Fundamentals of Combustible Gas Detection

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FUNDAMENTALS OF COMBUSTIBLE GAS DETECTION

A Guide to the Characteristics of Combustible Gases and Applicable Detection Technologies

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Chapter 1

Nature and Properties of Combustible Gases

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Nature & Properties of Combustible Gases

To develop an appropriate strategy for the implementation of a combustible gas detection system, a basic understanding of the properties of combustible materials is necessary. In our discussion we will identify the general properties necessary for determining a material's hazardous potential, then turn our attention to specific information on combustible gases and liquids.

Properties of Combustible Gases & Liquids

The following properties represent those that are important in evaluating the hazardous potential of a substance.

Flash Point.

This is the lowest temperature at which a liquid gives off sufficient vapor at its surface to form a flammable or an explosive mixture. Many hazardous liquids have flash points at or below room temperature and are covered by a layer of flammable vapors that will ignite immediately if exposed to an ignition source. Vaporization increases as temperature rises and consequently they are more hazardous at elevated temperatures.

Open-Cup Flash Point.

The minimum temperature at which the liquid gives off sufficient vapor to form an ignitable mixture with air. Open cup testing is a method of determining this flash point, and although less accurate than closed cup testing, it is necessary for certain substances.

Auto-ignition Temperature.

Sometimes referred to as spontaneous ignition temperature, or "SIT," this is the minimum temperature for self-sustained combustion of a substance, independent of the heating or heated element. This temperature is generally well above the open-cup flash point.

Lower Explosive Limit (LEL) or Lower Flammable Limit (LFL).

This is the minimum concentration of a flammable gas or vapor that will propagate flame when exposed to a source of ignition. Commonly abbreviated LEL or LFL, a mixture below this concentration level is considered too "lean" to burn. An increase in atmospheric temperature or pressure will decrease the LEL of a gas or vapor.

Explosive Range.

This includes all concentrations (measured as a percent of volume in air) of a flammable gas or vapor that will propagate flame when exposed to a source of ignition. Many common flammable liquids have very wide explosive ranges. The explosive range of all flammable gases and vapors will vary with temperature and pressure.

Upper Explosive Limit (UEL) or Upper Flammable Limit (UFL).

The maximum concentration of gas in air that will combust. Any higher percentage of combustible gas or lower amount of oxygen in the mixture of the two, and the mixture will be too “rich” to sustain combustion.

Vapor Density.

This is the relative density of the vapor as compared with air. It is calculated as the ratio of the molecular weight of the vapor to the molecular weight of air. A vapor density less than one indicates a substance lighter than air; conversely, densities greater than one indicate a substance heavier than air. All flammable liquid vapors are heavier than air and can travel along a gradient for considerable distances to an ignition source.

Common Flammable Industrial Gases

For our purpose, we will use the term “industrial gases” to refer to a variety of compressed gases and liquids used in manufacturing processes. Under this definition a particular gas may have a variety of applications, such as a source of heat or power generation, or as a solvent or for medical applications. As a rule, these gases and liquids are manufactured elsewhere and then transported to and stored at the end-user’s facility. We will limit our consideration to flammable gases.

A flammable gas is one that can burn when brought in contact with heat or flame. A flammable compressed gas is one in which a mixture of 13 percent or less (by volume) with air is flammable or the flammable range with air is under 12 percent. Under certain conditions, flame velocities of these gases after ignition can progress to detonation speeds producing violent explosions and damage.

Acetylene.

Acetylene is colorless and odorless in its pure state, lighter than air and highly flammable. Its low LFL and wide flammability range make it extremely easy to ignite. In the presence of moisture, acetylene can react with copper, silver and mercury to form metallic acetylides that are shock-sensitive, explosive compounds.

Ammonia.

Used in a variety of commercial applications, ammonia is colorless, alkaline, toxic and lighter than air. It has a high LFL and a narrow flammability range and therefore small leaks are not likely to form hazardous flammable mixtures in air.

Hydrogen.

Hydrogen is a highly flammable, extremely light elemental gas with a wide flammability and explosive range. It also has a low ignition temperature and low minimum ignition energy. Static electricity can ignite leaking or venting hydrogen.

Liquefied Petroleum Gas (LPG).

This is the generic name for a number of low-pressure, liquefied hydrocarbon gases. The most common are butane and propane. They are readily liquefied by pressurizing at atmospheric temperatures and are used in the vapor phase as a fuel with air or oxygen.

Flammable and Combustible Liquids

Almost every industrial plant has some quantity of flammable and combustible liquids stored in its facility. A flammable liquid is defined as one having a flash point below 100°F (37.8°C) with a vapor pressure not exceeding 40 psi (276 kPa). They are volatile in nature, constantly giving off heavier-than-air vapors that cannot be seen with the naked eye. Combustible liquids have a flash point at or above 100°F (37.8°C). When heated above their flash points, these liquids take on many of the characteristics of flammable liquids.

One of the significant differences between flammable and combustible liquids has to do with the behavior of their vapors. Vapors from flammable liquids tend to flow along slopes and inclines, much like a liquid, and collect in low areas. Vapors from combustible liquids, on the other hand, do not readily travel away from the source of a leak or spill unless the atmospheric temperature remains above the flashpoint of the liquid. This distinction must be taken into account when determining sensor use and positioning because liquids themselves do not burn or explode, but rather the flammable vapors resulting from evaporation. The site of the spill or leak may not be the only zone of danger.

