Explosion Protection and Intrinsic Safety 101

Understanding Hazardous Locations and Protection Methods

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Hazardous Locations and Methods of Protection

Introduction

This document deals with the physical principles and fundamentals of explosion protection. In addition, this document will cover the two Division Model used in North America and the Three Zone Model used in Europe and International Electrical Code (IEC) countries of hazardous (classified) locations. Regardless of geographic location, the physical principles of explosion protection are identical. What differentiates one country from another are national deviations and varying requirements associated with the explosion protection methods.

About Hazardous Locations

By definition, a hazardous (classified) location is an area in an industrial complex where the atmosphere contains flammable concentrations of gases or vapors by leakage, or ignitable concentrations of dust or fibers by suspension or dispersion.

The treatment of dangerous substances, where the risk of explosion or fire exists that can be caused by an electrical spark, arc, or hot temperatures, requires specifically defined instrumentation located in a hazardous location. It also requires that interfacing signals coming from a hazardous location be unable to create the necessary conditions to ignite and propagate an explosion.

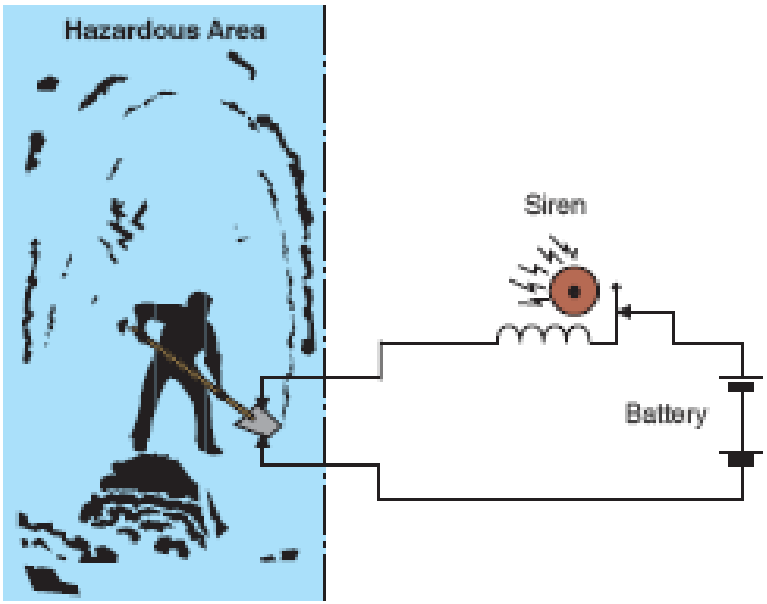
The introduction of semiconductor devices, such as transistors and integrated circuits, along with the reduction in working voltages and energy levels, made the energy-limitation protection technique called ***intrinsic safety***.

How it all Began

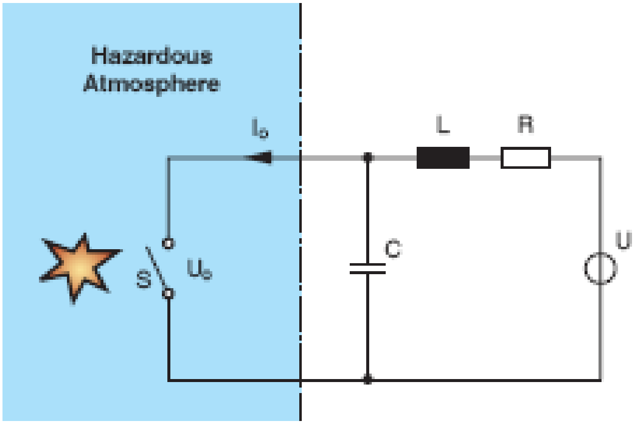
The Intrinsic Safety Story

In 1913, there was a disastrous methane gas explosion at a coal mine in England. The commission in charge of the investigation debated whether or not the explosion was caused by the low-voltage signaling system used to advise the surface crew when coal cars were ready to be brought to the surface.

