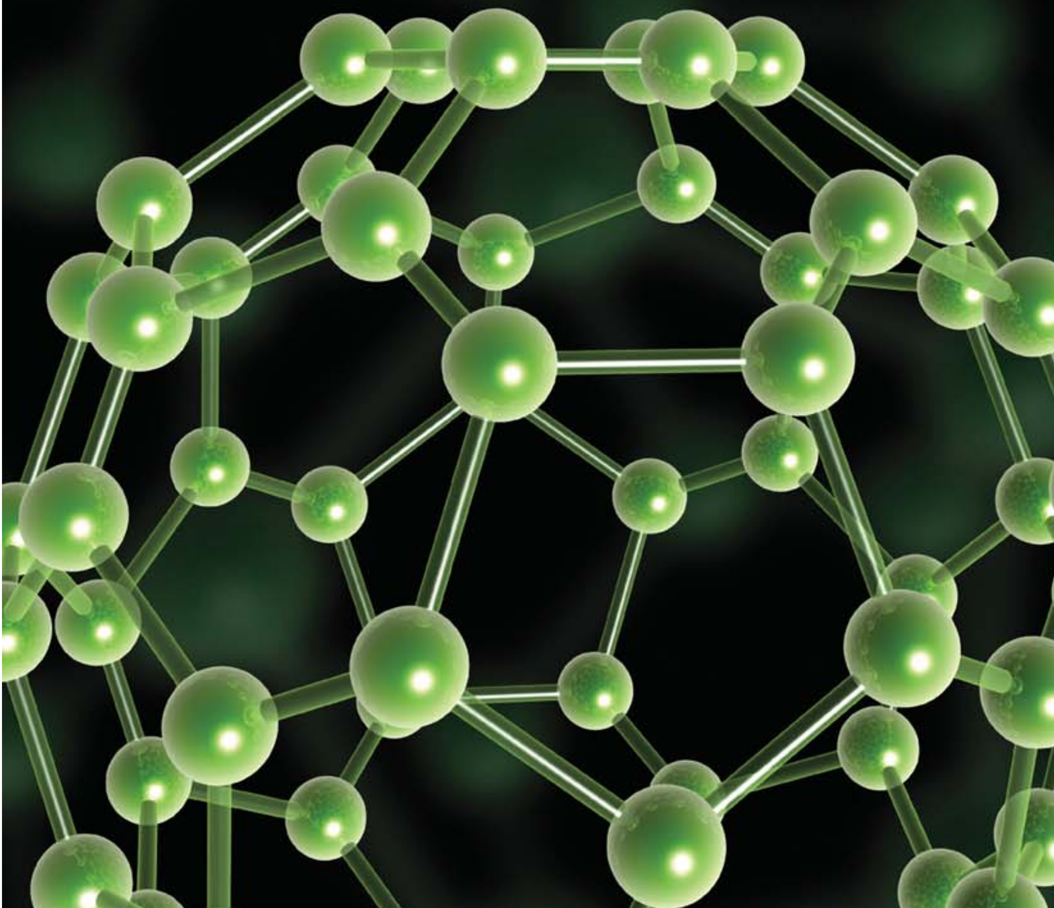
When monitoring multiple combustible gases, calibrate the instrument for the least sensitive gas.

Note: *This is for informational purposes only and is intended for use as a general guide to important considerations in sensor placement. It is not intended to serve as an exhaustive review of all considerations. Due to the large number of variables present, each site should be considered individually by a trained professional. The services of a Certified Industrial Hygienist (CIH) or Certified Safety Professional (CSP) should be considered if an onsite survey is required.*

Section 7
Section 7

Section 7

Calibration



Calibration

Instrument Calibration

Whether an instrument warns and/ or alarms at the proper time depends on its ability to translate the quantity of gas it detects into an accurate reading. “Calibration” refers to an instrument’s measurement accuracy relative to a known concentration of gas. Gas detectors perform relative measurements: rather than independently assessing the quantity of gas present, they measure the concentration of the air sample and then compare it to the known concentration of the gas that the instrument is configured to sample. This “known concentration” serves as the instrument’s measurement scale, or reference point.

If the instrument’s reference point has moved, then its reading will also move. This is called “calibration drift” and it happens to most instruments over time. (Common causes of calibration drift include the normal degradation of sensors, exposure of the sensor to poisons, and harsh operating conditions.) When an instrument experiences calibration drift it can still measure the quantity of gas present, but it cannot convert it into an accurate numerical reading. Regular calibration with a certified standard gas concentration updates the instrument’s reference point, re-enabling it to produce accurate readings.

There are two methods of verifying instrument calibration: through a functional or “bump” test (or span check) or by performing a full calibration. Each is appropriate under certain conditions.