In evaluating the hazardous potential of a particular liquid, the flash point is generally considered the most important criterion to consider. However other factors, ignition temperature, explosive range, vapor density and rate of evaporation, have a bearing on the liquid's hazardous potential. For example, the concentrations of a vapor in air determine the intensity of an explosion. Concentrations near the lower and upper limits of flammability are less violent than those occurring when concentrations are near the median range.

Physical and Chemical Properties Charts

The following chart identifies the primary properties necessary for determining the hazardous potential of various flammable and combustible liquids.

Properties of Flammable Liquids and Gases

Name	Formula	TWA (OSHA PEL)	Flash Point F°		Explosive Limits		Ignition Temp., F°	Specific Gravity	Vapor Density
			Closed Cup	Open Cup	LEL %	UEL %			
1,3- Butadiene	$CH_2{=}CHCH{=}CH_2$	1 ppm	Gas	Gas	2.0	12.0	788	—-	1.90
Acetaldehyde	CH_3CHO	200 ppm	-38	....	4.0	60.0	347	0.78	1.52
Acetic Acid (glacial)	CH_3COOH	10 ppm	103	110	4.0	19.9	867	1.05	2.07
Acetone	CH_3COCH_3	1000 ppm	-4	15	2.5	13.0	869	0.79	2.00
Acetonitrile	CH_3CN	40 ppm	....	42	3	16	975	0.78	1.42
Acrylonitrile	$CH_2{=}CHCN$	2 ppm	30	32	3.0	17.0	898	0.80	1.83
Ammonia (anhydrous)	NH_3	50 ppm	Gas	Gas	15.0	28.0	1204	——	0.60
Amyl acetate-n	$CH_3COO[CH_2]_4CH_3$	100 ppm	77	....	1.1	7.5	714	0.88	4.49
Amylamine (mono)	$C_5H_{11}NH_2$		30	45	2.2	22	....	0.75	3.01
Benzene	C_6H_6	1 ppm	12	....	1.2	7.8	928	0.88	2.77
Butane-n	$CH_3CH_2CH_2CH_3$	——	-76	Gas	1.9	8.5	550	0.60	2.06
Butene-1	$CH_3CH_2CH{:}CH_2$	——	Gas	Gas	1.6	10.0	725	——	1.94
Butyl acetate-n	$CH_3COO[CH_2]_3CH_3$	150 ppm	72	98	1.7	7.6	797	0.88	4.00
Butyl alcohol-n	$CH_3CH_2CH_2CH_2OH$	100 ppm	98	110	1.4	11.2	650	0.81	2.55
Butyl alcohol-sec	$CH_3CH(OH)CH_2CH_3$	150 ppm	75	85	1.7 @ 212°F	9.8 @ 212°F	761	0.81	2.55
Butyl alcohol-tert	$(CH_3)_3COH$	100 ppm	52	60	2.4	8.0	892	0.79	2.55
Cyclohexane	C_6H_{12}	300 ppm	-4	....	1.3	8	473	0.80	2.90
Decane-n	$CH_3(CH_2)_8CH_3$	——	115	....	0.8	5.4	410	0.70	4.90
Diethyl ether	$C_2H_5OC_2H_5$	400 ppm	-49	....	1.9	36.0	356	0.72	2.55
Dimethylformamide	$HCON(CH_3)_2$	10 ppm	136	155	2.2 @ 212° F	15.2	833	0.90	2.52
Dimethylamine, anhydrous	$(CH_3)_2NH$	10 ppm	Gas	Gas	2.8	14.4	752	——	1.60
Dioxane-p	$C_4H_8O_2$	100 ppm	54	65	2	22	356	1.0+	3.00
Dodecane-n	$CH_3(CH_2)_{10}CH_3$	——	165	....	0.6	....	397	0.75	5.86
Ethane	CH_3CH_3	——	Gas	Gas	3.0	12.5	882	....	1.04
Ethyl alcohol	CH_3CH_2OH	1000 ppm	55	71	3.3	19.0	685	0.79	1.59
Ethyl benzene	$CH_3CH_2C_6H_5$	100 ppm	70	75	0.8	6.7	810	0.87	3.66
Ethyl ether	$C_2H_5OC_2H_5$	400 ppm	-49	....	1.9	36.0	356	0.72	2.55
Ethylamine	$CH_3CH_2NH_2$	10 ppm	1	....	3.5	14.0	725	0.80	1.60
Ethylene	$H_2C{:}CH_2$	——	Gas	Gas	2.7	36.0	842		0.98
Ethylene oxide	C_2H_4O	1 ppm	-20	-4	3.0	100.0	1058	0.89	1.52
Formaldehyde gas	$HCHO$	.75 ppm	Gas	Gas	7.0	73.0	795	....	1.00
Gasoline, aviation-commercial	——	....	-50	....	1.3	7.1	824	....	....
Gasoline, aviation-military	——	....	-50	....	1.2	7.1	880	....	....
Heptane-n	$CH_3[CH_2]_5CH_3$	500 ppm	25	30	1.1	6.7	399	0.70	3.50
Hexane-n	$CH_3[CH_2]_4CH_3$	500 ppm	-7	-14	1.1	7.5	437	0.70	3.00
Hydrogen	H_2	——	Gas	Gas	4.0	75.0	932	....	0.10