The signaling system was composed of a set of batteries and a bell, which was activated by shorting two bare conductors routed along the mine's galleries. The system was considered safe because the low voltage and current level in the circuit were within recognized safety parameters.



Research, however, revealed that ***the most important factor in determining the safety of an electrical circuit is the energy stored in the circuit***. Without the use of limitation methods, the inductive energy stored in the bell and wiring produced energy levels sufficient enough to generate an electric arc that was able to ignite the dangerous air/gas mixture.



This research lead to new circuit designs in which the stored energy was reduced to a level that would prevent the generation of arcs, sparks, or other thermal effects that could ignite a potentially hazardous atmosphere.

The first regulation for testing and certification of signaling systems for mines was issued. Shortly thereafter, the intrinsic safety concept was applied to other industries where explosive atmospheres were easier to ignite than methane.

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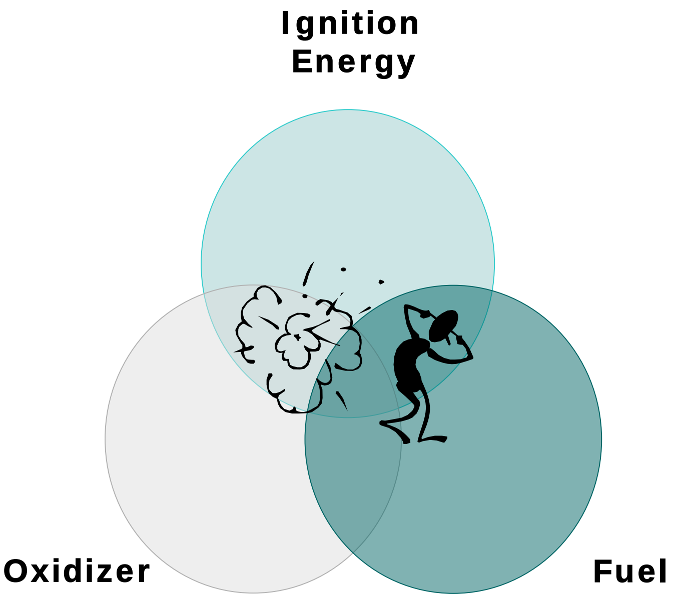
Explosion Protection Fundamentals

The Ignition Triangle

From a chemical point of view, oxidation, combustion, and explosion are all exothermic reactions with different reaction speeds. ***For such reactions to take place, it is essential that three components be present simultaneously in suitable proportions.*** *These components are:*

- Ignition energy (electrical or thermal)
- Oxidizer (generally air or oxygen)
- Fuel (flammable vapors, liquids or gases, or combustible dusts or fibers)



Once the reaction is ignited, and depending on how the exothermic energy is released, the results can be a controlled combustion, flame wave or explosion.

All protection methods used today are based on eliminating one or more of the triangle components in order to reduce the risk of explosion to an acceptable level.

There are materials that can explode spontaneously without supplied energy. However, this document only deals with the prevention of explosions that can be ignited.

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Explosive Mixture Characteristics

Explosion characteristics of an energy source are evaluated to determine the minimum energy required to ignite the air/gas mixture.

The following definitions will help you gain a better understanding of commonly-used words when discussing hazardous locations:

- **Minimum Ignition Energy (MIE)**
  There is a MIE for every fuel, which represents the *ideal ratio* of fuel to air where the mixture is most easily ignited.

- **Lower Explosive Limit (LEL)**
  When the concentration value is below the MIE, it has the smallest fraction of combustible gas/fuel and, therefore, cannot be ignited.

- **Upper Explosive Limit (UEL)**
  When the concentration value is above the MIE, it has the smallest fraction of air/oxidizer and, therefore, cannot be ignited.

Order your copy of the Pepperl+Fuchs Engineer's Guide for further details regarding ignition characteristics and determining limits and risk.

