Engineer's Guide

USA Headquarters web: www.am.pepperl-fuchs.com
phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com

Worldwide Headquarters web: www.pepperl-fuchs.com
phone: +49 621 776-0 • email: pa-info@de.pepperl-fuchs.com

Asia Pacific Headquarters web: www.pepperl-fuchs.com
phone: +65 67799091 • email: sales@sg.pepperl-fuchs.com

Preface

After World War II, the increased use of oil and its derivatives brought the construction of a great number of plants for extraction, refining and transformation of the chemical substances needed for technological and industrial development.

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

This risk of explosion or fire has been the limiting factor when using electrical instrumentation because energy levels were such that the energy limitation to the hazardous location was difficult, if not impossible, to obtain. For this reason, those parts of the process that were considered risky were controlled with pneumatic instrumentation.

The introduction of semiconductor devices (transistors first and, subsequently, integrated circuits), along with the capability to reduce the working voltages and energy levels, made the energy-limitation protection technique, called intrinsic safety, easier to apply when using electronic instrumentation in hazardous locations. Thus, a more economical and more efficient solution to the problem was created.

The purpose of this publication is to:

- explain the principles on which the protection techniques against the danger of explosion are based
- present intrinsic safety and its application to anyone who faces the problems relative to design, installation and maintenance

Section 1
Introduction to Intrinsic Safety

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

The signaling system, composed of a set of batteries and a bell, was activated by shorting, with a metallic tool or by hand, two bare conductors routed along the mine's galleries (refer to Figure 1.1). The system was considered safe because the low voltage and current level in the circuit were within recognized safety parameters.

The research that followed 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 proper 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—causing the fatal explosion.

The concept of intrinsic safety was born.

The electrical apparatus and their associated circuits had to be designed in a manner that would prevent the generation of arcs, sparks or thermal effects that could ignite a potentially dangerous substance, during both normal and fault conditions of the circuit.

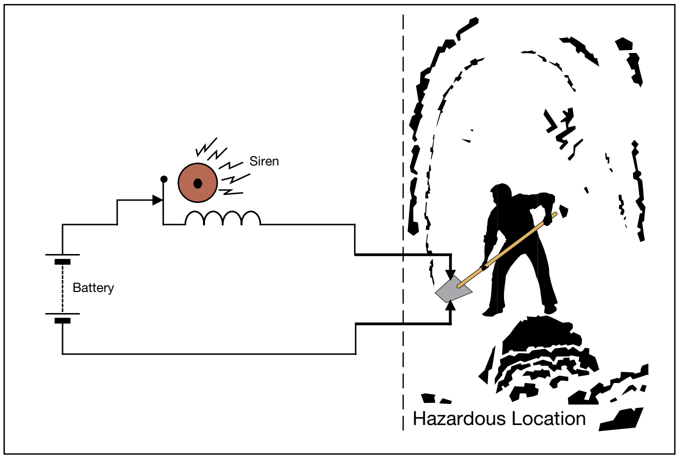

Figure 1.1

Mine signaling system erroneously considered safe causes an explosion

The first regulation for testing and certification of signaling systems for mines was issued. Subsequently, the study of the lighting mechanism was expanded to include alternative current (AC) circuits and other dangerous gas mixtures.

The intrinsic safety concept was then applied to the surface industries where dangerous mixtures, i.e., containing hydrogen or acetylene, are easier to ignite than the methane present in coal mines.

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 the following three components be present simultaneously in suitable proportions:

- Fuel: flammable vapors, liquids or gases, or combustible dusts or fibers;
- Oxidizer: generally, air or oxygen;
- Ignition Energy: electrical or thermal.

These three components are identified in the ignition triangle displayed in Figure 1.2.

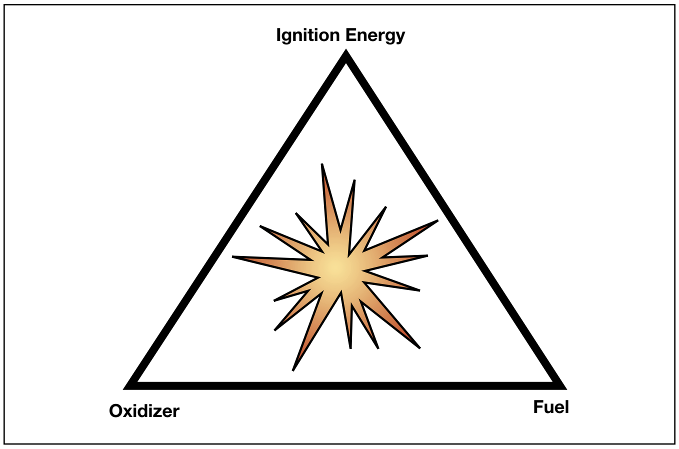

Figure 1.2

Ignition triangle

Once the reaction is ignited, 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. In a properly designed safety system, it is generally acceptable that two or more independent faults must occur, each one of low probability, before a potential explosion can occur.

There are also materials that can explode spontaneously without supplied energy; however, this subject will not be addressed here. This publication deals with the prevention of explosions that can be ignited

Explosive Mixture Characteristics

The risk of an ignition of an air/gas mixture depends on the probability of the simultaneous presence of the following two conditions:

1. Formation of flammable or explosive vapors, liquids or gases, or combustible dusts or fibers with atmosphere or accumulation of explosive or flammable material;
2. Presence of an energy source—electrical spark, arc or surface temperature—that is capable of igniting the dangerous mixture present.

It is possible to draw an ignition characteristic for each type of fuel. The characteristic curves of hydrogen and propane are illustrated in Figure 1.3. A minimum ignition energy (MIE) exists for every fuel that represents the ideal ratio of fuel to air. At this ratio, the mixture is most easily ignited. Below the MIE, ignition is impossible for any concentration.

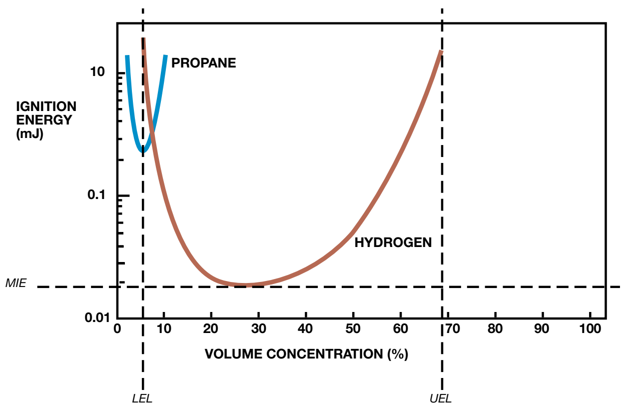

Figure 1.3

Ignition energy in relation to hydrogen and propane air/gas concentration

For a concentration lower than the one corresponding to the MIE, the quantity of energy required to ignite the mixture increases until a concentration value is reached below which the mixture cannot be ignited due to the low quantity of fuel. This value is called the lower explosive limit (LEL). In the same way, when increasing the concentration the energy requirement increases, and a concentration value is identified above which ignition cannot occur due to the low quantity of an oxidizer. This value is called the upper explosive limit (UEL).

For example, the following table lists the explosive characteristics of hydrogen and propane.

	MIE	LEL	UEL
Hydrogen	20 micro-Joules	4%	75%
Propane	180 micro-Joules	2%	9.5%

From a practical point of view, LEL is more important and significant than UEL because it establishes, percentage-wise, the minimum quantity of gas needed to create an explosive mixture. This data is important when classifying hazardous locations.

The MIE (minimum energy required to ignite an air/gas mixture in the most favorable concentration) is the factor upon which the intrinsic safety technique is based. With this technique, the energy released by an electrical circuit, even under fault conditions, is limited to a value lower than the MIE.

Ignition Temperature

The minimum ignition temperature of an air/gas mixture is the temperature at which the dangerous mixture ignites without electrical energy being supplied.

This parameter is important because it establishes the maximum surface temperature allowed for devices located in a hazardous location, under both normal and fault conditions. This must always be lower than the ignition temperature of the gas present.

Flash-point Temperature

The flash-point temperature is a characteristic of a volatile liquid, and it is defined as the lowest temperature at which the liquid releases sufficient vapors that can be ignited by an energy source.

Since a liquid above its flash point constitutes a source of danger, this parameter must be considered when classifying locations.

Evaluation of the Risk of Explosion

In any situation involving an explosive material, the risk of ignition must be taken into account. Generally, this evaluation will involve industry specialists, safety and mechanical engineers as well as chemists and other critical facility personnel.

In addition to the nominal rating of materials under consideration, parameters related to the process involved are especially important in the evaluation. As an example, the risk of explosion may be caused by the evaporation of a liquid or by the presence of liquid sprayed under high pressure.

It is also important to know what atmospheric conditions are present normally and abnormally. The range of concentration between the explosion limits generally increases as the pressure and temperature of the mixture increases. The relationship between explosion limits and flash point for ethyl alcohol is illustrated in Figure 1.4.

USA Headquarters web: www.am.pepperl-fuchs.com
phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com
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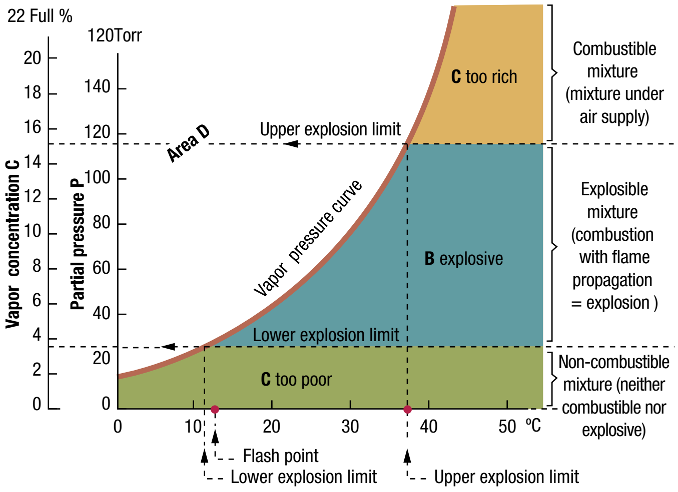

Figure 1.4

Graph representing the vapor pressure of ethyl alcohol

The atmosphere is capable of exploding within the explosion limits and is shown as Area B of the image. Area A is below the LEL; therefore, the mixture is no longer capable of ignition since it is too "lean". The mixture is also not capable of ignition in Area C since it is too "rich" (i.e. the oxygen content is too low for an explosion). If air is introduced, the mixture will again become flammable.

In the area surrounding the vapor pressure curve (Area D), mixtures are in equilibrium; therefore, a gas that is handled or stored within the critical temperature range of Area B is explosive.

