

# PROTECTIVE CONCEPTS IN COMBUSTIBLE GAS AND VAPOR DETECTION

Dealing with the actual or potential presence of combustible gases and vapors in the workplace involves a complex series of decisions. Decisions related to “what to do” should be implemented by means of an integrated explosion protection plan based on a hierarchy of priorities. The most desirable approach – when feasible – is to implement engineering controls and practices that completely prevent the release or formation of explosive gases and vapors. This is often referred to as “Primary Explosion Protection.” If it is impossible to completely control or eliminate the possibility of an explosive atmosphere, the next best solution is to implement use of equipment and techniques to monitor for the presence of gas, and to take appropriate action when explosive gas is determined to be present. Equipment used in hazardous locations that are subject to the potential presence of explosive gas must be designed and certified as safe for use in the intended area for the intended purpose.

Combustible gas hazardous locations are areas where the atmosphere contains, or has the reasonable potential for containing, flammable gases and vapors. A flammable concentration of gas is one that is capable of being ignited if a source of ignition is present. The presence of flammable gas may be a consequence of leakage, chemical process, displacement, microbial activity (such as decomposition or fermentation), or some other specific process or activity. In order for an explosion to occur there must be sufficient oxygen, an ignitable concentration of gas, a source of ignition, and sufficient molecular energy to propagate the explosion chain reaction. Equipment that is used in areas that potentially contain flammable gas must be designed so that hot surface temperatures, electrical discharge, and other forms of stored energy, (such as inductance and capacitance) associated with the equipment are not capable of causing ignition of the flammable gas, given the type and severity of the hazardous conditions in which the equipment is installed or operated.

It should be noted that this article is treating these concepts on a somewhat simplistic level. For instance, oxygen in air is not the only oxidizer capable of reacting with another gas in an explosive chain reaction. The fuel used to propel the Proton rocket on its way to the International Space Station consists of dinitrogen tetroxide ( $N_2O_4$ ) and dimethyl hydrazine ( $CH_3NHNHCH_3$ ). But at most industrial sites, the oxidizer is the oxygen in the ambient air. Similarly, there is more than one type of hazardous location with the potential to contain an explosive atmosphere. A location may be hazardous because of the presence of combustible dusts, or ignitable concentrations of flyings or fibers. This article is focused exclusively on locations that are hazardous because of combustible gases and vapors in concentrations sufficient to lead to a potential explosion hazard.

The lower explosion limit (LEL) is the minimum concentration of gas or vapor in air that will support combustion, if a source of ignition is present. If the gas is present in air in concentrations less than the LEL it is too “lean” to be ignited. The upper explosion limit (UEL) is the highest concentration of a gas or a vapor in

air capable of burning explosively when a source of ignition is present. Above the UEL the concentration of gas in air is no longer capable of being ignited because the ratio of fuel molecules to oxygen molecules is too high for the explosion chain reaction to propagate. In this case the mixture is too “rich” to be ignited. The flammability range is the concentration range between the LEL and the UEL concentration. Gas can burn explosively when present in concentrations within the flammability range when a source of ignition (such as arc, flame or heat) is present.

The minimum ignition energy (MIE) is the minimum energy sufficient to ignite a particular flammable gas in air, when the gas is present in the ideal ratio of fuel to air for the gas to be most easily ignited. Different gases, and different mixtures of flammable gases, have different LEL and MIE values. Even when gas is present in concentrations within the flammability range, sources of energy less than the MIE are not capable of igniting the gas.

Combustible gas hazardous locations are defined a little differently in North America compared to the UK and Europe. In North America, the most widely used hazardous location classification scheme is based on the National Electric Code (NEC) NFPA® 70, Articles 500 - 506. The NFPA® scheme divides hazardous locations into three classes that are based on the characteristics of the flammable materials. “Class I” includes gases and vapors, “Class II” includes combustible dusts, and “Class III” includes flammable fibers and “flyings.” The classes are further divided into divisions based on the risk of fire or explosion the class of material represents, and the probability of being present in a potentially hazardous quantity.