Evaluating the Potential for an Explosion

In any situation involving an explosive material, the risk of ignition must be taken into account and an evaluation should involve industry specialists, safety and mechanical engineers, chemists, and other critical personnel. Some of the most important factors to consider when making an evaluation are:

- Knowing the nominal rating of materials under consideration
- Knowing the parameters related to the process, such as the risk of an explosion caused by the evaporation of a liquid
- Knowing the atmospheric conditions that are present, normally and abnormally

Although the physical principles of explosion protection are the same worldwide, the methods are determined by national legislation. As mentioned above, evaluating all hazards and determining hazardous areas in a plant is normally performed by experts of various disciplines.

Understanding Hazardous Areas

Hazardous areas are most frequently found in places where there is a possibility of an emission of flammable gas or dust. The hazardous area can occur in normal operation, in the event of a fault (mechanical defect), or due to wear and tear of seals or other components. A hazardous area ranges from the area of release to areas in which the affected substance is so diluted with air that ignition is no longer possible (LEL). The extent of the area is dependent on the type and quantity of released gases or dispersed dust, the degree of ventilation, or other similar conditions.

Classifying Hazardous Areas

The categorization of hazardous areas are carried out in North America in accordance with the National Electrical Code (NEC) NFPA 70, article 500. The NFPA establishes area classification using three factors: classes, division and groups. Hazardous areas are dependent on the type of flammable material present and are first divided into one of the following classes:

- **Class I**
  Locations containing flammable gases or liquid mixtures, liquid-produced vapors, or combustible liquid-produced vapors.
- **Class II**
  Locations containing combustible dust. Hazards associated with dust are equally important to that of flammable gases since dispersed dust can also lead to explosions. Such explosion hazards can occur in various sectors of industry, such as rubber, plastics, timber, and in food products (flour and sugar).
- **Class III**
  Locations containing fibers and flyings. Examples of industries belonging in this class usually include parts of textile mills, clothing manufacturing plants, cotton gins, and woodworking plants. Fibers and flyings that are easily ignitable include rayon, cotton, hemp, Spanish moss, etc.

Two Division Model

Classes are further categorized into Division 1 and Division 2 according to the probability of occurrence of these materials being present in a potentially hazardous quantity. The table below illustrates how hazardous areas are broken down.