Bump (or Span) Check

A bump check is a means of verifying calibration by exposing the instrument to a known concentration of test gas. The instrument reading is then compared to the actual quantity of gas present (as indicated on the cylinder). If the instrument’s response is within an acceptable range of the actual concentration, then its calibration is verified. When performing a bump test, the test gas concentration should be high enough to trigger the instrument alarm. If the bump test results are not within the acceptable range, then a full calibration must be performed.

Calibration

Full Calibration

A full calibration is the adjustment of the instrument's reading to coincide with known concentrations (generally a certified standard) of zero and span gases, to compensate for calibration drift. In most cases, a full calibration is only necessary when an instrument does not pass the bump test (or after it has been serviced).

Zero Check

A zero check is performed to verify that the instrument reads true zero (also referred to as the "baseline") in an environment in which no amount of target gas is present. Common situations in which a zero check is performed include:

- after exposure of the sensor to a sensor contaminant
- after the sensor has been exposed to a very high concentration of the target gas
- as the sensor ages, since it may gradually drift
- after the unit has operated in varying background conditions (e.g. humidity levels)
- after exposure to extreme conditions (e.g. high temperature or humidity)

If the instrument fails the zero check, then a zero adjustment should be performed, where the instrument is adjusted to true zero.

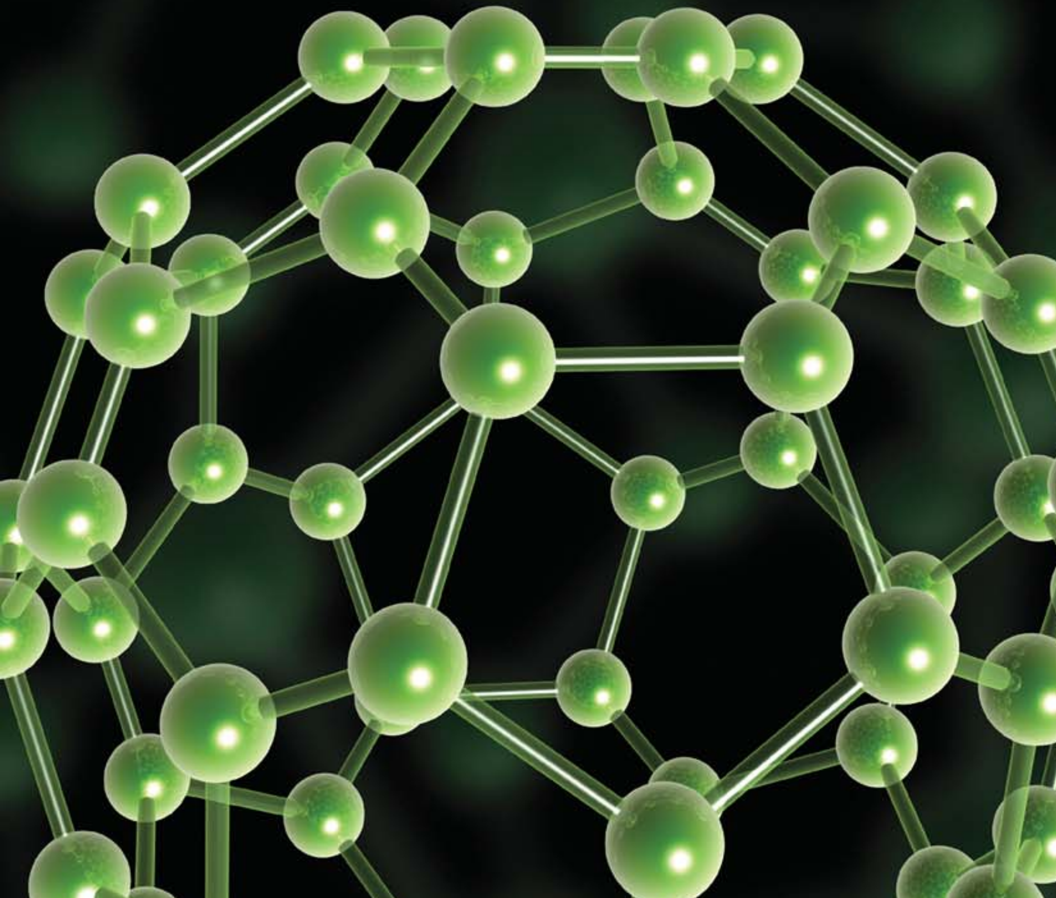
Frequency of Calibration

The frequency of calibration depends on the sensor's operating time, conditions of use (including chemical exposure) and user experience with the instrument. New sensors should be calibrated more often until the calibration records prove sensor stability. The calibration frequency can then be reduced to the schedule set by the safety officer or plant manager. Before calibrating the sensors, it is good practice to apply power to the unit to allow the sensor to adapt to the new environment. Sensors should be powered at least one full hour before any calibration attempt is made.