Properties of Flammable Liquids and Gases

Name	Formula	TWA (OSHA PEL)	Flash Point F°		Explosive Limits		Ignition Temp., F°	Specific Gravity	Vapor Density
			Closed Cup	Open Cup	LEL %	UEL %			
Isoprene	$CH_2{:}C[CH_3]CH{:}CH_2$	——	-65	....	1.5	8.9	743	0.70	2.40
Isopropyl alcohol	$[CH_3]_2CHOH$	400 ppm	53	60	2.0	12.7 @ 200°F	750	0.79	2.07
Isopropyl ether	$[CH_3]_2CHOCH[CH_3]_2$	500 ppm	-18	-15	1.4	7.9	830	0.73	3.52
Isopropylamine	$[CH_3]_2CHNH_2$	5 ppm	——	-35	——	——	756	0.69	2.00
"Jet fuel, JP-4"			-10 to +30	....	1.3	8.0	464	——	——
Methane	CH_4		Gas	Gas	5.0	15.0	999	....	0.55
Methyl alcohol	CH_3OH	200 ppm	52	54	6.0	36.0	867	0.79	1.11
Methyl ethyl ketone	$CH_3COCH_2CH_3$	200 ppm	16	24	1.4 @ 200°F	11.4 @ 200°F	759	0.81	2.48
Methyl methacrylate	$CH_2{=}C(CH_3)COOCH_3$	100 ppm	50	50	1.7	8.2	....	0.94	3.60
Naphtha		100 ppm	-57	....	1.1	5.9	550	0.60	2.5
Octane-n	$CH_3(CH_2)_6CH_3$	500 ppm	56	....	1.0	6.5	403	0.70	3.86
Pentane-n	$CH_3(CH_2)_3CH_3$	1000 ppm	-57	....	1.5	7.8	500	0.63	2.48
Propane	$CH_3CH_2CH_3$	1000 ppm	Gas	Gas	2.1	9.5	842	—-	1.56
Propyl acetate-n	$CH_3COOCH_2CH_2CH_3$	200 ppm	55	70	1.7 @ 100°F	8.0	842	0.89	3.52
Propyl alcohol-iso	$[CH_3]_2CHOH$	400 ppm	53	60	2.0	12.7 @ 200°F	750	0.79	2.07
Propyl alcohol-n	$CH_3CH_2CH_2OH$	200 ppm	74	77	2.2	13.7	775	0.80	2.07
Propylamine-n	$CH_3(CH_2)_2NH_2$	—-	-35	....	2.0	10.4	604	0.72	2.03
Propylbenzene-n	$C_3H_7C_6H_5$	—-	86	....	0.8	6	842	0.90	4.14
Propylene	$CH_2{:}CHCH_3$	—-	Gas	Gas	2.0	11.1	851	—-	1.49
Propylene oxide	C_3H_6O	100 ppm	-35	....	2.3	36.0	840	0.83	2.00
Styrene	$C_6H_5CH{=}CH_2$	100 ppm	88	100	0.9	6.8	914	0.91	3.60
Tetradecane-n	$CH_3(CH_2)_{12}CH_3$	—-	212	....	0.5	....	392	0.77	6.83
Tetrahydrofuran	C_4H_8O	200 ppm	6	....	2.0	11.8	610	0.89	2.50
Tetrahydrofurfuryl alcohol	$C_4H_7OCH_2OH$	—-	167	167	1.5	9.7	540	1.06	3.52
Toluene	$C_6H_5CH_3$	200 ppm	40	45	1.1	7.1	896	0.87	3.14
Triethylamine	$(C_2H_5)_3N$	25 ppm	—-	16	1.2	8.0	480	0.73	3.48
Trimethylamine	$(CH_3)_3N$	—-	Gas	Gas	2.0	11.6	374	—-	2.03
Vinyl acetate	$CH_2{=}CHOOCCH_3$	—-	18	30	2.6	13.4	756	0.90	2.97
Vinyl Chloride	$CH_2{=}CHCl$	1 ppm		-108.4	3.6	33.0	882	0.91	2.20
Vinyl ethyl ether	$CH_2{=}CHOC_2H_5$	—-	<-50	....	1.7	28.0	395	0.75	2.50
Xylene-m	$C_6H_4(CH_3)_2$	100 ppm	81	....	1.1	7.0	982	0.87	3.66
Xylene-o	$C_6H_4(CH_3)_2$	100 ppm	90	....	0.9	6.7	867	0.89	3.66
Xylene-p	$C_6H_4(CH_3)_2$	100 ppm	81	....	1.1	7.0	984	0.87	3.66

Chapter 2

Detection Technologies

- Electrocatalytic Detectors
- Infrared Detectors

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Detection Technologies

Combustible gas detectors can be divided into two general categories. The first category includes a variety of "passive" technologies of which the electrocatalytic (catalytic bead) type is the most common. The second category is based on technology that uses infrared absorption as the detection technique. This technology is considered "active" since an IR source emits a signal many times a second, and the amount of energy falling on the detector serves as an active measure of the gas concentration at that moment. Any failure of the source or detector, or blockage of the signal by dirt, is detected immediately as a malfunction. For this reason, IR detectors are also considered to be *fail-to-safe*. IR gas detectors can be used for "point" (single location) or "open path" (line of sight) applications. In the following chapter we will discuss the basic design operation, as well as the advantages and limitations of each detector type.

Electrocatalytic Detectors

Electrocatalytic or "catalytic" detectors have been around for over 30 years and are widely used in a variety of industries as single-point detectors for combustible gases. They function on the relatively simple and reliable principle that a combustible gas can be oxidized to produce heat. The resulting temperature change can be converted, via a standard Wheatstone Bridge, to a sensor signal. That signal can then be used to activate alarms and initiate fire preventative action.

Operating Principles

The heart of this system is a heterogeneous catalytic element that assists oxidation. Generally these elements consist of a platinum coil embedded in a catalyst. Since the reactants are all gaseous, the reaction takes place on the surface of this element with the combustible gases reacting exothermically with oxygen in the air to heat up the catalytic element. This causes a change of resistance within the embedded coil that is measured and monitored.