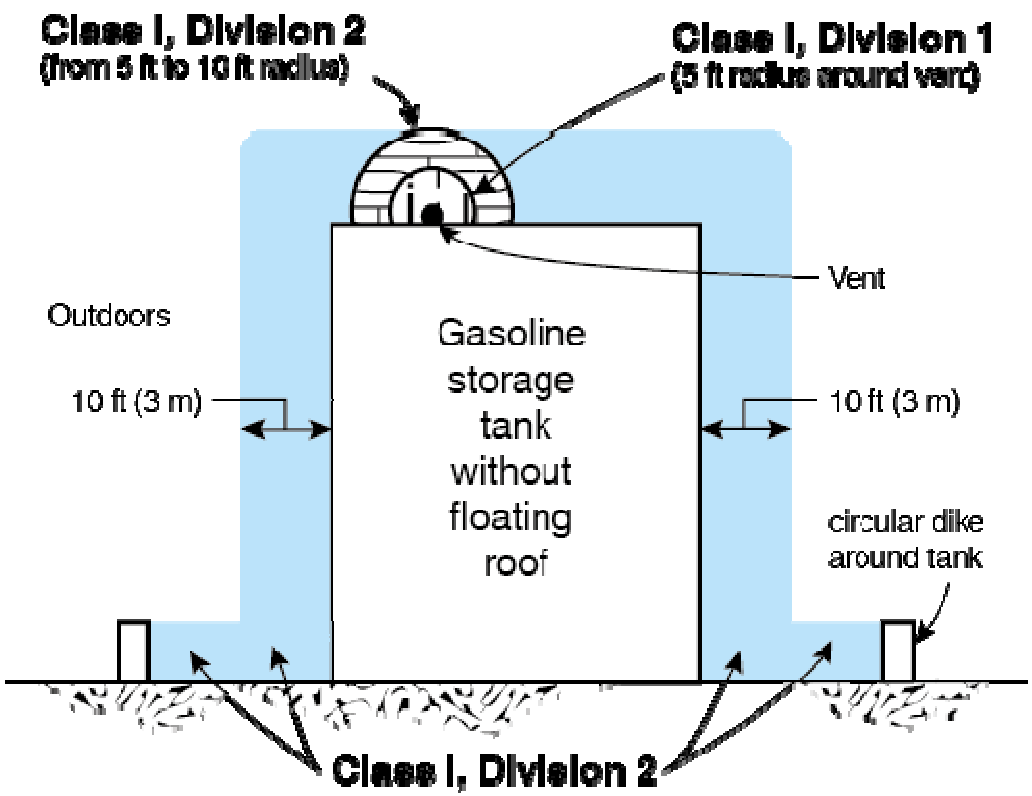
	Class I **(Gases and Vapors)** In accordance with NEC 500.5 and CEC J18-004	**Class II** **(Flammable dust or powder)** In accordance with NEC 500.6 and CEC 18-008	**Class III** **(Flammable fibers or suspended particles)** In accordance with NEC 500.7 and CEC 18-010
Division 1	Areas containing dangerous concentrations of flammable gases, vapors or mist continuously or occasionally under normal operating conditions	Areas containing dangerous concentrations of flammable dusts continuously or occasionally under normal operating conditions.	Areas where dangerous concentrations of easily ignitable fibers or flyings are continuously or occasionally used, such as the handling and use in the manufacturing process.
Division 2	Areas probably not containing dangerous concentrations of flammable gases, vapors or mist under normal operating conditions	Areas probably not containing dangerous concentrations of flammable dusts under normal operating conditions.	Areas probably not containing dangerous concentrations of ignitable or suspended particles of fibers and flyings, such as storage.

Class Subgroups

Class I and Class II hazardous areas are divided into subgroups based on the type of flammable gas or vapor present. The chart below illustrates this subdivision. Class III is the exception – it does not get divided into subgroups.

Class I	Group A	Atmospheres containing acetylene.
	Group B	Atmospheres containing hydrogen and flammable process gasses with more than 30% hydrogen by volume, or gasses or vapors posing a similar risk level such as butadiene and ethylene oxide.
	Group C	Atmospheres such as ether, ethylene or gasses or vapors posting a similar risk level.
	Group D	Atmospheres such as acetone, ammonia, benzene, butane, cyclopropane, ethanol, gasoline, hexane methanol, methane, natural gas, naphtha, propane, or gasses or vapors posting a similar risk level.
Class II	Group E	Atmosphere containing combustible metal dusts, including aluminum, magnesium and their commercial alloys, or other combustible dusts whose particle size, abrasiveness and conductivity present similar hazards in the use of electronic equipment.
	Group F	Atmospheres containing combustible carbonaceous dusts including carbon black, charcoal, coal, or coke dusts that have more than 8 percent total entrapped volatiles, or dusts that have been sensitized by other materials so that they present an explosion hazard.
	Group G	Atmospheres containing combustible dusts not included in Groups E or F, including flour, grain, wood, plastic, and chemicals.

Classification Example



The picture above is an example of a typical classification of a fuel storage tank.

Practices of the Division Method vs. Three-Zone Model

To have an understanding of the differences between the North American and European practices regarding the classification of hazardous locations, refer to the table below. From a practical point of view, the two systems have some minor differences but, for the most part, they are equivalent.