The flash point is generally a few degrees above the lower explosive limit. A liquid is considered flammable if its flash point is below 38°C while it is considered combustible if its flash point is above 38°C.

Historical Growth of Electrical Safety Standards

Over the past several decades, the increased use of electrical instrumentation in chemical plants and refineries throughout North America and Europe has brought about an increase in the magnitude of safety problems and the need for safety standards relating to the requirements of equipment in hazardous locations.

In the 1930s, equipment was mostly mechanical in nature and posed few safety problems. In hazardous areas, explosion-proof enclosures were the norm. Even though the explosion-proof protection method was very costly to implement, there was no motivation at the time to look toward alternative measures of safety.

Equipment became more complex during the 1940s, but it was still largely pneumatic and mechanical by nature. Electrical potentiometers were, however, used in control rooms. When safety was a concern, explosion-proof enclosures were still generally used.

Along with the advancements in technology, the demand for faster, more versatile control systems during the 1950s brought about a change in the way systems were designed. The use of systems with hundreds of electrical components became commonplace. It was no longer possible to ignore the high installation costs of using the explosion-proof protection method to ensure a high degree of safety. Also, explosion-proof enclosures are not easily accessible when performing routine maintenance. Other protection methods had to be considered. The method that best solves the economic and accessibility problems is that of intrinsic safety, which gained wide acceptance in Europe first and is continuing to experience phenomenal growth in North America.

During the 1950s, there were no industry-accepted safety standards. Up until that time, rules and regulations were created by individuals (designers, engineers, government agencies, etc.) trying to be safe. However, with the increase in demand for more and more complex electronic equipment for use in hazardous locations, a movement began toward the standardization of safety requirements.

Many organizations, including NFPA, NEC, ISA, UL, FM, CSA, NEMA, IEC, BASEEFA, PTB, and CENELEC, perform different functions in ensuring the safety of industrial plants and refineries (refer to Appendix C, Glossary, for definitions of acronyms). When reference books about standards and safety requirements become too confusing, just remember that the operative word here is safety.

United States Practice

Electrical installation practices in the United States are based on the National Electrical Code (NEC). Even if government agencies and insurance companies have their own set of safety requirements, these requirements are based, directly or indirectly, on the NEC. The National Electrical Code is an ever-changing document—open to its members for proposals and recommendations. The National Fire Protection Association (NFPA) has acted as a sponsor of the National Electrical Code since 1911. The original Code document was developed in 1897 as a result of the united efforts of various insurance, electrical and architectural interests. The NFPA has given the authority for maintaining and revising the NEC to the National Electrical Code Committee. The code-making panels and the chairmen of correlating committees present their recommendations to meetings of the Electrical Section at the NFPA annual meeting. If adopted, these recommendations become part of the Code.

According to the National Electrical Code, "the conductors and equipment required or permitted by this Code shall be acceptable only if approved." Because of the passage of the 1971 Occupational Safety and Health Administration (OSHA) Act, "approved" equipment has come to mean equipment "listed or labeled" by Underwriters Laboratories (UL), Factory Mutual Research Corporation (FM) or any Nationally Recognized Testing Laboratory (NRTL), including the Canadian Standards Association (CSA).

Many of the testing laboratories have developed their own set of standards relating to intrinsic safety and the installation of electrical equipment in hazardous locations, such as ANSI/UL 913, FM 3610 and CSA 22.2, No. 157. The user can specify that a manufacturer use any approved NRTL.

The 1993 edition of the NEC recognized the importance of the use of intrinsic safety as a protection method by the significant expansion of Article 504, Intrinsically Safe Systems. A further expansion of the NEC occurred in 1999 when Article 505 was added. The importance of this section is based on the fact that it included the so-called zone method for classifying hazardous locations. With the addition of this Article, a user could now use protection methods previously available to users outside the United States.

The Instrumentation, Systems and Automation Society (ISA) has been very active in the development of hazardous location standards including intrinsic safety. ISA has continued to update the standards for intrinsic safety equipment, as in ANSI/ISA RP12.06.01 Recommended Practice for Wiring Methods for Hazardous (Classified) Locations Instrumentation Part 1: Intrinsic Safety. Historically, ISA has concentrated on education and making recommendations for changes to the National Electrical Code. However, when ISA cannot influence another organization to undertake a project, it will still write the standards, as is the case with RP12.06.01 and other important safety standards.

ISA Committee SP12 was established in 1949, and its members have been influential in the standards activities of the NFPA, the American Petroleum Institute (API) and many other organizations. ISA influence has not only been widespread in the United States, but also internationally, as shown by ISA involvement in the activities of the International Electrotechnical Commission (IEC).

The IEC prepares international recommendations for construction and use of electrical apparatus. The current trend is toward harmonization of standards, and most nations find it advantageous to promote their own national interests at an international forum. Costly mistakes can be avoided by adhering, where possible, to IEC standards when designing and installing equipment in another country.

Canadian Practice

In Canada, the Canadian Electrical Code (CEC) is similar to the National Electrical Code and is the standard for electrical equipment installations. The Canadian Standards Association (CSA) publishes standards for specific equipment requirements and is a certification authority for equipment marketed in Canada. CSA is also recognized by OSHA as a Nationally Recognized Testing Laboratory.

European Practice

The European Electrotechnical Standards Committee (CENELEC) was originally composed of members of the European Economic Community (EEC). Today, CENELEC has expanded to include nearly 30 countries plus many affiliate members. CENELEC standards that are adopted become law in the member nations. Because of the current trend toward harmonization, CENELEC attempts to use IEC standards when possible. If CENELEC standards do not exist for a specific requirement, national standards prevail.

Two EEC regulations that fundamentally changed the hazardous location landscape in Europe are Directive 94/9/EC (ATEX 95) and Directive 1999/92/EC (ATEX 137). ATEX 95 is focused mainly at manufacturers of electrical equipment for hazardous areas while ATEX 137 is centered primarily on operators of systems within hazardous locations. These two Directives have created a standardized method of how products are distributed within member countries. For the purposed of this document, we will discuss a few portions of Directive 94/9/EC relating to product certification and marking since it relates most directly with the topic of this publication. Pepperl+Fuchs has developed a comprehensive document that provides an exhaustive review of these topics as well as other important subjects relating to the European explosion protection market.

Focusing on the differences between safety standards can cause one to lose sight of the purpose of the standards—safety. When designing and installing industrial equipment, safety should always be the main goal, no matter which standards are used.

Section 2
Hazardous (Classified) Locations and Apparatus

The identification of hazardous (classified) locations in a plant is normally carried out by experts or highly qualified personnel, such as process or chemical engineers. The presence of the possibility of a hazardous atmosphere, in what condition and for how long, must be established. The most common dangerous areas are located where the possibility of a leakage of flammable gas is present. The leakage can occur during a normal or fault condition, or due to the deterioration of the components operating in the process. Depending on the type of leakage - continuous or intermittent (if intermittent, with what frequency) - the classification of the hazardous location is determined.

The area surrounding the location identified as hazardous is extended to a distance where the flammable substance becomes so diluted with air that ignition is no longer possible. This distance is related to a number of factors, such as the nature and quantity of the gas, degree of ventilation, etc.

The Classification of Hazardous Locations for Divisions

In the United States, the classification of hazardous locations is based on the National Electrical Code, NFPA 70, Articles 500 through 504. Article 505 includes the the Zone Method and is discussed later.

In Canada, C22.1, Part I of the Canadian Electrical Code applies. Similar to the United States, Canada has adopted the zone method for identifying hazardous locations; however, Canada has been much more aggressive in its pursuit to harmonize to international requirements

In both countries, hazardous locations are categorized into the following three classes, depending on the type of flammable substances present:

Class I	Hazardous due to the presence of flammable substances such as *gases or vapors.*
Class II	Hazardous due to the presence of flammable substances such as *dusts or powders.*
Class III	Hazardous due to the presence of flammable substances in a *fiber or flying state*.

Each classification is further divided according to the level of risk present. In general, the divisions are as follows:

Division 1	Danger can be present during normal functioning, during repair or maintenance, or where a fault may cause the simultaneous failure of electrical equipment.
Division 2	Combustible material is present but confined to a closed container or system, is normmally vented or is in an area adjacent to a Division 1 location.

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Class I (Gases or Vapors)

Class I hazardous locations are subdivided into the following four groups, depending on the type of flammable gases or vapors present:

Group A	Atmospheres containing acetylene.
Group B	Atmospheres containing hydrogen, fuel and combustible process gases containing more than 30 percent hydrogen by volume, or gases or vapors of equivalent hazard such as butadiene, ethylene oxide, propylene oxide and acrolein.
Group C	Atmospheres such as ethyl ether, ethylene, or gases or vapors of equivalent hazard.
Group D	Atmospheres such as acetone, ammonia, benzene, butane, cyclopropane, ethanol, gasoline, hexane, methanol, methane, natural gas, naphtha, propane, or gases or vapors of equivalent hazard.

The following illustrates a fuel tank with fixed lid and breather, which is typical of a North American Class I hazardous location.

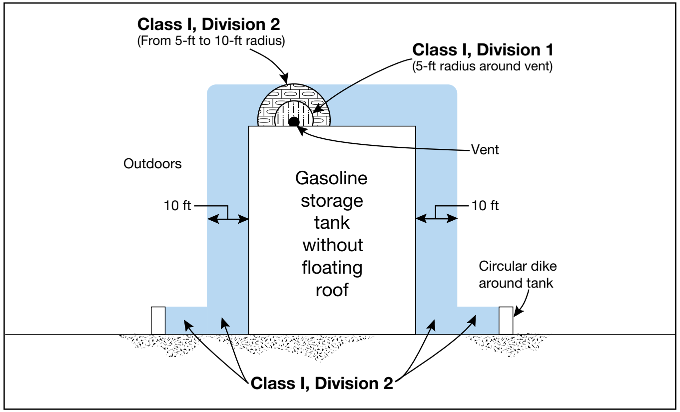

Figure 2.1

Schematic of the classification of a Class I hazardous location fuel tank with fixed lid and breather

Class II (Combustible Dusts or Powders)

Class II hazardous locations are subdivided into the following three groups, depending on the type of combustible dusts or powders present:

Group E	Atmospheres 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 electrical 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 Group E or Group F, including flour, grain, wood, plastic and chemicals

Class III (Easily Ignitable Fibers or Flyings)

Class III hazardous locations are those that are hazardous because of the presence of easily ignitible 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 ignitible mixtures.

Class III, Division 1 locations are those in which easily ignitible fibers or materials producing combustible flyings are handled, manufactured or used.