In the UK and Europe, the hazardous location classification scheme is based on “Zones” that are defined by International Electrotechnical Commission (IEC) and European Committee for Electrotechnical Standardization (CENELEC) standards. The most important difference is that the IEC/CENELEC system is based on dividing the level of hazard probability into three zones rather than two divisions.



The G999 is a compact, one to six gas atmospheric monitor with optional wireless communication used to transmit real-time monitoring results to a remote collection point. The instrument is certified as an intrinsically safe “Ex i” device for use in Zone 1, gas group IIC, temperature class T4 hazardous locations.

Type of Hazardous Material	NEC / NFPA® Class / Division	IEC / CENELEC Zone
Gases and vapors	Class I, Division 1	Zone 0 Zone 1
	Class I, Division 2	Zone 2
Combustible dusts	Class II, Division 1	Zone 20 Zone 21
	Class II, Division 2	Zone 22
Fibers and flyings	Class III, Division 1	(Not yet determined)
	Class III, Division 2	

Once again, this article is focused on NEC NFPA Class I, and IEC / CENELEC Zones 0, 1 and 2 hazardous locations characterized by flammable gases and vapors.

Probability of occurrence of flammable concentrations	NEC / NFPA Division System	IEC / CENELEC Zone System
Present continuously	Class I, Division 1	Zone 0 (Flammable mixture present 1000 hours or more per year.)
Present occasionally		Zone 1 (Flammable mixture present between 10 and 1000 hours per year.)
Present in abnormal or emergency conditions	Class I, Division 2	Zone 2 (Flammable mixture present less than 10 hours per year.)

The classes and zones are additionally divided into sub-groups based on the type of flammable gas. The NEC / NFPA scheme divides flammable gases into four "gas groups" identified by means of a "typical" gas with flammability characteristics that fall into the group. The groups include additional gases with similar flammability characteristics. For instance, Group B includes butadiene and ethylene oxide as well as hydrogen, while Group D includes ammonia, ethanol, methanol, natural gas, methane, acetone, and many other VOC vapors, as well as propane. The IEC / CENELEC zone gas group classification is based on three rather than four groupings.

Typical Gas	NEC / NFPA Class / Division Gas Groups	IEC / CENELEC Zone Gas Groups
Acetylene	A	II C
Hydrogen	B	
Ethylene	C	II B
Propane	D	II A

The equipment used to monitor for the presence of flammable gas must be designed for use in the intended hazardous location. In most jurisdictions, the equipment must carry a certification from a qualified testing laboratory or agency. In North America, qualified testing laboratories are referred to as Nationally Recognized Testing Laboratories (NRTLs). In Europe, qualified testing laboratories are referred to as Notified Bodies. Examples include CSA®, UL®, FM®, DEKRA EXAM®, ITS® and many others. Testing laboratories assess the conformity of the equipment to the relevant standard for use in the specified hazardous location. The certification marking includes the protection method, ambient operating temperature range, types of gas, and the temperature class or "T code" of the gases to which the certification applies.

The temperature class is based on the auto-ignition temperature of the class of gases used for the certification evaluation. The auto-ignition temperature (ATI) is the minimum temperature at which a flammable gas spontaneously ignites in normal atmosphere without an external source of ignition, such as a flame or spark. For instance, a T3 temperature class marking indicates the equipment is certified for use with flammable gases with an ATI of 200°C or higher, while a T4 marking indicates the equipment is certified for use for gases with an ATI of 135°C or higher. Acetaldehyde is an example of a gas with a very low ATI of only 135°C. A T3 temperature class certification is not sufficient for this gas. For acetaldehyde a T4 certification is minimally required.

There are three commonly used protection methods used to prevent the ignition of flammable gas by equipment designed for use in hazardous locations.

**1. Contain the explosion:**

In this protection method a flame proof enclosure is used to house the electrical equipment, and to prevent the explosion from spreading or igniting the surrounding atmosphere. The explosive energy is contained within the enclosure. In addition, the enclosure is designed to prevent external surfaces from reaching a temperature high enough to ignite the surrounding atmosphere.