While Division 2 and Zone 2/22 are comparable, the North American Division Method has no direct equivalent to the European Zone 0. Instrumentation designed for a Division 1 location has measures built in that usually allow them to be used in either Zone 0/20 or Zone 1/21. However, instrumentation designed for Zone 1/21 cannot necessarily be directly used in a Division 1 location due to the inability to quantify the expressions, "long period of time" for Zone 0/20, "can be present" for Zone 1/21 and Division 1, and "not normally present" for Zone 2/22 as defined in the cited standards. Zone 0 is the most dangerous and any instrumentation designed for that zone must be incapable of generating or accumulating sufficient energy to ignite the fuel mixture.

Classification Method	**Constant Risk**	**Occasional Risk**	**Risk only in the case of a fault**
Divisions (North America)	Division 1		Division 2
Zones (IEC/Europe)	Zone 0/20	Zone 1/21	Zone 2/22

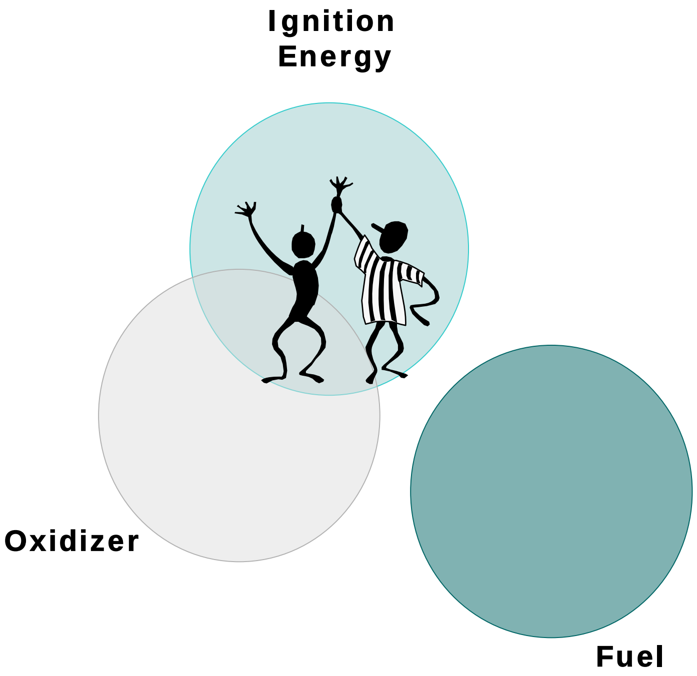
The Pepperl+Fuchs Engineer's Guide has complete coverage on the European Zone procedures.

Ignition Protection

Three Methods of Ignition Protection

In order to reduce the risk of explosion, ***eliminating one or more of the components of the ignition triangle*** is necessary. The three basic methods of protection are:

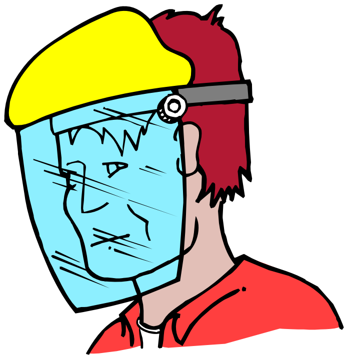
- **Explosion containment**
  The only method that allows the explosion to occur but confines it to a well-defined area, thus avoiding transmission to the surrounding atmosphere. Flameproof and explosion-proof enclosures are based on this method.
- **Segregation**
  A method that attempts to physically separate or isolate the electrical parts or hot surfaces from the explosive mixture. This method includes various techniques, such as pressurization, encapsulation, etc.
- **Prevention**
  A method that limits the energy (electrical and thermal) to safe levels under both normal operation and fault conditions. Intrinsic safety is the most representative technique of this method.



Selecting a Protection Method

Things to consider when selecting a protection method are:

- The normal function of the apparatus
- Degree of safety required for the classified area
- Size of the equipment
- Power requirements
- Flexibility of the protection method for maintenance
- Installation costs



None of the protection methods can provide absolute certainty of preventing an explosion. Choosing a specific protection method depends on the degree of safety needed for the type of hazardous location. When a standardized protection method has been properly installed and maintained, the probability of an explosion is so low that statistically, there has never been a verified incident.