Class III, Division 2 locations are those in which easily ignitible fibers are stored or handled.

Locations belonging in this class usually include parts of textile mills, cotton gins, flax-processing plants, clothing manufacturing plants, woodworking plants, etc.

Easily ignitible fibers and flyings include rayon, cotton, sisal, hemp, cocoa fiber, kapok, Spanish moss, excelsior, etc.

Class III locations are not further subdivided.

The Classification of Apparatus for Divisions

Intrinsically Safe Apparatus

According to Article 504 of the United States' National Electrical Code, apparatus can be classified as intrinsically safe when all the circuits are intrinsically safe; i.e., containing circuits in which any spark or thermal effect is incapable of causing ignition of a mixture of flammable or combustible material in air under prescribed test conditions.

Pressure, temperature and flow transmitters, solenoid valves, I/P converters and other instrumentation are typical of intrinsically safe apparatus.

Associated Apparatus

Associated apparatus can be defined as apparatus in which the "circuits are not necessarily intrinsically safe themselves, but that affect the energy in the intrinsically safe circuits and are relied on to maintain intrinsic safety." Associated apparatus is classified as either:

1. Electrical apparatus having an alternative type protection for use in the appropriate hazardous location; or
2. Electrical apparatus not protected and therefore must not be used within a hazardous location.

Intrinsic safety barriers are typical of associated apparatus. These barriers must be placed in non hazardous locations (unless protected by other suitable methods, ie. nonincendive techniques for Div. 2) and must be certified as intrinsically safe.

Simple Apparatus

Simple apparatus is defined as "a device that will neither generate nor store more than 1.5 V, 0.1 A or 25 mW."

Examples include switches, thermocouples, LEDs, connectors and RTDs. Simple apparatus themselves do not have to be approved, but must be used with an approved barrier and installed in accordance with the control drawing.

Installation Requirements for Intrinsically Safe and Associated Apparatus

Intrinsically safe and associated electrical equipment or apparatus must be installed subject to the following two conditions:

1. Control Drawing: The manufacturer must provide a control drawing of the intrinsically safe or associated apparatus that details the allowed interconnections between the intrinsically safe and associated apparatus. The control drawing identification must be marked on the apparatus.
2. Location: Intrinsically safe and associated apparatus can be installed in any hazardous location for which it has been approved. Equipment rated for use in Division 1 may also be used in Division 2 for the same gas group and temperature class.

Intrinsically Safe System

An intrinsically safe system is defined as "an assembly of interconnected intrinsically safe apparatus, associated apparatus and interconnecting cables in that those parts of the system that may be used in hazardous (classified) locations are intrinsically safe circuits."

Surface Temperature Classification for Divisions

An apparatus directly located in a *hazardous location* must also be classified for the maximum surface temperature that can be generated by the instrument, either during normal functioning or under a fault condition.

The maximum surface temperature must be lower than the minimum ignition temperature of the gas present.

In the United States and Canada, temperature classifications are divided into six classes—T1 through T6. Classes T2, T3 and T4 are further subdivided, as shown in the following table.

Maximum Temperature Degrees C	Maximum Temperature Degrees F	North American Temperature Classification
450	842	T1
300	572	T2
280	536	T2 A
260	500	T2 B
230	446	T2 C
215	419	T2 D
200	392	T3
180	356	T3 A
165	329	T3 B
160	320	T3 C
135	275	T4
120	248	T4 A
100	212	T5
85	185	T6

Table 2.1

Surface temperature classifications in North America

Each gas is associated with a temperature class based on its ignition temperature. It is important to note that there is no correlation, for any specific mixture, between ignition energy and ignition temperature.

For example, hydrogen has a minimum ignition energy of 20 µJ and an ignition temperature of 1040°F (560°C), while acetaldehyde has an ignition energy greater than 180 µJ and an ignition temperature of 284°F (140°C).

Maximum surface temperature, calculated or measured under the worst conditions, is not to be confused with the maximum working temperature of the apparatus. For example, an electrical apparatus designed to work with a maximum ambient temperature of 158°F (70°C), even under the worst conditions of the expected temperature range, must not have a temperature rise greater than the safety margin specified by the applicable standards.

An apparatus classified for a specific temperature class can be used in the presence of all the gases with an ignition temperature higher than the temperature class of the specific instrument. For example, an apparatus classified as T5 can be used with all gases having an ignition temperature greater than 212°F (100°C).

According to FM 3610 and UL 913, all temperature data shall be referred to a base ambient temperature of 104°F (40°C). Tests to be based on an ambient temperature of 104°F (40°C) may be conducted at any ambient temperature within the range of 68-104°F (20-40°C). The difference between the ambient temperature at which the test was conducted and 104°F (40°C) shall then be added to the temperature measured.

EXCEPTION: Temperatures other than those for determining temperature marking on components of associated apparatus, such as protective transformers, shall be referred to a base ambient temperature of 77°F (25°C) or the maximum rated ambient temperature of the apparatus, whichever is higher.

All of the protection methods against explosion or the danger of fire require temperature classification in relation to any surface that can come in contact with a potentially explosive atmosphere.

The Classification of Hazardous Locations for Zones

In the United States and Canada, the zone classification method is recognized and applied; however, it is generally considered the secondary method used verses the division method. For simplification, we will identify the division method for North America and the zone method for Europe.

In Europe, the tendency is to follow the recommendations of EN 60079-10, based on which any place where the probability of the presence of a flammable gas exists must be classified according to the subdivision in one of the following zones:

Zone 0	An area in which an explosive air/gas mixture is continuously present or present for long periods
Zone 1	An area in which an explosive air/gas mixture is likely to occur in normal operation
Zone 2	An area in which an explosive air/gas mixture is unlikely to occur; but, if it does, only for short periods of time
Zone 20	An area in which a combustible dust cloud is part of the air permanently, over long periods of time or frequently
Zone 21	An area in which a combustible dust cloud in air is likely to occur in normal operation
Zone 22	An area in which a combustible dust cloud in air may occur briefly or during abnormal operation

Any other plant location that is not classified as a hazardous location is to be considered a non hazardous location.

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The Classification of Apparatus for Zones

European standard EN50014 requires that apparatus be subdivided into two groups:

Group I	Apparatus to be used in mines where the danger is represented by methane gas and coal dust
Group II	Apparatus to be used in surface industries where the danger is represented by gas and vapor that has been subdivided into three groups: A, B and C. These subdivisions are based on the maximum experimental safe gap (MESG) for an explosion-proof enclosure or the minimum ignition current (MIC) for intrinsically safe electrical apparatus.

The groups indicate the types of danger for which the apparatus has been designed. Since Group I is intended for mines, this subject will not be addressed in this publication.

The apparatus in Group II can be used in an area where gases or vapors are present (Class I hazardous location).

Surface Temperature Classification for Zones

European standard EN 50014 requires that the maximum surface temperature be subdivided into six classes from T1 to T6, assuming a reference ambient temperature of 40°C. Should the reference temperature be different, this temperature must be specified on the respective instrument.

Maximum Surface Temperature (°C)	European Temperature Classification
450	T1
300	T2
280	
260	
230	
215	
200	T3
180	
165	
160	
135	T4
120	
100	T5
85	T6

Table 2.2

Surface temperature classifications in Europe

ATEX Summary

With the introduction of the ATEX requirements, a new marking program took affect on all products for use within the EC. The intent of the marking requirements is based on uniformity. The CE conformity mark on the product is an indication that all relevant directives (i.e. ATEX, Low Voltage – 73/23/EEC, Electro-Magnetic Compatibility-EMC – 89/336/EEC, Machinery – 98/37/EEC) have been satisfied and that the product is suitable for use according to the manufactures instructions. For hazardous area products, the following chart applies:

Device Group	Device Category	Type of Atmosphere	Protection to be Ensured	Hazardous Area Characteristics	Zone Comparison
I (mining)	M1	–	Very High	Present continuously – equipment cannot be de-energized	–
	M2		High	Present continuously – equipment can be de-energized	–
II (all areas except mining)	1	G (gas, vapor, mist) D (dust)	Very High	Present continuously, for long periods or frequently	Zone 0 Zone 20
	2		High	Likely to occur in normal operation and for short periods of time	Zone 1 Zone 21
	3		Normal	Not likely to occur in normal operation or infrequently	Zone 2 Zone 22

The following example identifies the key elements of the equipment marking:

II (1) G D [EEx ia] IIC PTB 00 ATEX 2080

	Ex	Symbol identifies the product for hazardous locations
Ex ATEX Portion	II	Device Group – Non-mining application
	1	Device Category – Can be used in Zone 0 and/or 20 – (...) indicates only part of the device meets the requirements of the category.
	G	Atmosphere Type – Can be used in/for areas with flammable gas
	D	Atmosphere Type – Can be used in/for areas with flammable dust
CENELEC/IEC Portion	[...]	Associated apparatus that supplies safety into the hazardous area.
	E	Standard – European
	Ex	Product Type – Explosion protection
	ia	Protection Type – Intrinsic safety
	IIC	Equipment Group – IIC is most hazardous area
Certificate Details	PTB	Certifying Test Agency
	00	Test Year
	ATEX	Compliance with Directive 94/9/EX
	2080	Certificate Number

Differences Between Division and Zone Practices

The following table shows the differences between the North American and European practices, regarding the classification of hazardous locations.

Method	Continuous Hazard	Intermittent Hazard	Abnormal-condition Hazard
Division	Division 1		Division 2
Zone	Zone 0/20	Zone 1/21	Zone 2/22

Table 2.3

Classification of hazardous locations

It is evident from the above table that Zone 2/22 (IEC/Europe) and Division 2 (North America) are almost equivalent, while Division 1 includes the corresponding Zones 0/20 and 1/21. An instrument designed for Zone 1/21 cannot necessarily be directly used in Division 1. In the stated definition from the cited standard, no quantification of 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, is given.

In common practice, for Zone 0/20 a level of probability of a dangerous mixture present more than 1% of the time is accepted.

The locations classified as Zone 1/21 have a level of probability of a dangerous mixture present between 0.01% and 1% (maximum 100 hr/yr), while Zone 2/22 locations can be considered dangerous when said mixture is present for no more than 1 hr/yr.

The main difference between the North American and the European classification of hazardous locations is that there is currently no direct equivalent to the European Zone 0 in the North American system.

Zone 0 is therefore the most dangerous. An instrument designed for Zone 0 must be incapable of generating or accumulating sufficient energy to ignite the fuel mixture.

In Europe, the apparatus are certified on the basis of design and construction characteristics. From a practical point of view, the two systems are equivalent even if there are minor differences, as shown in the following table.