One such sensor uses two identical beads, one active, which oxidizes any combustible gases present, and one glass coated, which is used for reference. The glass coating on the reference bead allows it to respond to changes in temperature, humidity and pressure without responding to combustible gases, which cannot penetrate the glass coating. The reference bead serves as a “baseline” signal, which can then be compared to the resistance of the active bead to determine the concentration of gas present. As gas oxidizes on the active bead, the bead temperature increases in direct proportion to the concentration of the gas in the atmosphere. This temperature rise increases the resistance of the active bead, and when compared with the reference bead resistance, results in a measurable voltage differential, which is used by the instrument.

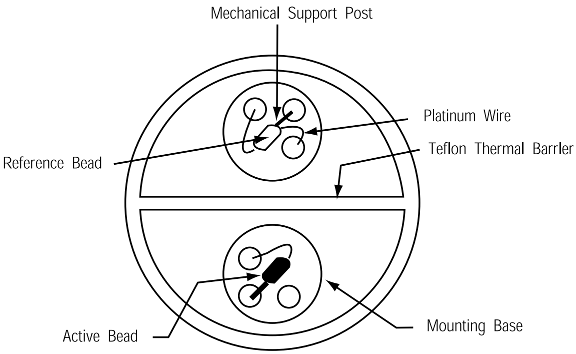

Figure 1. Catalytic Bead Sensor

The catalyst employed in these sensors is critical to the accuracy and life of the sensor, and determines the range of combustible gases the sensor can detect. As a rule, the entire surface of a bead may not be catalytically active, and therefore, the oxidation reaction may occur only at certain points. In the manufacture of the sensor, the catalytic material must be chosen and fashioned in such a way as to maximize the number of these “active” sites.

Contamination and Poisoning

The sensitivity of catalytic detectors is typically affected by two things — contamination or poisoning of the active bead, or blockage of the flame arrestor which gas must pass through to reach the beads.

In some cases the sensor may lose response due to the reference bead becoming "active" to gas with aging. Reference bead activity is avoided in high quality sensors by glass coating, which renders it completely passive for the life of the sensor. Contamination of the sensor can be caused by a variety of factors, depending primarily on the environment in which the sensor is used. If the sensor is exposed to dust or other particulate matter, particles can become trapped in the flame arrestor or deposited on the beads. In marine environments, the sensor can be affected by salt and mineral deposits. If the sensor is exposed to heavy oil or grease, the assembly can become coated resulting in lost sensitivity. Exposure to paint, lacquer, or varnish vapors may also result in the sensor becoming coated. During normal maintenance of the system, an increase in the response time to calibration gas, an increase in recovery time after exposure, or a loss of sensitivity, may indicate contamination.

Poisoning of the catalytic element is the result of the strong absorption of the poison on the sensor's active sites. This inhibits the access of the reacting substances to these sites and results in reduced sensor output in response to the presence of a combustible gas. Since the active sites in some devices constitute only a fraction of the total surface area, relatively small amounts of poison can have a considerable effect on the response of the sensor.

Various substances can act as catalyst poisons. These include silicones and silicon compounds including silanes, halogens, halogenated hydrocarbons, sulfur compounds, strong acids, bases, and heavy metals. These substances contaminate the sensor in different ways. For example, silicon compounds form a glass (SiO_2) layer on the bead while strong acids or bases can attack and remove the catalyst's metal itself. In all cases, poisoning the catalyst will reduce the sensitivity of the sensor.

In some cases, sensor poisoning is temporary. In the case of fire extinguishant gases, for example, full sensitivity can be restored within a few hours if the extinguishant is removed. In general, heavy metal compounds and silicon compounds are considered permanent poisons and, in severe cases, the sensor must be replaced. However, there are many examples of sensors continuing to operate for considerable periods of time in environments containing catalyst poisons. Moreover, recent improvements in catalyst formulation have increased sensor resistance to poisoning.

The only means of identifying detector sensitivity loss due to catalytic poisons is by gas-checking and calibration. When a sensor is located in an area known to contain potential poisons, it should be gas-checked at regular intervals and calibrated if necessary.

A recommended calibration interval should be provided by the manufacturer, and followed in the field. The degree of potential poisoning is dependent upon the concentration and exposure time to the poison, bead temperature and, most significantly, the fine structure of the catalyst support material, which can vary between manufacturers.

Mechanical Damage

Sensors may be damaged by shock or vibration causing the fine platinum wire to break. In a good quality catalytic sensor, the beads are mounted on a support to minimize this possibility and extend the sensor life.

While other methods of detecting combustible gases are available, electrocatalytic sensors offer simplicity, accuracy and relatively low unit cost in a single-point detector.

Infrared Detectors

An alternative method of measuring gas concentration is based on absorption of infrared (IR) radiation at certain wavelengths as it passes through a volume of gas. Devices using this technology have a light source and a light detector and measure the light intensity at two specific wavelengths, one at an absorption (active) wavelength and one outside of the absorption (reference) wavelength. If a volume of gas passes between the source and detector, the amount of light in the active wavelength falling on the detector is reduced, while the amount of light in the reference wavelength remains unchanged. Much like the catalytic detectors, the gas concentration is determined from the relative difference between the two signals.