Protection Method Codes

Codes Make Identifying Protection Methods Easy

In Europe, CENELEC and IEC standards refer to protection methods with symbols, such as Ex d for the flame-proof method. Using the symbol and labeling of the relevant apparatus, the protection method in use can be easily identified. These symbols are not used by the United States and Canada for Division rated products. However, they are used when the CEC zone method or NEC 505 are used. As a general rule, North America and Canada use only the top three code designations – Europe and other countries are more accustomed to using the other protection method codes.

Order the Pepperl+Fuchs Engineer's Guide to learn more.

Protection Method	Code Designation
Pressurization	Ex p
Intrinsic safety	Ex i
Flameproof	Ex d
Oil immersion	Ex o
Powder filling	Ex q
Encapsulation	Ex m
Increased safety	Ex e
Ignition protection	Ex n
Apparatus with optical radiation	op

Explosion Protection

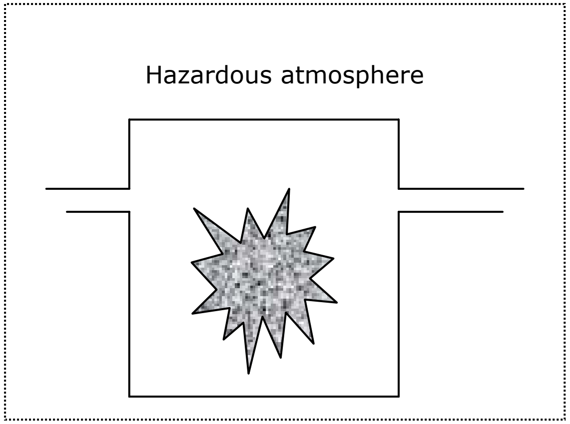
All Protection Methods Are Not the Same

On the next several pages, we will outline several different protection methods which, as discussed previously, should be ***chosen based on the degree of safety needed for your type of hazardous location.***

Flameproof and Explosion-proof Enclosures

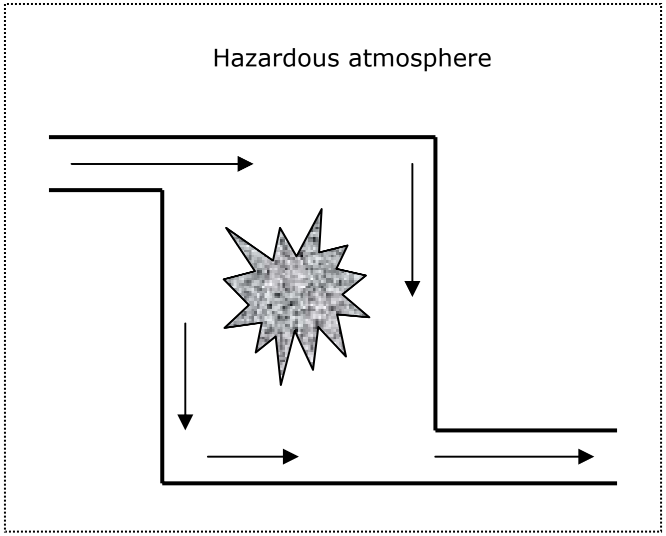
This protection method is the only one based on the ***explosion containment concept***. This method allows the energy source to come in contact with the dangerous air/gas mixture. As a result, the explosion takes place but is confined in an enclosure built to resist the excess pressure created by an internal explosion.

The explosion proof protection method is one of the most widely used and is suitable for electrical apparatus located in hazardous locations. However, high maintenance and calibration costs make this method less cost effective than that of intrinsic safety, ***a specialty of Pepperl+Fuchs.***



Purge and Pressurization Method

Purging and/or pressurization is a protection method based on the *segregation concept*. This method does not allow the dangerous air/gas mixture to penetrate the enclosure containing electrical parts that can generate sparks or dangerous temperatures. A protective air or inert gas is contained inside the enclosure with a pressure slightly greater than the one of the external atmosphere, preventing the flammable air/gas mixture from coming in contact with the electrical components.