**2. Isolation:**

This protection method physically separates or isolates electrical parts or hot surfaces from the ignitable gas. The method includes various techniques such as encapsulation, pressurization and use of electrical (Zener diode) barriers.

**3. Limit the energy:**

Intrinsically safe equipment is designed to limit the energy (thermal as well as electrical) capable of being released by the equipment. Certification for intrinsic safety is based on the



The CC-33 is a fixed system gas transmitter equipped with a catalytic LEL sensor. The transmitter is certified as a flameproof "Ex d" device for use in Zone 1, gas group IIC hazardous locations.

maximum energy that is capable of being released both during normal operation, as well in fault conditions. Equipment that is certified as intrinsically safe is not capable of releasing the minimum ignition energy necessary to ignite the type and temperature class of gases, over the ambient operating temperature range to which the certification applies.

Equipment that is certified as safe for use as a consequence of the "Increased Safety" protection method is designed to prevent "arcs and sparks" during normal and specified abnormal operating conditions. Increased Safety is achieved by use of barriers to prevent the discharge of energy, and enhanced insulation to ensure that surface temperatures are controlled below incandive values.

The equipment certified for use in a hazardous location may include use of more than one protection method. For instance, most portable gas detectors are certified as intrinsically safe for use in combustible gas hazardous locations. Many of these intrinsically safe instruments include a catalytic LEL sensor that detects gas by oxidation. The oxidation occurs at a small active bead in the sensor, which may, in the presence of gas, reach temperatures in excess of 550°C. The LEL sensor itself is generally designed as a flame proof device. The active bead and other elements in the sensor are contained within a robust housing, and protected by a flame arresting sinter that prevents energy being released by the sensor in the event that gas within the sensor is ignited. While the entire instrument is intrinsically safe, the LEL sensor is a flame proof device.

Many portable instruments also include a battery pack with rechargeable cells that are encapsulated in potting material that serves to dissipate heat, and isolate heated surfaces within the battery pack from contact with gas in the event there is a short circuit or fault within the battery. While the entire instrument is intrinsically safe, the battery pack is rendered safe (in part) by encapsulation.

The type of protection method used in the equipment is identified in the certification label. In the UK and Europe, CENELEC and IEC standards identify protective methods by means of a code designation included in the certification label. Certification for intrinsic safety is indicated by the code designation "Ex i", certification for Increased Safety is indicated by "Ex e", and flameproof certification as is indicated by "Ex d".

Once the hazards are fully understood, the next question is what to do about monitoring the atmosphere in the hazardous location. An important decision is whether to rely on portable atmospheric monitors that are used when workers are in the area, on permanently installed fixed detection systems, or on a combination of both fixed and portable monitoring equipment.

Fixed detection systems monitor the atmosphere continuously. They are typically used in process control, to provide local alarms, to communicate real-time monitoring and alarm information from multiple locations to a central location, to activate external alarms such as lights, horns and sirens, to actuate other peripheral devices such as fans; as well as to demonstrate compliance with regulatory requirements.

An advantage of installing a fixed detection system is that workers entering the monitored area are not usually involved in the day-to-day operation of the system. Procedural issues are much more complex when workers are required to use personally assigned portable gas detectors. Addition of a fixed detection system coupled with other engineering controls, such as permanently installed ventilation, may render otherwise hazardous areas safe for continuous occupancy, and eliminate the need for procedural controls such as entry permits.

Purchase and installation of a fixed gas detection system can be a significant capital expense. However, equipping workers individually with atmospheric monitors can also be expensive, while training, testing, calibration and maintenance of portable instruments can be a significant additional cost. A permanently installed fixed system is often the most cost-effective solution. The system can be configured as a simple "standalone" system that provides information and alarms on a local basis, or as a larger integrated system that can communicate real-time monitoring results literally on a world wide basis.