There are several key advantages to using IR-based detectors:

- Immune to all chemical poisons
- Does not need oxygen or air to detect gas
- Can work in continuous exposure gas environments
- Fail-to-safe technology
- Internal compensation virtually eliminates span drift

IR-based detectors can be either single-point or open path devices and, with the sophisticated optical designs currently being used, are factory calibrated and virtually maintenance free. This is particularly desirable when sensors must be located in inaccessible areas and cannot be easily calibrated on a periodic basis. Maintenance of IR detectors is typically limited to periodic cleaning of the optical windows and reflectors to ensure dependable performance. The current availability of reliable, low cost electronics and solid state IR detectors has reduced costs and made the technology feasible for many commercial applications. However, IR detectors cannot be used for the detection of hydrogen and certain other gases for which the catalytic method is suitable.

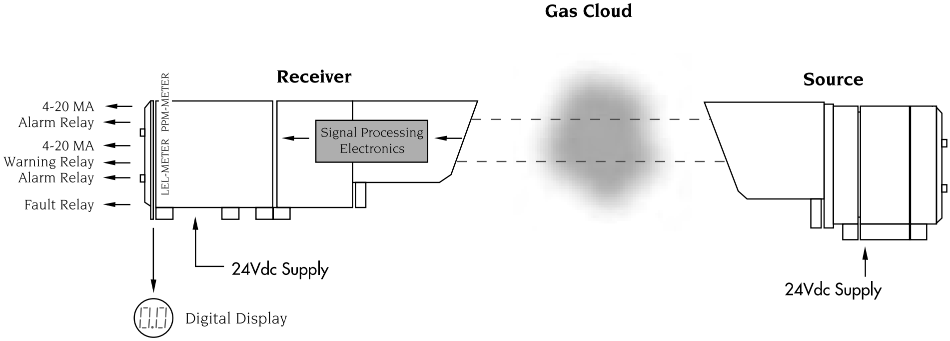

Figure 2. Open Path System

Theory of Operation

Infrared gas detection is based on the ability of some gases to absorb IR radiation. It is well known that almost all hydrocarbons (HC) absorb IR at approximately 3.4 µm and at this region H_2O and CO_2 are not absorbed, making the system immune to humidity and atmospheric changes. It follows therefore that a dedicated spectrometer operating at that wavelength could be used to detect hydrocarbons in air. Such a system would follow the Beer-Lambert Law which states:

$$T=\exp(-A \times C \times L)$$

Where:

T is the transmittance of IR

A is the absorption coefficient of the particular gas molecule

C is the concentration of the gas

L is the path length of the beam through the gas

Chapter 2

Open Path IR Detectors

Gas leaks can either form a relatively stationary cloud or readily dissipate depending upon such factors as wind, rate of leak, density of leaked gas, and the structural environment around the leak. If a gas leak creates a cloud it will generally have the following characteristics:

- The highest gas concentration of a cloud is at the source and it decreases in concentration towards the edges
- The shape of the gas cloud is elongated or has an irregular pattern, depending upon air currents
- In outdoor environments gas clouds dissipate faster and can have very low gas concentrations (see Figure 3)

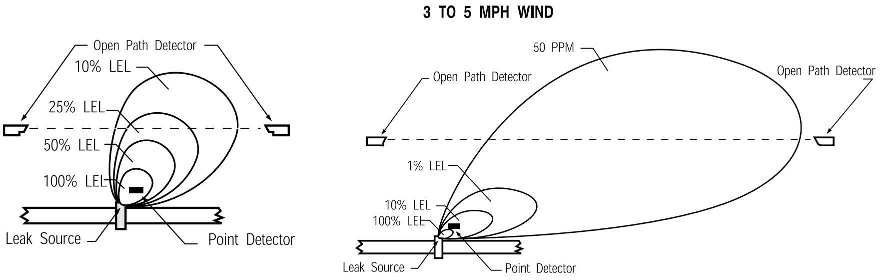

Figure 3. Cloud dispersion

Open path IR detectors are particularly useful in situations where a gas release has been dispersed by wind or natural diffusion. The gas can still be detected, even though its point concentration may have fallen below normal alarm settings. Open path systems also have the advantage of being able to cover large open areas or a line of several potential leak sources, such as a row of valves or pumps.

With an open path system the path length is not fixed, so the measurement is expressed as a product of the average gas concentration and the gas cloud width passing between the source and receiver. This means that a small dense cloud of hydrocarbon gas could give the same output signal as a large dispersed cloud if the product of the concentration of the leak and the path length were the same. In essence the system “counts” the number of HC molecules that absorb IR radiation in the beam path.

The gas concentration output for open path detectors is expressed in ppm•meters (parts per million of combustible gas times the path length in meters: a highly sensitive range for detection of low level leaks) or LEL•meters (a hazardous gas level). Typical readings are as follows:

Gas Cloud		Calculation		
Concentration	Length	Concentration x Length	=	Measurement
50 ppm	2 meters	50 x 2	=	100 ppm•meters
10 ppm	10 meters	10 x 10	=	100 ppm•meters
100 ppm	20 meters	100 x 20	=	2000 ppm•meters
100% LEL	2 meters	100 x 2	=	2 LEL•meters

As a reference, methane gas concentration can be defined as:

1% LEL methane = 500 ppm = .01 LEL
10% LEL methane = 5,000 ppm = 0.1 LEL
100% LEL methane = 50,000 ppm = 1.0 LEL

Open path IR detection offers immunity to poisons, high sensitivity gas leak detection, hazardous level gas detection, low maintenance, easy installation and fail-to-safe operation. However, it is not an all-encompassing answer to combustible gas detection. It offers an alternative solution to gas detection challenges and should be used in combination with point gas detection due to its limitations in targeting the specific location of gas leaks.