Evaluating the Pros and Cons

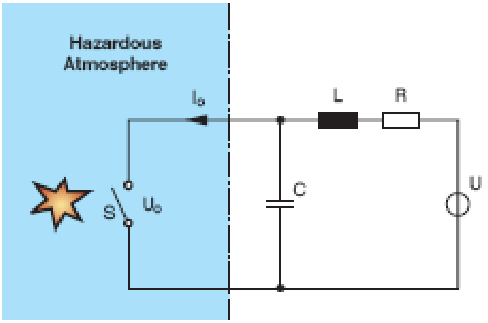
Below we evaluate of the pros and cons of two widely used protection methods used in North America and Canada.

	PROS	CONS
Explosion Proof	• Explosion containment • High-power equipment • No electronics	• Explosion ruins expensive equipment • Installation and maintenance errors • Limited access • Labor intensive maintenance • Heat build-up • Extremely heavy • Promotes condensation leading to corrosion
Purge and Pressurization	• Inhibits corrosion • Reduces heat build-up • Low maintenance • Equipment longevity • No special enclosure • Fast maintenance • Continuous status indication	• Requires air supply • Requires a hot permit

Intrinsic Safety

Intrinsic safety is based on the principle of preventing a source of ignition. The electrical energy is kept below the MIE required for each hazardous area. The intrinsic safety level of an electrical circuit is achieved by limiting current, voltage, power and temperature; therefore, ***intrinsic safety is limited to circuits that have relatively low levels of power.***

In normal operation and in the event of a fault, no sparks or thermal effects may occur that could lead to the ignition of a potentially explosive atmosphere. Intrinsically safe circuits may be connected and disconnected during operation, even when live, as they are guaranteed to be safe in the event of a short circuit or disconnection. Intrinsic safety is the only ignition protection class that allows connectors to be opened and intrinsically safe apparatus to be removed and replaced by an equivalent device in a hazardous area. Because intrinsic safety offers an unmatched level of freedom, it has become one of the most important methods of protection in the industrial automation industry.



When making a comparison of the three most widely used protection methods (Ex i, Ex d, Ex p), it is evident that **intrinsic safety**, where applicable, **is preferred for safety and reliability reasons**.

Intrinsic Safety Pros and Cons

Below we evaluate of the pros and cons of intrinsic safety. After reviewing the pros and cons on the comparison chart for explosion protection and purge and pressurization, you can determine which protection method is most preferred and why.

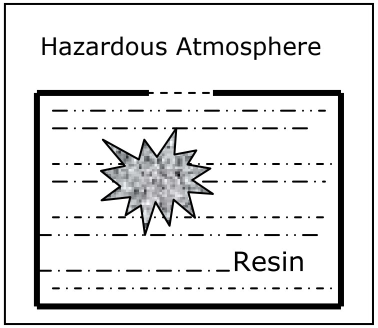
	PROS	CONS
Intrinsic Safety	• Least expensive and easiest to install of all the protection methods • Inherently safe • Eliminates the possibility of explosion • Ideal for low power devices • Little to no maintenance required • Live maintenance without required hot permit	• Documentation required for IS circuits and installation • Only suitable for low-power devices

The Engineer's Guide will explain why Pepperl+Fuchs is the world leader in intrinsic safety.

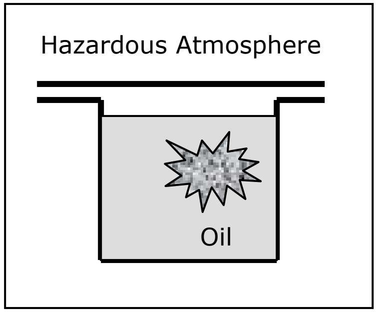
Other Protection Methods

Below are several ***segregation protection methods***. Each method protects in relatively the same manner – by separation of the electrical components from the external atmosphere. However, it is the material in which the electrical components are housed that makes it the protection method of choice for any given circumstance. As a note, segregation methods are not normally used in North America or Canada.