Hazard Categories	Apparatus Classification		Ignition Energy
	Europe	North America	
Methane	Group I (mines)	Class I, Group D	
Acetylene Hydrogen Ethylene Propane	Group IIC Group IIC + H_2 Group IIB Group IIA (Zones 0, 1, 2)	Class I, Group A Class I, Group B Class I, Group C Class I, Group D	> 20 µJoules > 20 µJoules > 60 µJoules > 180 µJoules
Metal Dust Coal Dust Grain Dust	Group II (Zones 20, 21, 22)	Class II, Group E Class II, Group F Class II, Group G	↑ More easily ignited
Fibers		Class III	

Table 2.4

Apparatus classification in North America and Europe

Each subgroup of Group II and of Class I is associated with a certain number of gases having an ignition energy included in the value reported and is represented by the gas referenced in the above table that is used in certification tests.

Group IIC and Class I, Groups A and B are the most dangerous because they require the lowest level of ignition energy. An apparatus designed for these groups must be incapable of igniting, by electrical means, any potentially explosive air/gas mixture.

Section 3
Methods of Protection

In order to reduce the risk of explosion, elimination of one or more of the components of the ignition triangle is necessary (refer to Section 1 for a discussion of the ignition triangle). There are three basic methods of protection—explosion containment, segregation and prevention.

1. Explosion containment: The only method that allows the explosion to occur but confines it to a well-defined area, thus avoiding the propagation to the surrounding atmosphere. Explosion-proof enclosures are based on this method.
2. 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.
3. Prevention: A method that limits the energy, both electrical and thermal, to safe levels under both normal operation and fault conditions. Intrinsic safety is the most representative technique of this method.

For each method, one or more specific techniques are present that translate into practice the basic philosophy that at least two independent faults must occur in the same place and at the same time in order to ignite an explosion. A fault in a circuit or system that subsequently leads to a failure of another circuit or system is considered a single fault. Naturally, there are limits in considering faults or certain events. For example, the consequences of an earthquake or other catastrophic action may not be considered, because damage caused by the malfunctioning of the protection system during these particular events become insignificant when compared to the damage generated by the main cause.

What, then, are the conditions to be considered?

Conditions and faults to be considered when selecting a protection method

First of all, the normal functioning of the apparatus must be considered. Secondly, eventual malfunctioning of the apparatus due to faulty components must be a consideration. Lastly, all those conditions that can accidentally occur, such as a short circuit, open circuit, grounding and erroneous wiring of the connecting cables, must be evaluated.

The choice of a specific protection method depends on the degree of safety needed for the type of hazardous location considered in such a way as to have the lowest probable degree of an eventual simultaneous presence of an adequate energy source and a dangerous concentration level of an air/gas mixture.

None of the protection methods can provide absolute certainty of preventing an explosion. Statistically, the probabilities are so low that not even one incident of an explosion has been verified when a standardized protection method has been properly installed and maintained.

The first precaution to be used is to avoid placing electrical apparatus in hazardous locations. When designing a plant or factory, this factor needs to be considered. Only when there is no alternative should this application be allowed.

Other secondary, but important, factors for consideration are the size of the apparatus to be protected, the flexibility of the system, the possibility of performing maintenance, the installation cost, etc. Respective of these factors, intrinsic safety has many advantages; however, to better understand these advantages, it is necessary to know and understand the limitations of the other protection methods.

The purpose of this section is to briefly present the different methods of protection. In Europe, CENELEC and IEC standards refer to protection methods with symbols, such as Ex "d" for the explosion-proof method. These symbols are not used by the United States and Canada for Division rated products. The principle function of placing symbols on the label of each apparatus is to allow the immediate identification of the protection method in use.

Explosion-proof Enclosure

This protection method is the only one based on the explosion-containment concept. In this case, the energy source is permitted to come in contact with the dangerous air/gas mixture. Consequently, the explosion is allowed to take place, but it must remain confined in an enclosure built to resist the excess pressure created by an internal explosion, thus impeding the propagation to the surrounding atmosphere.

The theory supporting this method is that the resultant gas jet coming from the enclosure is cooled rapidly through the enclosure's heat conduction and the expansion and dilution of the hot gas in the colder external atmosphere. This is only possible if the enclosure openings or interstices have sufficiently small dimensions (refer to Figure 3.1).

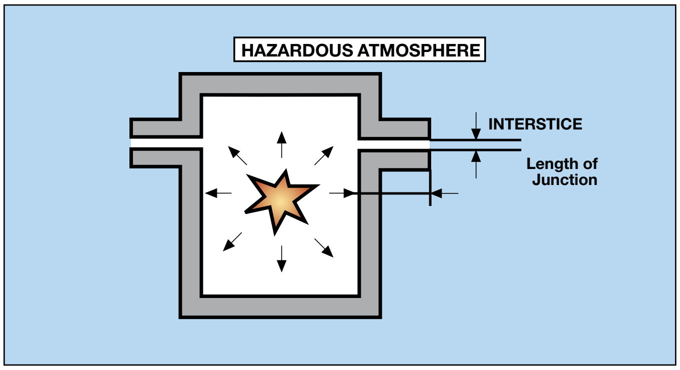

Figure 3.1

Schematic of an explosion-proof enclosure

Fundamentally, the required characteristics for an explosion-proof enclosure include a sturdy mechanical construction, contact surfaces between the lid and the main structure, and the dimension of any other opening in the enclosure.

Large openings are not permitted, but small ones are inevitable at the junction points. It is not necessary for the enclosure to be airtight. Sealing the junction is only to increase the degree of protection toward corrosive atmospheric conditions and not to eliminate the interstices.

The maximum opening allowed for a particular type of joint depends on the nature of the explosive mixture and width of the adjoining surfaces (joint length).

The enclosure classification is based on the gas grouping and the maximum surface temperature, which must be lower than the ignition temperature of the gas present in the location where they are installed (refer to ***Section 2***, *Surface Temperature Classification for Divitions* and *Surface Temperature Classification for Zones*).

The material used to build the explosion-proof enclosure is generally metallic (aluminum, cast iron, welded steel, etc.). Plastic or non-metallic materials can be used for enclosures with a small internal volume (<3 cu. dm.).

In designing an explosion-proof enclosure, the current standards of the country in which the enclosure is to be installed must be consulted.

In North America each testing laboratory (e.g., FM, UL, CSA) has its own standard, while in Europe the approval of the authorized laboratory is based on standard EN 60079-1.

North American practice

The North American practice is to test prototypes of the enclosure with a safety margin and not to require additional tests on production models if they conform to the prototype.

European practice

The European practice tests the prototype of the enclosure with a much lower safety margin; however, additional tests on the actual production model are required.

Installation and maintenance problems of explosion-proof enclosures

Often, explosion-proof enclosures have installation and maintenance problems that can be summarized as follows:

1. A medium-weight enclosure is very heavy, and its installation creates mechanical and structural complications.
2. Particularly corrosive atmospheric conditions (characteristic of chemical or petrochemical plants, or oil platforms), require the use of material such as stainless steel or bronze, resulting in dramatically higher costs.
3. Cable entries require a particular arrangement (reductions, cable clamps, conduits, metal-clad cable, sealing) and, in some cases, such items may represent a cost higher than the enclosures themselves.
4. In a particularly humid atmosphere, condensation may cause problems inside the enclosure or conduit pipe.
5. The safety of an explosion-proof enclosure is based entirely on its mechanical integrity; therefore, periodic inspections are needed.
6. Opening of the enclosure is not permitted while the apparatus is functioning; this may complicate maintenance and inspection operations. Usually, the process must shut down and the area inspected in order to perform routine maintenance.
7. It is difficult to remove the lid (a special tool is needed or sometimes 30-40 bolts must be unscrewed). After removing the lid, it is important to ensure the integrity of the joint before restarting the system.
8. Changes to the system are difficult to implement.

The degree of safety of an explosion-proof enclosure, over time, depends on the correct use and maintenance by the plant personnel. Because of this vulnerability, the explosion-proof method is not always allowed, such as in the European Zone 0.

In the United States, not having a direct equivalent to Zone 0, there are particular restrictions in using explosion-proof enclosures in Division 1. Practically speaking, it is not allowed in any location that would be classified as Zone 0.

This protection method is one of the most widely used and is suitable for electrical apparatus located in hazardous locations where high levels of power are required, such as for motors, transformers, lamps, switches, solenoid valves, actuators, and for all parts that generate sparks. On the other hand, practical matters such as high maintenance and calibration costs make the use of this method less cost effective than that of intrinsic safety.

Purging or Pressurization Method

Purging 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 gas—air or inert gas—is contained inside the enclosure with a pressure slightly greater than the one of the external atmosphere (refer to Figure 3.2).

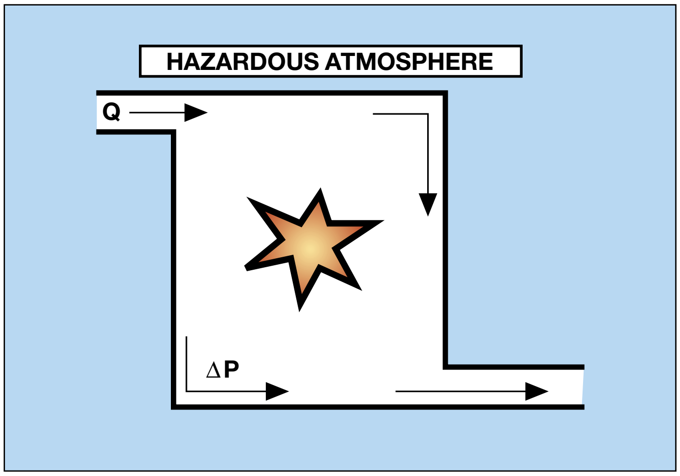

Figure 3.2

Schematic of a pressurized enclosure

The internal overpressure remains constant with or without a continuous flow of the protective gas. The enclosure must have a certain degree of tightness; however, there are no particular mechanical requirements because the pressure supported is not very high.

To avoid pressure loss, the protective gas supply must be able to compensate, during operation, for enclosure leakage and access by personnel where allowed (the use of two interlocked doors is the classical solution).

Because it is possible for the dangerous mixture to remain inside the enclosure after the pressurization system has been turned off, it is necessary to expel the remaining gas by circulating a certain quantity of protective gas before restarting the electrical equipment.

The classification of the electrical apparatus must be based on the maximum external surface temperature of the enclosure, or the maximum surface temperature of the internal circuits that are protected with another protection method and that remain powered even when the protective gas supply is interrupted.