Section 8
Section 8

Section 8

Resources



Resources:

Code of Federal Regulations (CFR) Title 29 Part 1910, U.S. Department of Labor (DOL), Occupational Safety and Health Administration (OSHA), Washington, D.C. Available online at: www.osha.gov/comp-links.html and www.access.gpo.gov/nara/cfr/waisidx_01/29cfr1910_01.html

NIOSH Pocket Guide to Chemical Hazards, Department of Health and Human Services (DHHS), National Institute of Occupational Safety and Health (NIOSH), 85-114. Available online at: www.cdc.gov/niosh/npg/npg.html

Occupational Health Guidelines for Chemical Hazards, DHHS, DOL, Washington, D.C., January 1981, DHHS (NIOSH) No. 81-123. Available online at: www.cdc.gov/niosh/81-123.html

Fire Protection Guide to Hazardous Materials, 13th edition, National Fire Protection Association (NFPA) One Battery Park, Quincy, MA 02269 (2002). Available online at: www.nfpa.org

2002 TLVs® and BEIs®, American Conference of Governmental Industrial Hygienists (ACGIH), Cincinnati, OH 45240. Available online at: www.acgih.org

Many governmental agencies and other safety organizations with health and safety expertise maintain web sites on the Internet.

GOVERNMENT AGENCIES:

Agency for Toxic Substances and Disease Registry (ATSDR) www.atsdr.cdc.gov

Bureau of Labor Statistics (BLS) www.bls.gov

Center for Disease Control and Prevention (CDC) www.cdc.gov

Code of Federal Regulations (CFR) www.access.gpo.gov/nara/cfr/cfr-table-search.html

Department of Transportation (DOT) Office of Hazardous Materials Safety www.hazmat.dot.gov

Federal Mine Safety and Health Review Commission www.fmshrc.gov

National Institute of Environmental Health Sciences www.niehs.nih.gov

National Institute for Occupational Safety and Health (NIOSH) www.cdc.gov/niosh/homepage.html

National Institute of Health (NIH) www.nih.gov

National Safety Council (NSC) www.nsc.org

Nuclear Regulatory Commission (NRC) www.nrc.gov

Occupational Safety and Health Administration (OSHA) www.osha.gov

Office for Mine Safety and Health Research www.cdc.gov/niosh/mining

U.S. Department of Health and Human Services (US DHHS) www.os.dhhs.gov

U.S. Department of Labor, Mine Safety and Health Administration (MSHA) www.msha.gov

U.S. Environmental Protection Agency (EPA), Washington, D.C. www.epa.gov

Resources:

PROFESSIONAL & TRADE ASSOCIATIONS:

Air and Waste Management Association www.awma.org

American Board of Industrial Hygiene www.abih.org

American Conference of Governmental Industrial Hygienists (ACGIH) www.acgih.org

American Industrial Hygiene Association (AIHA) www.aiha.org

American Society of Heating, Refrigerating and Air Conditioning Engineers www.ashrae.org

American Society of Safety Engineers (ASSE) www.asse.org

Building Officials and Code Administrators (BOCA) International www.bocai.org

Center for Chemical Process Safety, American Institute of Chemical Engineers www.aiche.org/ccps/index.htm

Chemical Manufacturers Association www.cmahq.com

Compressed Gas Association www.cganet.com

International Society for Measurement and Control (ISA) www.isa.org

National Fire Protection Association (NFPA) www.nfpa.org

National Safety Council (NSC) www.nsc.org

Water Environment Federation® (WEF) www.wef.org

World Health Organization (WHO) www.who.int

World Safety Organization www.worldsafety.org

APPROVALS & STANDARDS ORGANIZATIONS:

American National Standards Institute (ANSI) www.ansi.org

Canadian Standards Association (CSA) International www.csa-international.org

European Committee for Electrotechnical Standardization (CENELEC) www.cenelec.org

National Electrical Manufacturers Association (NEMA) www.nema.org

Underwriters Laboratories, Inc. (UL) www.ul.com

International Electrotechnical Commission (IEC) www.iec.ch

GAS DETECTION INSTRUMENTATION SUPPLIER:

Mine Safety Appliances Company (MSA)

www.msagasdetection.com

MSA

The Safety Company

MSA Instrument Division
P.O. Box 427
Pittsburgh, PA 15230

Phone: 1.800.MSA.INST
Fax: 1.724.776.3280

www.msagasdetection.com

ID 5555-312-MC / Aug 2007

ISO 9001 CERTIFIED Quality System