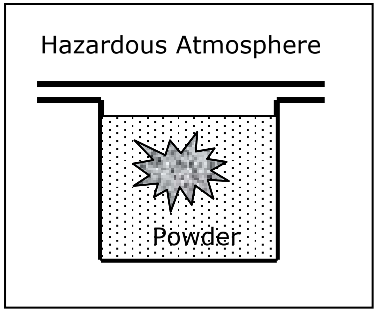
Encapsulation



Oil-Immersion



Sand-Filled (Powder-Filled)



The Pepperl+Fuchs Engineer's Guide covers in-depth information on the Encapsulation, Oil-Immersion and Sand-Filled Protection Methods.

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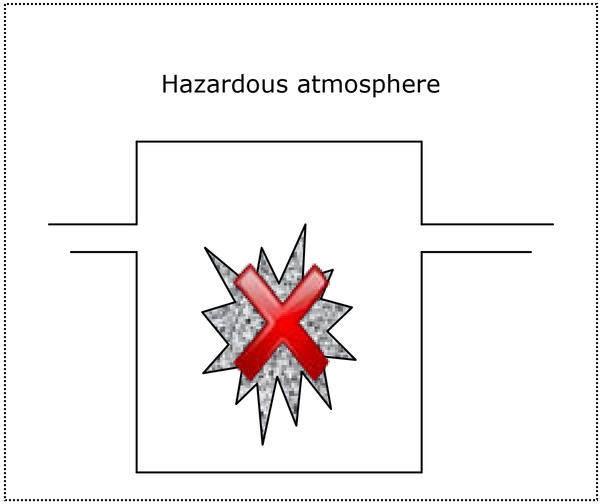
Prevention

Increased Safety

As you might guess, increased safety is based on ***prevention***. This method requires that measures must be applied to the electrical apparatus to prevent the possibility of reaching excessive temperature or generating arcs or sparks inside and outside the apparatus during normal operating conditions. Increased safety is achieved by means of design parameters, such as air distances or tensile strength of connections and cable glands.



In Summary

We hope you enjoyed this overview on explosion protection and intrinsic safety. Here’s a summary of key points:

- A hazardous location is an area in which the atmosphere is explosive or anticipated to be explosive
- Intrinsic safety dates back to 1913 following a disastrous mine explosion in England
- The Ignition Triangle consists of three components (fuel, ignition energy and oxidizer) that must be present simultaneously, and in suitable proportions, to cause an explosion.
- Minimum Ignition Energy (MIE) is the ideal ratio of fuel to air where the mixture is most easily ignited
- Any area above or below the Minimum Ignition Energy contains a smaller fraction of air or combustible gas/fuel and cannot be ignited
- Hazardous areas in North America are broken down into three classifications: Class I (flammable gases or liquids), Class II (dust), and Class III (fibers and flyings)
- The classifications are further broken down in Division 1 or Division 2 based on the probability of the materials being present in a potentially hazardous quantity
- The Division Method of North America is comparable to the Three-Zone Model practiced in Europe
- There are three basic methods of explosion protection: containment, segregation, and prevention
- Intrinsic safety is the principle of keeping the electrical energy below the MIE and is the preferred method of explosion protection for low power devices

Want to Learn More?

This e-book provides an overview from one chapter of our Interface Technology Engineer's Guide, Edition 3.1. The entire Guide will teach you about:

- **Basic principles of field signals**
- **Functional safety (SIL)**
- **Applications and practical solutions**
- **Isolated barriers**
- **Zener barriers**
- **Surge protection**
- **HART interface solutions**
- **Signal conditioning**

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