The purging or pressurization technique is not dependent upon the classification of the gas. Rather, the enclosure is maintained at a pressure higher than the dangerous external atmosphere, preventing the flammable mixture from coming in contact with the electrical components and hot surfaces inside.

North American practice

In the United States, the term "pressurization" is limited to Class II applications. This is the technique of supplying an enclosure with clean air or an inert gas, with or without continuous flow, at sufficient pressure to prevent the entrance of combustible dusts. Internationally, the term "pressurization" refers to a purging technique for Zones 1 and 2.

The North American practice of the purging protection method is based on the reduction of the classification inside the enclosure to a lower level. The following three types of protection (X, Y and Z) are identified in relation to the hazardous-location classification and the nature of the apparatus.

Types of protection in relation to classification and nature of apparatus

1. Type X: reduces the inside of the enclosure from Division 1 to a non hazardous state that requires an automatic shutdown of the system in case of pressure loss.
2. Type Y: reduces the inside of the enclosure from Division 1 to Division 2.
3. Type Z: reduces the inside of the enclosure from Division 1 to a non hazardous state, requiring alarm signals only.

European practice

The European standard regarding this protection method, CENELEC EN 60079-2, requires that particular safety systems function regardless of internal protective gas loss due to leakages, shutdowns, compressor breakdowns or operator errors.

Pressurization is allowed as a method of protection in Zones 1 and 2. In the case of pressure loss, an automatic shutdown of the power supply can occur even with a slight delay for Zone 1, while a visual or audible signal is sufficient for Zone 2.

The European and the American practices are quite similar. In fact, The European standards have been revised to include three new protection methods of px, py and pz. These methods are similar to the North American counterparts and show the level of harmonization taking place in the world. The safety devices (pressure sensors, flowmeters, delay relays, etc.) needed to activate the alarm or the shutdown of the power supply must be either explosion-proof or intrinsically safe because, as a general rule, they are in contact with the dangerous mixture both on the outside of the enclosure and on the inside during the expulsion phase or during pressure loss.

Sometimes the internal overpressure protection method is the only possible solution, i.e., when no other method of protection is applicable. For example, in the case of large electrical apparatus or control panels where the dimensions and high-energy levels make it impractical to use an explosion-proof enclosure or the application of the energy limitation method, the internal overpressure protection method is often the only answer.

The use of pressurization is limited to the protection of apparatus that do not contain the source of an inflammable mixture. For

USA Headquarters web: www.am.pepperl-fuchs.com
phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com
Worldwide Headquarters web: www.pepperl-fuchs.com
phone: +49 621 776-0 • email: pa-info@de.pepperl-fuchs.com
Asia Pacific Headquarters web: www.pepperl-fuchs.com
phone: +65 67799091 • email: sales@sg.pepperl-fuchs.com

this type of apparatus, such as gas analyzers, the continuous-dilution technique must be used. This technique always keeps the protective gas—air or inert gas—in a quantity such that the flammable mixture concentration never exceeds 25% of the lower explosive limit of the gas present.

Encapsulation

The encapsulation protection method is based on the segregation of those electrical parts that can cause the ignition of a dangerous mixture in the presence of sparks or heating, by potting in resin that is resistant to the specific ambient conditions. (refer to Figure 3.3).

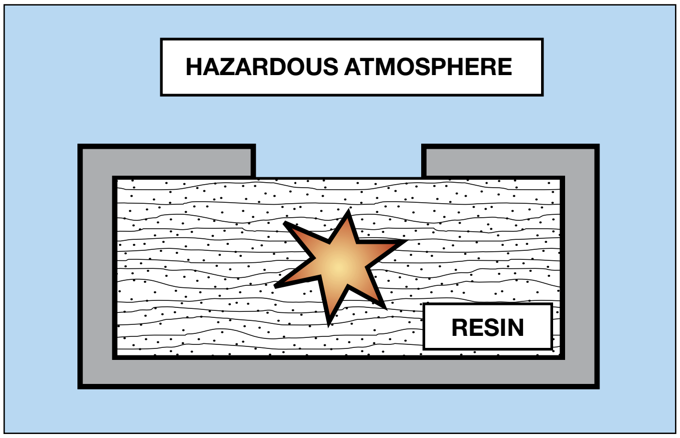

Figure 3.3

Schematic of encapsulation protection method

This protection method is not recognized by all the standards.

Encapsulation ensures a good mechanical protection and is very effective in preventing contact with an explosive mixture. Generally, it is used to protect electrical circuits that do not contain moving parts, unless these parts, (e.g. reed relays) are already inside an enclosure that prevents the resin from entering. This technique is often used as a complement to other protection methods.

Intrinsic safety requires that some electrical components must have adequate mechanical protection in order to prevent an accidental short circuit. In this situation, potting with resin is very efficient. Zener barriers, for example, are usually potted in resin as required by the standards.

Oil-immersion Protection Method

According to this protection method, all electrical parts are submersed in either nonflammable or low-flammability oil, which prevents the external atmosphere from contacting the electrical components. The oil often serves also as a coolant (refer to UL 698 or EN 50015).

The most common application is for static electrical equipment, such as transformers, or where there are moving parts, such as transmitters.

This method is not suitable for process instrumentation or for apparatus that require frequent maintenance or inspections.

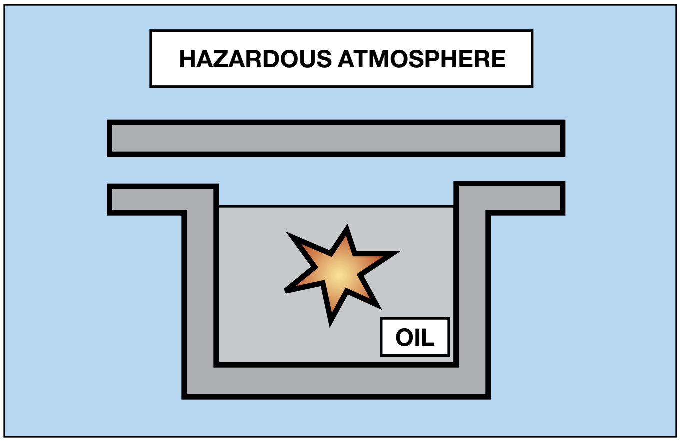

Figure 3.4

Schematic of oil-immersion protection method

Powder-filling Protection Method

This protection method is similar to the oil-immersion method of protection, except that the segregation is accomplished by filling the enclosure with powdered material so that an arc generated inside the enclosure will not result in the ignition of the dangerous atmosphere (refer to Figure 3.5).

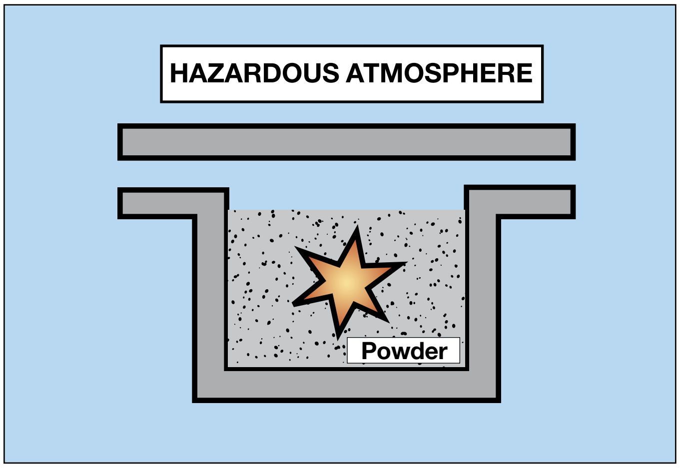

Figure 3.5

Schematic of powder-filling protection method

The filling must be made in such a way as to prevent empty spaces in the mass. The filling material that is generally used is quartz powder, and its granularity must comply with the standard.

Sealing, Limited-breathing and Dust-proofing Protection Methods

Based on the segregation concept, these techniques do not have a specific standard, but they are often used as a complement to other protection methods.

The principle purpose of these techniques is to ensure that an enclosure containing electrical parts or hot surfaces is sufficiently tight to limit the entry of gas or flammable vapors so that the accumulated gas or vapor is for a period longer than the one relative to the presumed presence of the dangerous mixture in the external atmosphere.

Therefore, the enclosure must have a certain degree of protection (protection index [IP] against the input of solid material and water) that is not inferior to the one required for the type of expected usage.

It is important not to confuse a tight enclosure with an explosion-proof one. Generally, an explosion-proof enclosure, due to its nature, is also tight, but the opposite is not true; a tight enclosure, even with a very high protection index, is not explosion-proof.

Increased Safety Protection Method

This protection method is based on the prevention concept. Measures must be applied to the electrical apparatus such as to prevent, with an elevated safety coefficient, the possibility of having excessive temperature or the generation of arcs or sparks inside and outside the apparatus during normal functioning (refer to Figure 3.6).

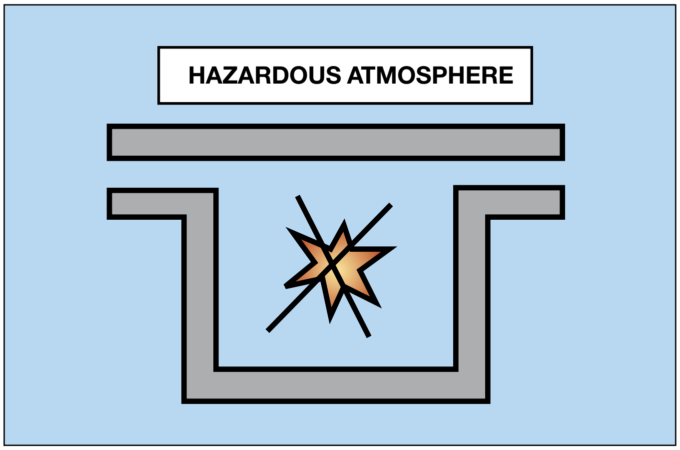

Figure 3.6

Schematic of increased safety protection method

The increased safety method of protection was developed in Germany and is recognized in Europe by the CENELEC EN 60079-7 standard.

The increased safety technique is suitable for Zones 1 and 2. This technique can be used for the protection of terminals, electrical connections, lamp sockets and squirrel gauge motors, and is often used in combination with other methods of protection.

According to the standard, the prescribed means of construction must be made in such a way as to obtain an elevated safety coefficient during normal functioning. In the case of eventual allowed overloading, construction must comply to very specific standards regarding connections, wiring, components, distances in air and on surfaces, isolators, mechanical impact and vibration resistance, degree of protection of the enclosure, etc. Particular attention must be given to those parts of the apparatus that could be sensitive to temperature changes, such as motor windings.

