

2.0 Gas Detection Basics

The gas detection industry, like many other technical industries, uses some terms and abbreviations that require some familiarity with basic concepts. The following sections divide gas detection into three broad areas: Combustible Gas, Toxic Gas, and Oxygen Deficiency. In addition, several properties of gases and vapors are discussed to give the reader a general background on gas nature to assist in evaluating gas or vapor monitoring applications.

2.1 Combustible Gas And Explosive Limits

The primary risk associated with combustible gases and vapors is the possibility of explosions. Explosion, like fire, requires three elements: fuel, Oxygen, and an ignition source. Each combustible gas or vapor will ignite only within a specific range of fuel/Oxygen mixtures. Too little or too much gas will not ignite—these conditions are defined as the Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL). Any amount of gas between the two limits is explosive. It is important to note that each gas has its own LEL and UEL, as shown in chart 1. The gas concentrations are shown by percent of total volume, with the balance as normal air.

Chart 1 - Common Combustible Gas LEL's and UEL's

Combustible Gas/Vapor	LEL	UEL
Acetone (CH ₃) ₂ CO	2.15%	13.0%
Benzene (C ₆ H ₆)	1.2%	8.0%
Butadiene C ₄ H ₆	1.1%	12.5%
Butane C ₄ H ₁₀	1.5%	8.5%
Isobutane C ₄ H ₁₀	1.8%	8.5%
Ethane C ₂ H ₆	3.0%	15.5%
Ethyl Alcohol Ch ₂ H ₅ OH	3.3%	19.0%
Ethyl Ether (C ₂ H ₅) ₂ O	1.7%	36.0%
Hexane C ₆ H ₁₄	1.1%	7.5%
Hydrogen H ₂	4.0%	75.6%
Isopropyl Alcohol (IPA) (CH ₃) ₂ CHOH	2.0%	12.7%
Methane CH ₄	5.0%	15.0%
Methyl Alcohol CH ₃ OH	6.0%	36.0%
Methyl Ethyl Ketone MEK	1.8%	11.5%
Pentane C ₅ H ₁₂	1.5%	7.8%
Propane C ₃ H ₈	2.0%	9.5%
Toluene C ₆ H ₅ CH ₃	1.2%	7.0%

Between these two limits explosions can occur under some conditions, with the maximum explosive energy available at approximately the midpoint. Note that these limits are sometimes referred to as LFL (Lower Flammable Limit) and UFL (Upper Flammable Limit). These limits are empirically determined, and various authorities sometimes quote slightly different figures, based on slightly different experimental procedures.

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2.2 Why is The LEL Important in Combustible Gas Detection?

In environments with combustible gas hazards, it is important to know long before the gas concentration reaches the LEL. Typical safety standards require that a gas detection unit give warnings at 10% of the LEL. Do not confuse the alarm level with the volume of gas required to reach the LEL. For example: Methane has an LEL of 5% by volume in air. For a gas detector to give an alarm at 10% of the LEL, it must trigger when it detects 0.5% by volume. The detector for this application would most likely be calibrated for the range from 0% to 5% gas by volume, but display the reading as 0 - 100% LEL.

2.3 Toxic Gas Threshold Limit Values

The primary risk associated with toxic gas is the possibility of poisoning, which can result in chronic health problems, disability, or death. The American Conference of Governmental and Industrial Hygienists (ACGIH) has gathered data on the physical effects of a wide range of toxic gases, and those data are used to determine the Threshold Limit Values (TWA & STEL). The TWA is the concentration at which the gas becomes harmful to human health over long term exposure (8-hour workday). The ACGIH has also stated short-term exposure limits (STEL) for 15-minute periods for some gases. It is important to note that these values are different for each gas, and are expressed in parts per million (PPM), as shown in Chart 2.

Chart 2 - Common Toxic Gas TLV's

Gas		TWA	STEL
Ammonia	NH3	25.0 ppm	35 ppm
Arsine	AsH3	0.05	–
Benzene	C6H6	0.5	2.5
Bromine	Br2	0.1	0.2
Diborane	B2H6	0.1	–
Carbon Monoxide	CO	25	–
Chlorine	Cl2	0.5	1.0
Hydrogen Sulfide	H2S	10	15
Methyl Alcohol	CH3OH	200	250
Nitrogen Dioxide	NO2	3.0	5.0
Nitric Oxide	NO	25	–
Phosphine	PH3	0.3	1.0
Silane	SiH4	5.0	–
Sulfur Dioxide	SO2	2.0	5.0
Toluene	C6H5CH3	50	–

These TLV Values cannot be determined experimentally on humans, so they are deduced by long term experience and tests on animals. The published values are under constant review and are subject to change as further experience indicates. They generally are conservative.

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2.4 Oxygen Deficiency

The primary risks in environments deficient in Oxygen are poor performance and judgment, physical impairment, unconsciousness, and death. The normal level of Oxygen in the atmosphere is 20.9% by volume. Lower amounts of Oxygen cause progressively worse symptoms. Most safety authorities mandate a minimum safe Oxygen level of 19.5% by volume, providing a safe level of Oxygen if evacuation becomes necessary.