Point IR Detectors

In the case of Point IR Detectors, there is a fixed path length between the IR source and the IR detector. Typically the length is a few inches and the gas is assumed to be uniform across this length. With the path length being fixed, the Point IR Gas Detector is able to give a direct measurement of gas concentration in percent of the Lower Explosive Limit (LEL).

Chapter 3

Application

- Hazard Assessment
- Sensor Placement
- Combustible Applications

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Hazard Assessment

A thorough hazard assessment should be performed prior to selection, purchase, and installation of a hazardous gas detection system. The goal of this assessment is to minimize the risks to lives and property by:

- Selecting the most appropriate gas detection equipment
- Locating the sensors at the most likely sources of potential gas leaks

Because of the complexity, sophistication and cost of today's monitoring systems, careful attention needs to be given to hardware selection. It is equally important that the system selected be located where it will adequately monitor the hazards involved. When performing the hazard assessment, the first step should be to establish the most likely sources of gas leaks. Plant ventilation is also a major consideration when planning and arranging a gas detection system. The entire ventilation system should be evaluated before locating sensing devices. The evaluation should involve both natural and forced air ventilation patterns within the plant. It is critical to understand how gases can be carried along natural air currents, as well as through the plant's ventilation system, to various areas of the facility.

Special attention should be paid to locations such as pits, alcoves, roof peaks, and dormers, which are frequently poorly ventilated, and where gas is likely to accumulate. Because ventilation needs and patterns differ from season to season, consider year-round ventilation patterns when planning and installing a monitoring system.

It is recommended that the applicable regulations be examined, including OSHA, NFPA, state and local codes, which will itemize the rules and guidelines for the hazards in question, and provide direction for gas detection and monitoring.

Changes within a facility should be considered when they occur. Construction within the plant, the use of new equipment and power shutdowns can affect air movement patterns. As a result, new demands may be placed on the monitoring system.

Chapter 3

When considering the design of a combustible gas detection system, it is important to select the correct product for the purpose intended. It is likely that a combination of point and open-path detection will be appropriate, so it is a good idea to discuss the selection with the chosen manufacturer.

To summarize, an analysis of the risk and equipment selection process will likely include:

- Potential leak sources
- Factors affecting rate and direction of gas diffusion when a leak occurs
- Density and other physical properties of the gas
- Detector environment, e.g., temperature, vibration, cleanliness, ventilation, etc.

Sensor Placement

The placement of combustible gas detection sensors is dependent upon many factors, which can only be dealt with here in brief.

When approaching a potential combustible hazard situation, there are generally two ways to determine the location of sensors. One way is to place the sensors close to where a leak is most likely to occur. This utilizes gas detection as a maintenance function for leak detection. The second way is to place sensors near areas where a concentration of hazardous gas may accumulate as a result of the diffusion of a leaking gas or vapor. The density of the gas or vapor determines whether it tends to rise or fall, and is a primary factor in determining the number and location of the sensors.

The wiring of sensors in series is often considered for cost reduction purposes, however, such an approach will result in cumulative outputs, difficulty in the calibration of the sensors and a reduction in the degree of safety the sensors can provide. Furthermore, an open circuit in one sensor will result in the loss of output of all other sensors in the series. A preferable approach is to have the sensors independently monitored and powered. The selected output then can be reliably utilized to warn of the presence of gas and to determine its location.

Sensor locations should take due recognition of the manufacturer’s stated temperature limits. Another factor that must be considered in sensor location is the amount of vibration to which the sensor may be exposed. For instance, installation near turbine engines or pumps may result in a vibration level damaging to the sensor. Furthermore, the natural resonant frequency of the sensor must be considered when evaluating the vibration characteristics of the location. The life of a sensor can be shortened significantly if resonance occurs between the sensor and the installation location.

When installing a sensor, proper instrument wiring practices must be observed. The sensor wiring should be separate from AC wiring. Most sensors are not affected by DC wiring, and therefore need not be shielded when mounted in close proximity to other DC applications. Wiring near high powered electric circuits, however, will most likely require shielding. When utilizing shielding, the wire should be grounded only at the controller or receiver end, and the outer braid must not contact the conduit or junction box. It is good engineering to always use shielded cable. Each sensor location should be checked and calibrated on a regular basis, using a calibration gas of known concentration. Typically this should be a 50% LEL mixture of gas or vapor. The frequency of inspection and the need for calibration is best determined by experience with the actual installation. The equipment manufacturer usually suggests intervals depending upon the application in question. In general, infrared detection requires less frequent calibration checks.

Sensors should be located so that they are accessible for calibration. If a sensor is not accessible, regular inspection and necessary calibration is unlikely to be performed. Sensors should be located where they will not be exposed to the possibility of immersion in water. Dust covers may be required for sensors that are located in particularly dirty environments and splashguards in areas where heavy rain is likely or where high-pressure wash-downs are performed. Catalytic sensors should be mounted with the sensor pointing downward while IR sensors should be mounted horizontally.