Intrinsic Safety Protection Method

Intrinsic safety will be discussed in detail later. At this time, only the essential characteristics will be discussed as a comparison to the other methods.

Intrinsic safety is the protection method most representative of the prevention concept and is based on the principle of the limitation of the energy stored in the electrical circuits.

An intrinsically safe circuit is virtually incapable of generating arcs, sparks or thermal effects that are able to ignite an explosion of a dangerous mixture, both during normal operation and during specific fault conditions (refer to Figure 3.7).

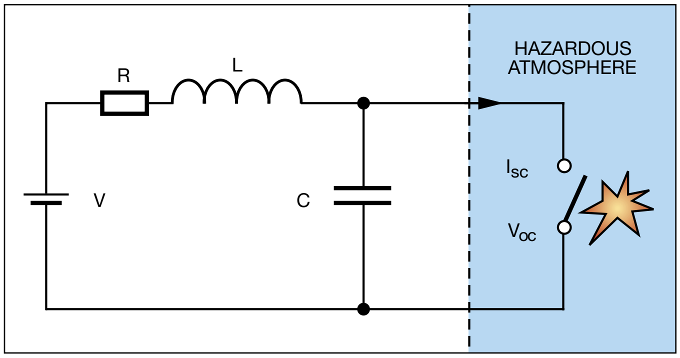

Figure 3.7

Schematic of an intrinsically safe circuit

North American practice

In the United States and Canada, intrinsically safe systems are allowed two independent faults. This means that two different and unrelated failures can occur, such as a short circuit of the field wiring and a component failure, and the system will still be safe.

European practice

According to the CENELEC EN 50020 standard, two categories of intrinsic safety—Ex "ia" and Ex "ib"—are specified, defining the number of faults allowed for specific classifications and the safety coefficients to be applied during the design phase.

Category "ia" allows up to two independent faults and can be used for a Zone 0 application, while category "ib" allows only one fault and can be used for a Zone 1 application.

The intrinsic safety method of protection is the only method that protects the apparatus and its relative wiring in hazardous locations, including the breaking, short-circuiting or accidental grounding of the connecting cable. Installation is greatly simplified because there are no requirements for metal-clad cables, conduits or special devices. Also, maintenance and check procedures can be carried out by competent personnel, even when the circuit is being powered and the plant is functioning.

The intrinsic safety method of protection is intended for process instrumentation applications where the low power required is compatible with the energy-limitation concept. In general, when the hazardous- location apparatus requires less than 30 V and 100 mA during fault conditions, intrinsic safety is the most effective, reliable and economical protection method. (For installation information, refer to ISA RP12.6 and NEC Article 504 and 505).

For those applications in the presence of gas or vapors belonging to Groups IIB, IIA, C and D, voltages and current values larger than the value indicated above can be used.

Non Incendive, or Simplified Protection Method

North American practice

The concept of non incendive circuitry is defined by the National Electrical Code, NFPA 70, as a circuit in which any arc or thermal effect produced, under intended operating conditions of the equipment, is not capable, under specified test conditions, of igniting the flammable gas, vapor or dust-air mixture. To better understand the entire non incendive energy concept, refer to ANSI/ISA S12.12.01 for further detail.

The non encendive technique, when applied to electrical apparatus, makes the apparatus incapable of igniting a surrounding dangerous mixture during normal functioning.

Non incendive and intrinsic safety protection methods are both based on the prevention concept. However, for the non incendive approach, the device or circuit is not evaluated for safety under fault conditions. As a result, energy surges, equipment faults and static electricity are not addressed. For this reason, non incendive devices are not approved for Division 1.

The determination of whether a circuit or system is non incendive is often left to the user. Many end-users are reluctant to install equipment classified as non incendive in Division 2 locations without further protection. As a result, the decision is often made to employ intrinsic safety as the protection method.

The prescribed methods of construction are similar to the ones required by the increased safety protection method—specifically, relating to components, enclosures, connection elements, surface temperatures, distances, etc.

This technique, due to its nature, is allowed only in Division 2 where the probability of danger is very low. This appears to be a limiting factor, but it is important to keep in mind that approximately 80% of the hazardous locations in a plant are classified as Division 2.

An excellent example in the use of the non incendive, or simplified protection method, is as follows:

> *A fieldbus distribution block is located in a Division 2 location and handles instruments also located in a Division 2 area as well as those in a Division 1 area. Due to the large number of instrument spurs intended to be connected/disconnected, the non-incendive method of protection represents the most rational, effective and economical solution for the Division 2 instruments while intrinsic safety provides the best alternative for the Division 1 field devices, thus a combination of protection methods best solved the entire application.*

Mixed Protection Methods

In the process instrumentation field, the use of several protection methods applied to the same apparatus is a common practice. For example, circuits with intrinsically safe inputs can be mounted in pressurized or explosion-proof enclosures.

Generally, this mixed system does not present installation difficulty if each of the protection methods is appropriately used and is in compliance with the respective standards.

Summary of Protection Methods

This section has briefly presented the protection methods against fire and explosion. The concepts upon which these methods are based were introduced, and the general methods of construction and application were discussed.

The purpose of this section is not to exhaust the subject, but rather to offer an overview of the applicable protection methods for the electrical instrumentation used in that part of the plant classified as hazardous.

Intrinsic safety will be discussed in detail in the next section. For all other techniques, refer to the respective standards.

The following table presents a summary of the protection methods against explosion, stating the functioning principles from both the North American and European practices.

SUMMARIZATION OF PROTECTION METHODS AGAINST EXPLOSION

General Priciples	European Practices	Zone	North American Practice	Division	Principle Characteristics	Relevant Standard
Explosion Containment	Explosion-Proof Ex "d"	1, 2	Explosion-Proof	1, 2	Relatively easy to be applied but with specific mechanical requirements. Difficulty in maintenance and checks.	EN 60079-1 (EN 50018)
	Enclosed Break Ex "nC"	2	Hermetic Seal	2	Similar to Ex "d" except suitable for Zone 2 only.	EN 60079-15 (EN 50021)
Segregation	Pressurization Ex "p" (px & py in future)	1, 2	Purging	1, 2	Suitable for large containers or for working area. Requires specific alarm systems.	EN 60079-2 (EN 50016)
	Simplified Pressurization Ex "nP" (pz in future)	2	Purging	2	Similar to Ex "p" except suitable for Zone 2 only.	EN 60079-2 (EN 50021)
	Encapsulation Ex "m"	1, 2	Not Recognized	2	Suitable for small circuits with good protection characteristics, both mechanical and electrical.	EN 60079-18 (EN 50028)
	Oil-Immersion Ex "o"	1, 2	Oil-Immersion	1, 2	Suitable for transformers and where there are moving parts. Generally not very widely used.	EN 50015 (IEC 60079-6)
	Restricted Breathing Ex "nR"	2	Not Recognized	–	Suitable for housings designed to restrict the ingress of gas.	EN 60079-15 (EN 50021)
	Powder-Filling Ex "q"	1, 2	Not Recognized	–	Suitable where there are non-moving parts. Present maintenance difficulty. Not very widely used.	EN 50017 (IEC 60079-5)
	Increased Safety Ex "e"	1, 2	Not Recognized	–	Suitable for non-sparking apparatus during normal functioning (terminals, connections, lamp sockets, motors). Particular construction requirements.	EN 60079-7 (EN 50019)
Prevention	Non-Sparking Ex "nA"	2	Non-Incendive Equipment	2	Suitable for non-sparking, low operational temperature devices.	EN 60079-2 (EN 50021)
	Intrinsic Safety Ex "ia"	0, 1, 2	Intrinsic Safety	1, 2	Suitable for process instrumentation. Does not require a particular enclosure. Economical and easy installation, maintenance and checks. Limited to low power circuits.	EN 50020 (IEC 60079-11)
	Intrinsic Safety Ex "ib"	1, 2	Not Recognized	–	Similar to Ex "ia" except for the number of faults to be considered. No North American equivalent.	EN 50020 (IEC 60079-11)
	Energy Limitation Ex "nL"	2	(Associated) Nonincendive Field Wiring Apparatus	2	Similar to Ex "ib" except no faults are applied.	EN 60079-2 (EN 50021)

Table 3.1

Comparisons Between the Most Widely Used Protection methods

In the process instrumentation field, the most widely used methods of protection to reduce fire and/or explosion dangers are intrinsic safety, the use of explosion-proof enclosures and purging, or pressurization. A summary comparison of these methods is shown in the following table in relation to the explosion-proof method of protection.

	Safety	Flexibility	Cost of Installation	Cost of Maintenance
Intrinsic Safety	Better	Better	Less	Less
Explosion-proof	=	=	=	=
Purging, or Pressurization	Better	Better	More or Less	Equal

Table 3.2

Comparison of the most widely used protection methods

The explosion-proof protection method is the most widely known and has been used in applications for the longest period of time. However, it is generally agreed that the intrinsic safety protection method is safer, more flexible and costs less to install and maintain.

Safety

The analysis of the probability of ignition of a dangerous mixture could make one believe that a particular protection method has a degree of protection greater or lower than the others.

The explosion-containment method, for example, has a much higher risk probability than does intrinsic safety (10^{-7} vs. 10^{-17}). However, from a statistical point of view after over 50 years of use, there has been no report of the occurrence of an accident due to the use of an explosion-proof enclosure. Therefore, the consideration of an increased safety factor of one protection method over another is incorrect. If a system is properly designed and installed, there is no practical difference where the safety factor is concerned.

The safety factor considers only the human factor as the principle cause of a dangerous event or fault. From this point of view, the argument for the use of intrinsic safety as a protection method above the other methods is that it presents a minor dependence on human error.

The use of pressurization and explosion-proof enclosures requires more maintenance; therefore, these methods are more subject to incorrect maintenance that could endanger the safety of the system.

Flexibility

Purging, or pressurization, is more flexible than the explosion-proof method because purging is not related to the type of dangerous atmosphere present and, despite its complexity, can be used where no other application is suitable.

Intrinsic safety, even if a relationship exists to the type of atmosphere present, is the only protection method that does not require specific wiring methods; therefore, the configuration and installation of the system is simplified, even for extremely dangerous hazardous locations classified as Division 1 or Zone 0.

Installation Costs

The standard relative to intrinsic safety allows the installation of apparatus in a similar way to the practice used for standard apparatus. This factor alone lowers the cost of installation.

Explosion-proof and pressurized enclosures require special devices, such as metal-clad cables, conduits, cable clamps, lead seals, etc. Purging, or pressurization also requires a pipeline for the protective gas. These are the principle reasons for the higher installation cost when these protection methods are used rather than intrinsic safety.