Fixed gas detection systems consist of a number of different components and assemblies including sensors, gas transmitters and controllers. The gas detecting sensor and associated electronics are referred to as the "gas transmitter." The gas transmitter is installed in the area that needs to be monitored. The transmitter is available with or without a display, with or without a local control interface, and may be connected to controllers and other system elements by means of (typically) a 4-20mA line power connection, or integrated digitally with the controller and other system elements by means of RS-485, MODBUS or HART protocol connection.

Fixed sensors may use the same or utilize different detection technology as portable sensors. Since power is provided to the system by means of termination to an external power source, fixed system sensors, compared to the sensors used in portable instruments, are not constrained (or as constrained) by the need to conserve power. Fixed system elements are similarly less constrained by the need to reduce the physical size of sensors, housings and other components.

There are distinct advantages (and disadvantages) with each protective method. It is very important to determine which protective method provides the best solution before specifying or purchasing a fixed system.

Flameproof certified "Ex d" gas transmitters are typically installed in heavy duty stainless steel or cast aluminum enclosures, and terminated to a line power source by cabling that is installed in expensive, explosion proof conduit. The cost of installing the cabling and conduit usually exceeds the cost of the actual gas detection equipment. Also, since the protection method depends on the integrity of the conduit and enclosure, mechanical damage or conditions that breach the mechanical integrity of the system may result in a dangerous discharge of energy. On the other hand, there are often advantages with regards to durability, and flameproof certification is the most suitable protective method for higher power devices. Existing systems are often based on this older protective concept, and site requirements often specify that gas transmitters and other system elements carry "Ex d" certification.

Intrinsically safe "Ex i" and increased safety "Ex e" certified gas transmitters have a number of potential advantages. Because the protective method does not depend on the integrity of the conduit and enclosure, a mechanical breach does not result in the loss of protection. It is not usually necessary to run the cabling through explosion proof conduit. The cabling and conduit simply needs to meet local electrical code requirements. This can substantially reduce the cost of installation. The intrinsically safe protective method is ideal for low power transmitters, but is not suitable for high power devices.



The IR-29 is a fixed system gas transmitter equipped with an infrared sensor used to measure LEL gas. The IR-29 is certified as an intrinsically safe "Ex i" device for use in Zone 0, gas group IIC, temperature class T4 hazardous locations. The sensor head of the low power transmitter can be removed and replaced while the transmitter is located in the hazardous location. The intrinsically safe design does not depend on an explosion proof housing, which reduces noise and improves performance of the IR sensor.

Intrinsically safe transmitters are often designed so that the sensor head can be removed without needing to declassify the area, making calibration, maintenance and repair much easier. For some types of sensing technology, there are specific advantages to not having to house the sensor within a sealed enclosure. For instance, infrared LEL sensors depend on the absorbance of IR light by molecules present in the optical sensing chamber to detect gas. When the absorbance occurs inside a flameproof enclosure, the result is an increase of pressure that potentially adds "noise"

to the detection signal. When the IR sensor is based on an intrinsically safe design, absorbance can occur in an optical sensing chamber that is open to the ambient atmosphere, resulting in less noise and better resolution.

In summary, remember that protection methods are not all the same! Make sure you understand the benefits and liabilities of using fixed versus portable atmospheric monitors, and the protective method that provides the optimal solution before you specify and acquire the monitoring equipment.

### about the author

Bob Henderson is President of GfG Instrumentation, Inc. in Ann Arbor, Michigan, a division of GfG, mbH, with worldwide headquarters in Dortmund, Germany. Bob has been a member of the American Industrial Hygiene Association since 1992. He is a member of the AIHA Real Time Detection Systems Technical Committee and the AIHA Confined Spaces Committee. He is also a past chair of the Instrument Products Group of the International Safety Equipment Association.

### Author Contact Details

Bob Henderson, GfG Instrumentation, Inc. • Email: [bhenderson@goodforgas.com](mailto:bhenderson@goodforgas.com) • Web: [www.gfg-inc.com](http://www.gfg-inc.com)

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