Combustible Applications

Industry Segments	Application	Gas	Applicable Sensors
Gas Pipelines Product Pipelines	Compressor Stations Pumping Stations	Methane Propane, Pentane Ethane, Crude Oil	Catalytic Bead Infrared
Sewage Plants Pollution	Digestor Gas, Plant Sumps or Plant Sewage Basins monitoring for solvent leaks or dumping	Methane Solvent Vapors	Infrared
Power Plants	Leaks at Crude Oil Heaters, Pumps, Pressure Reducing Stations, etc.	Crude Oil Methane	Catalytic Bead Infrared
Insecticide Manufacturers	Storage and filling of containers of hydrocarbon based compounds	Hydrocarbons	Catalytic Bead Infrared
Tank Farms	Protection against leaks, breaks, spills	Gasoline, Benzene Solvents, Crude Oil etc.	Catalytic Bead Infrared
Warehouses	Protection against leaks, spills or breakage of storage drums, tanks, etc.	Solvents, Oils, etc.	Catalytic Bead Infrared
Offshore Drilling Platforms	Protection against accumulations of flammable concentration of gases in storage areas, control rooms, living spaces, power generating rooms, compressors, etc.	Methane, etc.	Catalytic Bead Infrared
Utility Tunnels	Protection against accumulation of gases and vapors	Methane, Gasoline Solvents, etc.	Catalytic Bead Infrared
Edible Oils	Monitoring leakage of gas used in extraction of oil from soybeans, sesame seeds	Hexane, Hydrogen, Carbon Monoxide	Catalytic Bead Infrared
Natural Gas Processing Plants	Protection against hazardous concentrations of gases in unventilated areas	Methane	Catalytic Bead Infrared
Refineries and Petrochemical Plants	Instrument Houses. Protection against bourdon tube rupture in pressure recorders. Also leakage of flowmeter transmitters.	Methane, Propane, Process Gases, Waste Gases	Catalytic Bead Infrared
Power Peaking Plants	Gas burning turbine - generators. Monitoring piping leaks, turbine seals	Methane	Catalytic Bead Infrared
Mud Loggers	Hydrogen Sulfide and combustible gas monitoring	Hydrogen Sulfide, Methane	Catalytic Bead Infrared
Recording Tape Manufacturers	Solvent monitoring	Solvent Vapors	Catalytic Bead Infrared
LPG Storage	Combustible gas monitoring	Propane	Catalytic Bead Infrared
Solvent Storage Areas of Manufacturing Plants	Combustible gas monitoring	Solvent Vapors	Catalytic Bead Infrared
Aerosol Spray Paint	Combustible gas monitoring	Paint Vapors	Catalytic Bead Infrared
Synthetic Leather Manufacturers	Combustible gas monitoring	Solvent Vapors	Catalytic Bead Infrared

Combustible Applications

Industry Segments	Application	Gas	Applicable Sensors
Oil Tanker Pump	Monitoring concentration of vapors resulting from oil leakage	Hot Crude and Fuel Oil Vapors	Catalytic Bead Infrared
Power Plants	Hydrogen leaks, Generator cooling	Hydrogen	Catalytic Bead
Margarine Manufacturing	Hydrogenation of Edible Oils in manufacturing margarine	Hydrogen	Catalytic Bead
Semiconductor Manufacturing	Monitoring leakage of Hydrogen used in manufacturing Silicone Wafers	Hydrogen	Catalytic Bead
Printing Ink Manufacturing	Monitoring concentration of solvent vapors	Toluene Vapors	Catalytic Bead
Paint and Varnish Manufacturing	Solvent Vapor manufacturing	Toluene and other solvents	Catalytic Bead
Vinyl Chloride Manufacturing	Vinyl Chloride spills or breaks. NOTE: This is a difficult application. Do not sell without specific factory approval.	Vinyl Chloride Gases	Catalytic Bead
Power Cable Vaults	Leakage of combustible gases from adjacent pipelines	Methane	Catalytic Bead Infrared
LNG Storage Facilities	Leakage of LNG	Methane	Catalytic Bead Infrared
LNG Liquifying and Regasification	Combustible concentrations of Methane in confined areas	Methane	Catalytic Bead Infrared

Chapter 4

Area Classifications

- National Electric Code
- International Electrotechnical Committee
- Classification Comparison

General Monitors
Protection for life.

Area Classifications

National Electric Code (NEC)

Class I

Any location in which flammable gases or vapors are or may be present in the air in sufficient quantities to produce an explosive or ignitable mixture.

Class I, Division 1

Locations in which:

1. Ignitable concentrations of flammable gases or vapors exist under normal operating conditions.
2. Ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations, or because of leakage.
3. Breakdown or faulty operation of equipment or process might release ignitable concentrations of flammable gases or vapors, and might also cause simultaneous failure of electrical equipment.

Class I, Division 2

Locations in which:

1. Volatile liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined in containers or closed systems from which they can escape only in the case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment.
2. Ignitable concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operation of the ventilating equipment.
3. Is adjacent to a Class I, Division 1 location and to which ignitable gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided.

Class II

Any locations that are hazardous because of the presence of combustible dust.

Class III

Any locations that are hazardous because of the presence of easily ignitable fibers or flyings, but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitable mixtures.

General Properties

Flammable gases and vapors are separated into four different atmospheric groups:

Group A - atmospheres containing acetylene.

Group B - atmospheres containing hydrogen, fuel and combustible process gases containing more than 30% hydrogen by volume, or gases or vapors of equivalent hazard (butadiene, ethylene oxide, propylene oxide, and acrolien).

Group C - atmospheres such as cyclopropane, ethyl ether, ethylene, or gases or vapors of equivalent hazard.

Group D - atmospheres such as acetone, ammonia, benzene, butane, ethanol, gasoline, hexane, methane, natural gas, naphtha, propane, or gases or vapors of equivalent hazard.

Flammable Dusts and Debris

Flammable dusts and debris are separated into three different atmospheric groups:

Group E - atmospheres containing combustible metals regardless of resistivity, or other combustible dusts of similar hazard characteristics having resistivity of less than 102 ohms per centimeter.

Group F - atmospheres containing carbon black, charcoal, coal or coke dusts which have more than 8% total volatile material or atmospheres containing these dusts sensitized by other materials so that they present an explosion hazard, and having resistivity greater than 102 ohms per centimeter but equal to or less than 108 ohms per centimeter.