Maintenance Costs

Relative to maintenance costs, intrinsic safety is the most advantageous because this method allows live maintenance with no need for plant shutdown. Intrinsic safety is also more reliable due to the use of infallible and derated components as prescribed by the standards.

Explosion-proof enclosures require that particular attention be given to the integrity of the coupling joints and cable entrance, which adds to the cost of maintenance over a period of time.

For pressurized enclosures, there is an added cost for the maintenance of the protective gas supply system and its relative piping.

Conclusion

From the comparison of the three most widely used protection methods, it is evident that intrinsic safety, where applicable, is preferred for safety and reliability reasons. Intrinsic safety is also the most economical for installation and maintenance.

The use of intrinsic safety provides the best mix of an affordable system and safety requirements.

Section 4
The Philosophy of Intrinsic Safety

In the previous section, the different methods that are used to reduce the danger of explosion or fire were presented. The protection methods, based on the containment and segregation concepts, are methods that contain the explosion in order for the energy source—electrical or thermal—to avoid coming in contact with the potentially explosive mixture. In both cases, the use of appropriate enclosures and specific wiring and installation systems are required. This section will discuss how the intrinsic safety method prevents the ignition of the dangerous mixture, while simplifying the installation and use of the required apparatus that is connected to the electrical circuits directly located in a hazardous location.

The Intrinsically Safe Circuit

According to Article 504 of the National Electrical Code, NFPA 70, an intrinsically safe electrical circuit is defined as one in which no spark or thermal effect generated during normal functioning and/or during specific fault conditions is able to ignite a given explosive atmosphere (refer to Figure 4.1).

An electrical circuit typically consists of a voltage V, resistance R, inductance L, capacitance C and switch S, connected as shown below.

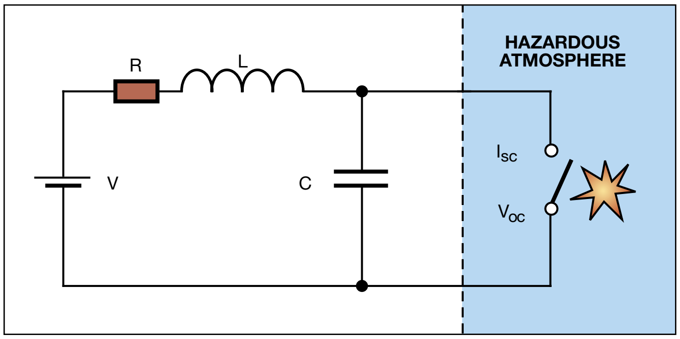

Figure 4.1

Schematic of an intrinsically safe circuit

In order to affirm than an electrical circuit is intrinsically safe, the parts of the circuit which are able to store energy, i.e., the inductor and the capacitor, must be considered. When the switch in the hazardous location is open, the capacitor accumulates energy that is discharged when the switch closes, thereby causing an electrical spark. In the same way, when the contact is closed, the inductor stores energy that is released in the form of an electrical arc when the switch opens. The energy that can be released by the circuit must be lower than the minimum ignition energy (MIE) of the air/gas mixture present in the hazardous location. Safety factors are then applied to ensure that the values allowed are well below that required for ignition.

A theoretical estimation of an energy inherent to an electrical circuit is not always possible, especially when the energy provided by the power source is higher, compared to the energy stored by the reactive components. For this reason, the data normally used in considering intrinsic safety is presented in the form of the correlation between electrical parameters of the circuit, voltage and current, and the minimum ignition energy level of the hazardous atmosphere.

An electrical circuit, no matter how complex, is sequentially examined as resistive, inductive and capacitive. If the safety criteria are satisfied by the different types of circuits, the circuit can be considered intrinsically safe.

Resistive Circuits

A circuit is considered as resistive when the reactive part, inductance and capacitance, is zero or negligible (refer to Figure 4.2)

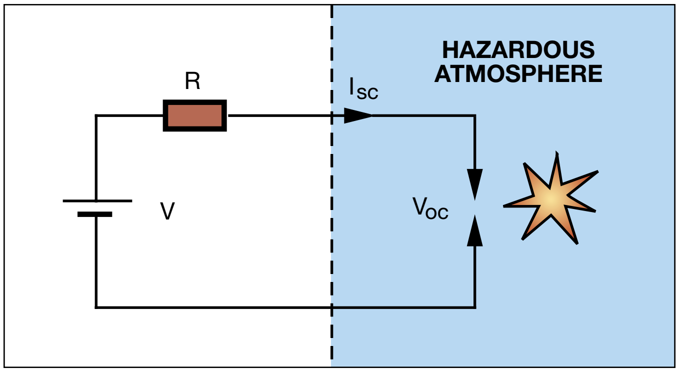

Figure 4.2

Schematic of a resistive circuit

The energy released by this type of circuit depends essentially on the power supply source V and the current limitation due to the presence of resistor R.

The experimental tests on this type of circuit have demonstrated that the capacity for igniting a dangerous mixture depends on the open-circuit voltage (V_{oc} = V) and the short-circuit current (I_{sc} = V/R).

The ignition curve for resistive circuits is shown in Figure 4.3.

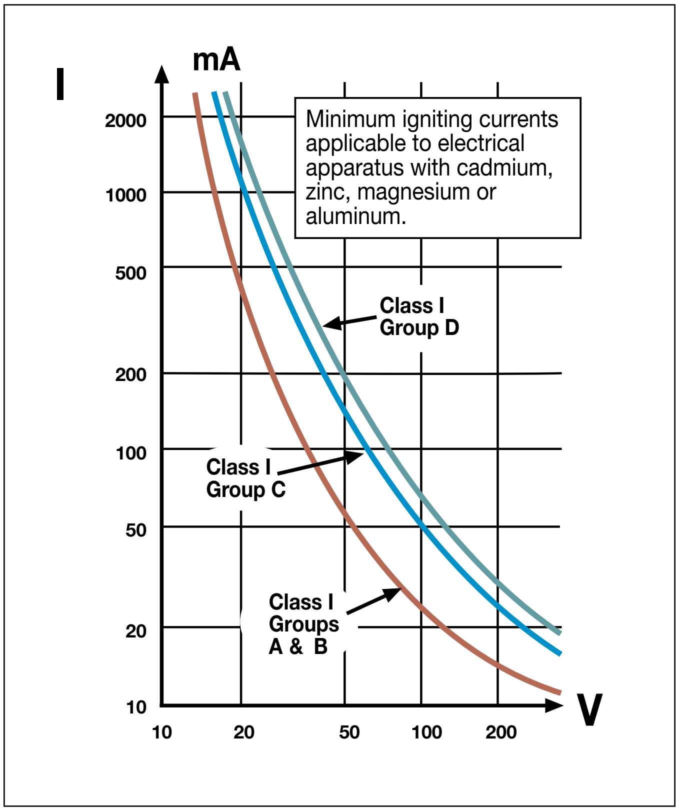

Figure 4.3

Ignition curve for a resistive circuit

The above graph shows the ignition curve relative to the group of gases that are considered by the standards.

By the trend of the curve, note that the lower the open-circuit voltage, the greater the amount of power that can be used safely. This characteristic allows process instrumentation that works with voltages on the order of 20-30 V to be used efficiently in intrinsic safety applications.

For a more detailed ignition curve, refer to the *Additional Information* section.

Inductive Circuits

An electrical circuit is inductive when the reactive part, due to its inductance, is high with respect to the resistive part (refer to Figure 4.4).

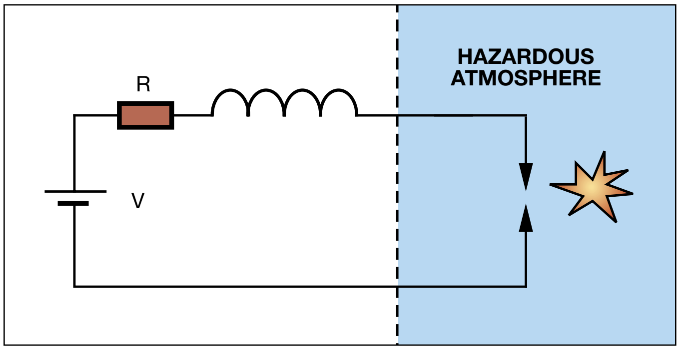

Figure 4.4

Schematic of an inductive circuit

Closed electrical circuits

The maximum current that circulates in a closed circuit is:

$$I_{sc} = V/R$$

The inductor L stores energy in the amount of:

$$E = 1/2\ L\ I_{sc}^2$$

Open electrical circuits

When the circuit is open, a voltage (V_l = L di/dt) is found at the ends of the inductor that is added to voltage V. Therefore, the energy stored in the inductive magnetic fields, plus the energy coming from the power source, is released in the form of an electric arc at the point of the circuit's opening.

If the inductor's stored energy is the only cause of the spark, the minimum ignition current for a certain hazardous atmosphere is bound to the L value according to the following relationship:

$$MIE = 1/2\ L\ I_{sc}^2 = Constant$$

Graphic representation on a logarithmic scale should present a rectilinear trend with an inclination of -2.

From the graph in Figure 4.5, you will note that the relationship can be verified except when the inductor value is lower than, or equal to, 1 mH.

This is due to the fact that, for high currents and low inductor values, the circuit becomes resistive. In this case, the power supply source becomes predominant as energy is released by the circuit.

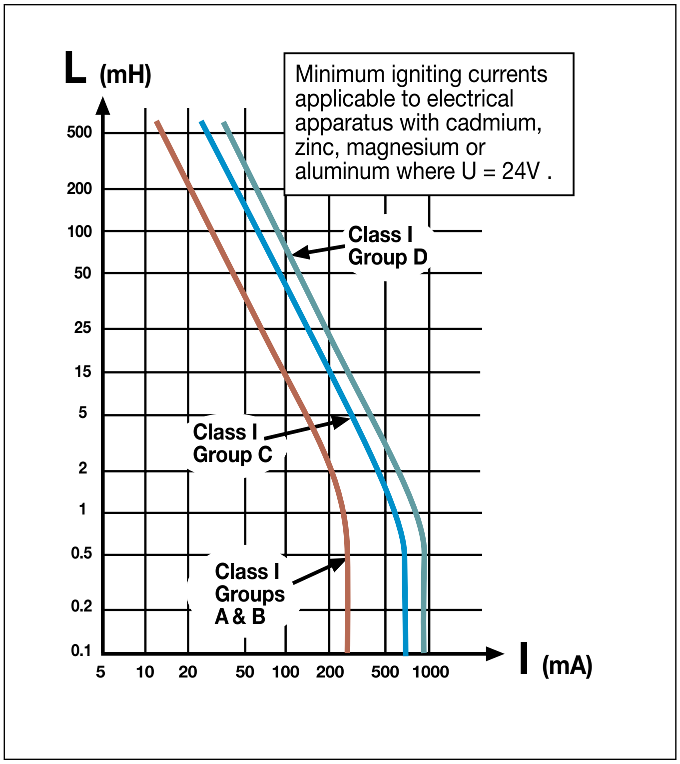

Figure 4.5

Minimum ignition current for inductive circuits

The curves in the above figure refer to a 24-volt power supply source. Experimental tests have shown that, for inductor values greater than 1 mH, the minimum ignition current is independent from the power source for values up to 24 volts, as illustrated in the graph in Figure 4.6.