2.5 Relationship Between PPM And % Volume

Gas and vapor levels are often given in terms of ppm (parts per million), or as % volume. Please note the following physical relationship between these two:

1	ppm	=	.0001	% Volume
10	ppm	=	.001	% Volume
100	ppm	=	.01	% Volume
1,000	ppm	=	.1	% Volume
10,000	ppm	=	1	% Volume
100,000	ppm	=	10	% Volume
1,000,000	ppm	=	100	% Volume

2.6 Flash Point

All liquids do not vaporize into gaseous form as readily as others. There are many flammable compounds that exist only in gas form at normal atmospheric temperatures and pressures. Some examples of these are natural gas (Methane) or propane. If these gases are pressurized, they can be changed into their liquid state. Many other substances such as gasoline or other liquid fuels, or solvents, may be in liquid form at normal atmospheric temperatures and pressures. These liquids will evaporate into a vapor if left in the open air, and some will evaporate faster than others. The "Flash Point" is the temperature that is necessary for a given liquid to reach in order for it to evaporate sufficient vapor to cause a flammable concentration at atmospheric pressures. For example, gasoline has a relatively low flash point, which enables it to vaporize and explode in the engine cylinder. Diesel fuel, on the other hand, has a relatively high flash point (over 100 degrees F), so it will not produce combustible levels of vapor until it is heated above this temperature. To emphasize this, imagine if you had a bucket of gasoline and a bucket of diesel fuel, both at about 60 degrees F, and you measured the air space immediately above the liquid in the buckets with an LEL meter. The gasoline would cause a reading of over 100% LEL, indicating that if a match were lit in this space, there likely would be an explosion. The diesel head space however, would likely read less than 5% or 10% of the LEL, indicating that if a match were lit directly above this fuel it would not ignite.

It is important to consider the Flash Point when considering the potential hazard of a flammable liquid. For example, many jet fuels have a flash point of over 100 to 150 degrees F. If these liquids are spilled onto a cold cement floor in cold weather, they may pose a danger from a ppm hydrocarbon breathing standpoint, but they will not pose any immediate flammable hazard (unless and until they are heated to temperatures above their Flash Point).

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2.7 Vapor Density

Not all gases or vapors weigh the same as air. Every gas has a “Vapor Density” or just “Density”, which is a physical constant of its weight in relationship to air. Therefore, air has a density of 1.0. Gases that are lighter than air have a density of less than 1.0, and gases that are heavier than air have a density greater than 1.0. Those lighter than air will tend to rise and those heavier than air will tend to sink or remain near the floor. The vapor density should be considered when evaluating sensor locations. For example, gasoline and Propane have a vapor density greater than 1.0, indicating they are heavier than air. Sensors for these gases should be located near the floor in order to provide the earliest warning of detection. On the other hand, Methane and Hydrogen have vapor densities less than 1.0, indicating they are lighter than air. Sensors for Methane and Hydrogen therefore should be located near the ceiling for best results.

2.8 Sample Draw Vs. Diffusion

RKI offers both sample draw and diffusion sensors for many toxic gases. A diffusion sensor assembly is a sensor that has its working surface open to the surrounding environment, and the gas migrates to the sensor by gaseous diffusion. A sample draw sensor has a pump or aspirator to draw the sample from the test space and blow it into the sensor sample chamber. In general, it is better to use diffusion sensors for monitoring of room air conditions, and sample draw sensors whenever the test space is inside a duct or other not easily accessible space.

Some manufacturers suggest the use of diffusion sensors even in duct mounting applications. RKI strongly recommends the use of only sample draw assemblies in these applications. Tests have proven that diffusion is not as sure or as accurate as the use of a sample drawing sensor/transmitter, since the flow effects of the air blowing in the duct can greatly influence the output of the sensor. The diffusion sensor reading can be in excess of 60% low at lower flow rates for some gases. For a sample draw sensor / transmitter, the gas always blows onto the sensor at the same rate and direction as used during initial calibration, providing superior accuracy and performance over a diffusion sensor. This situation is more pronounced for difficult-to-detect gases such as HCl, HF, BCl₃, F₂, and O₃.

2.9 Sample Draw Tubing Lengths

When using a sample draw system, it is important to keep the sample lines as short as possible and to use proper tubing type. In general, for toxic gases, Teflon (PTFE) tubing must be used to avoid excessive absorption of the test sample into the tubing. Some gases are more easily absorbed than others. Recommended maximum tubing lengths for different gases are provided in the “Recommended Tubing Type and Lengths” chart on the following page. These lengths are intended to be guidelines and can be exceeded by short distances without much loss in reading. In general though, short sample lines will provide readings that are more accurate and also provide faster response.

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Recommended tubing type and lengths chart

	Gas Type	Max. Tubing Length	Tubing Material	
1	Most easily absorbed gases (Critical) HCl, HF, O ₃ , SiH ₂ Cl ₂ (DCS), BCl ₃ , TEOA, POCl ₃ , ClF ₃ , WF ₆ , BF ₃ , NH ₃	5 meters	Teflon I.D. O.D.	(PTFE) 4mm 6 mm
2	Easily absorbed gases Cl ₂ , HBr, F ₂ , TEOS, TMB, NF ₃	10 meters	Teflon I.D. O.D.	(PTFE) 4mm 6 mm
3	Almost no absorption Hydride gases such as SiH ₄ , PH ₃ , AsH ₃ , etc., N ₂ O	30 meters	Teflon I.D. O.D.	(PTFE) 4mm 6 mm
4	No Absorbtion H ₂ , CO, O ₂	30 meters	Not Important I.D. 4mm O.D. 6 mm	

Filter Types:

Millipore: Gas types 1 and 2 above must use Millipore filter.

Balston: Gas types 3 and 4 above should use the Balston filter. Note that it is OK also for them to use the Millipore filter. These gases can use either one because there is not any worry about absorption into the filter for these gases. It is recommended to use the Balston though since it has more surface area and so will last longer if used in a dusty environment.

Note that filters are generally installed close to the instrument in an area that is accessible for future maintenance.