Group G - atmospheres containing combustible dusts having resistivity greater than or equal to 108 ohms per centimeter.

International Electrotechnical Committee (IEC)

The IEC is composed of approximately 40 countries including the United States. The purpose of the IEC is to establish standards for a wide variety of electrical products with the intent of encouraging international trade.

The IEC has assigned a technical committee, TC 31, to develop recommendations covering equipment, testing procedures and classification standards for areas where the potential for explosion exists because of flammable or explosive material present in the atmosphere.

Recommendations were based on explosion and ignition principles similar to those used to develop Articles 500-503 of the National Electrical Code. They can be found in IEC Publication 79, entitled, “Electrical Apparatus for Explosive Gas Atmospheres.” This publication consists of several parts covering various apparatuses intended for use in hazardous locations. It also defines the guidelines for classifying hazardous areas. Instead of using Classes and Divisions, the areas are defined in terms of zones:

ZONE 0 - an area in which an explosive gas-air mixture is continuously present or present for long periods. Generally, most industrial users try to keep all electrical equipment out of Zone 0 areas.

ZONE 1 - an area in which an explosive gas-air mixture is likely to occur in normal operations.

ZONE 2 - an area in which an explosive gas-air mixture is not likely to occur and if it does, it is only for a short period of time.

ZONE 10 - an explosive atmosphere, resulting from dust which is present continuously or for long periods of time.

ZONE 11 - a short-lived explosive dust atmosphere from unsettling dust deposits.

Chapter 4

Classification Comparison

HAZARDOUS MATERIAL	NEC STANDARDS	IEC EURONORM STANDARDS
Gas or Vapor	Class I, Div. 1 Class I, Div. 2	Zone 0 and 1 Zone 2
Dust	Class II, Div. 1 Class II, Div. 2	Zone 10 Zone 11
Fibers and Flyings	Class III, Div. 1 Class III, Div. 2	Zone 10 Zone 11

Appendix

Terminology

Terminology

Aerosol

A colloidal system in which a gas, frequently air, is the continuous medium and particles of solids or liquids are dispersed in it. Aerosol thus is a common term used in connection with air pollution control. Settling velocity is very low so particles stay in suspension for long periods of time.

Analyzer

Provides both quantitative and qualitative measurements of the composition of a mixture or compound. Not necessarily continuously.

Boiling Point

At a given pressure, the temperature at which molecules move fast enough to escape from the liquid surface. Solvents with low boiling points generate more vapor at a given ambient temperature than those with high boiling points. They are said to be volatile and are a high risk to store and handle. Solvents with high boiling points produce little vapor unless they are at an elevated temperature. The fire risk is therefore lower.

Colloid

A solid, liquid or gaseous substance made up of very small insoluble, non-diffusible particles that remain in suspension in a solid, liquid or gaseous medium of different matter.

Combustion

The rapid oxidation of a substance involving heat and light.

Diffusion

The movement of molecules away from a region of high concentration to a region of lower concentration. The term “diffusion” denotes the process by which molecules or other particles intermingle as a result of their random thermal motion. If an enclosure contains two gases, the lighter initially above, the heavier below, they will instantly begin to mingle because of their molecular motion.

Endothermic

Characterized by or formed with absorption of heat.

Appendix

Exothermic

Characterized by or formed with evolution of heat.

Explosion

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

Flammability Range

Flammable gases/vapors have limits below, and above, which flame propagation does not occur. The volume below which flame propagation does not occur is called the Lower Explosive (or Flammable) Limit (LEL). Below this concentration the mixture is said to be too “lean” for a flame to propagate. The volume of gas/vapor in air above which a flame does not propagate is called the Upper Explosive Limit (UEL).

Flash Point

The minimum temperature at which sufficient vapor is formed near the surface of the liquid to ignite it in the vessel in which it is contained. The lower the flash point, the greater the risk.

Gas

A state of matter, in which the molecules move freely and consequently the entire mass tends to expand indefinitely, occupying the total volume of any vessel into which it is introduced. Gases follow, within considerable degree of fidelity, certain laws relating their conditions of pressure, volume, and temperature. Gases mix freely with each other, and they can be liquefied through compression or temperature reduction.

Monitor

Provides a quantitative measurement, not qualitative. It measures continuously a condition that must be kept within prescribed limits. It does not differentiate between compounds.

Oxidation

The increase in oxygen content of a molecule. If an element combines with oxygen, it is said to be oxidized.

Propagate
To spread from one place to another.

Sensor
Converts a gas or vapor concentration to an electrical signal output. It is a type of "transducer."

Solvent
The substance doing the dissolving, or present as the major component, in the formation of a solution.

Spontaneous Ignition Temperature (SIT)
The minimum temperature to which a hydrocarbon must be heated to promote an ignition, in the presence of air, without the application of flame or spark.

Vapor and Vapor Pressure
Used to distinguish a substance in the gaseous state, but below its boiling point temperature. If a pure liquid partly filling a closed container is allowed to stand, the space above it becomes filled with the vapor of the liquid, which develops a pressure. This vapor pressure increases up to a certain limit, depending upon the temperature, where it becomes constant, and the space is then said to be saturated.

Vapor Density
The weight of a volume of pure gas/vapor compared with an equal volume of dry air at the same temperature and pressure. A gas/vapor with a vapor density greater than 1 may travel at low levels to find a source of ignition. With a vapor density less than 1, the gas/vapor tends to rise. Air currents, temperature gradients and other ambient conditions can affect gas/vapor diffusion characteristics, often more than vapor density.

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