For a more detailed ignition curve, refer to the *Additional Information* section.

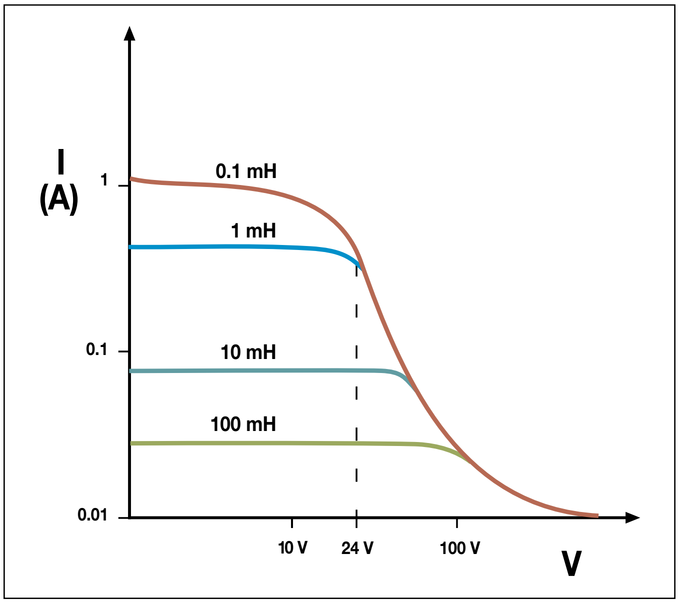

Figure 4.6

Minimum ignition current for inductive circuits in relation to voltage V

Capacitive Circuits

A capacitive circuit is illustrated in Figure 4.7.

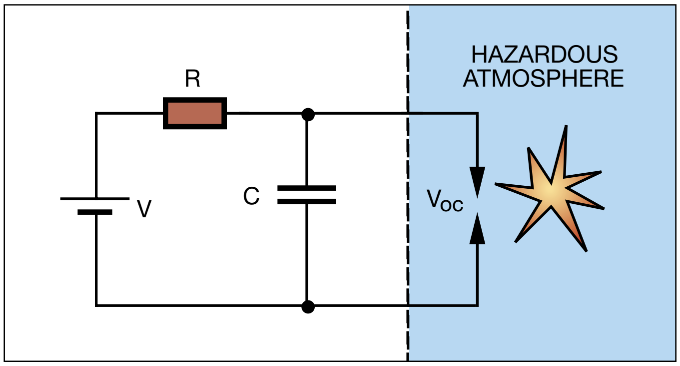

Figure 4.7

A capacitive circuit

When the circuit is open, the capacitor charges to a voltage V and accumulates an energy ($E = 1/2\ C\ V^2$) that is released in the form of a spark at the point where the circuit closes. For an analogy with the inductive circuit with an inclination of -2 on the logarithmic scale, a relationship appears to exist between the capacitance value and the voltage source. However, experimental tests have demonstrated that this theoretical relationship does not exist and the ignition curves are as shown in Figure 4.8.

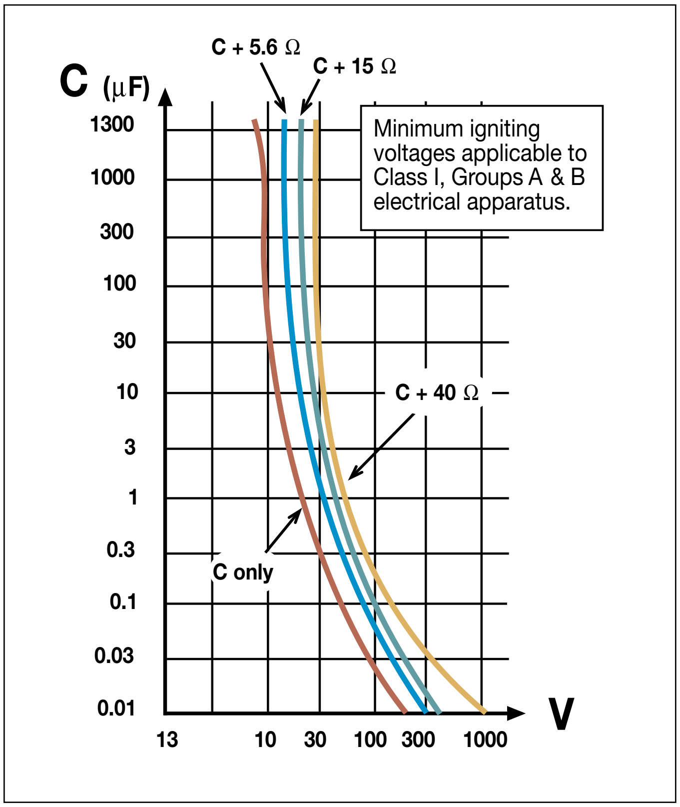

Figure 4.8

Minimum ignition voltages for capacitive circuits

This discrepancy between the theoretical values and experimental data is due to the fact that the capacitor's discharge is not complete and instantaneous. Each resistor inserted in the capacitor's discharge circuit, besides increasing the discharge time constant, dissipates part of the accumulated energy, thus reducing the energy released at the point of contact.

The curves in Figure 4.8 refer to the gases belonging to Class I, Groups A and B (hydrogen). For Class I, Group C (ethylene) and Class I, Group D (propane), the capacitance value is calculated by multiplying the value derived from Class I, Groups A and B by 3 and by 8, respectively.

Classification of Intrinsically Safe Electrical Apparatus

The standards relative to intrinsic safety include three types of apparatus:

- Simple apparatus
- Intrinsically safe electrical apparatus
- Associated electrical apparatus

Simple Apparatus

Simple apparatus include devices in which none of the following values are exceeded: 1.5 V; 0.1 A; 25 mW.

Passive sensors (thermocouples, resistance detectors, contacts, light emitting diodes [LEDs], etc.) are part of this category and can be directly placed in hazardous locations. There are no requirements for certification and labeling.

Intrinsically Safe Electrical Apparatus

Intrinsically safe electrical apparatus are electrical devices in which all of the circuits are intrinsically safe. Field instrumentation (transmitters, I/P, solenoid valves, etc.) used in hazardous locations must be certified as intrinsically safe. Certfication is based on the maximum energy level (group of gas) and the maximum surface temperature.

A label must be placed on the device that indicates the Approval Type, Class, Division and Group used, and references a specific Control Drawing.

An example of a European label is: Ex ia IIC T4

Associated Electrical Apparatus

Associated electrical apparatus are electrical devices in which not all of the circuits are intrinsically safe, and that contain parts of circuits that can interfere with the safety of the connected intrinsically safe circuits.

Passive barriers, DC isolated barriers and instrumentation in general, which are used to interface signals coming from hazardous locations, are part of the category and must be certified according to the maximum energy level (group of gas) that can be transferred to the hazardous location.

This apparatus must be placed in a safe area unless the apparatus are protected with another protection method that is appropriate for the given explosive atmosphere.

North American practice

A label is placed on the device that indicates the Approval Type, Class, Division and Group used, and references a specific Control Drawing.

Example 1:

> Associated apparatus for use in Class I, Division 2, Groups A,B,C,D hazardous locations provides intrinsically safe circuits for use in Class I, Division 1, Groups A,B,C,D hazardous locations when installed in accordance with Drawing No. ABC-1234.

European practice

Example 1: [Ex ia] IIC
(Associated Electrical Apparatus located in a non hazardous location)

Example 2: Exd [ia] IIC T4
(Associated Electrical Apparatus in an explosion-proof enclosure located in a hazardous location)

The marking between [ ] indicates that it is an associated electrical apparatus.

Intrinsically safe electrical apparatus and associated electrical apparatus are classified as Class I, II or III. Class I apparatus, subdivisions A,B, C and D can be associated, relative to the type of dangerous atmosphere in which the apparatus are to be used (refer to Section 2, Differences between European and North American Practices).

Intrinsically safe electrical apparatus located in hazardous locations must also be classified according to the maximum surface temperature (refer to Section 2, Surface Temperature Classification in North America and Surface Temperature Classification in Europe).

Electrical Apparatus Categories for Zone Classification

Intrinsically safe electrical apparatus and the intrinsically safe part of the associated electrical apparatus are divided into two categories—"ia" and "ib."

- Category "ia": An electrical apparatus belonging to category "ia" must not be able to ignite a dangerous mixture during normal functioning, during a single-fault condition or during a combination of a two-fault condition with the following safety coefficients:

  1.5 During normal functioning with one fault

  1 With two faults

- Category "ib": An electrical apparatus belonging to category "ib" must not be able to ignite a dangerous mixture during normal functioning or during a single-fault condition with the following safety coefficients:

  1.5 During normal functioning with one fault

  1 With one fault, but under the condition that the construction of the apparatus does not contain any unprotected part that can generate sparks. Also, the apparatus must not be exposed to a potentially dangerous atmosphere, and the fault must be automatically relieved

In conclusion, safety is guaranteed for the apparatus of category "ia" during a two-fault condition; safety is guaranteed for the apparatus of category "ib" during a single-fault condition. For both categories, the safety coefficient during normal functioning with one fault is 1.5.

Categories "ia" and "ib" can be used for any group of gas; however, category "ia" is the only category permitted for Zone 0. This is justified by the fact that, according to the safety concept expressed in Section 1, Ignition Triangle, there must be at least two independent events, each one of low probability, before the ignition can occur.

For Zone 0, where danger is ever present, category "ia" allows up to two nonsequential events. For Zone 1, where danger is intermittent, the two events are the simultaneous presence of the dangerous gas and a single-fault condition in intrinsically safe apparatus.

It is evident that apparatus designed for Zone 0, category "ia," can be used in Zones 1 and 2 with a greater margin of safety.

Intrinsic Safety in the North American System

In the United States, the competent authority for the classification of hazardous locations is the National Fire Protection Association (NFPA). The NFPA is responsible for the National Electrical Code, NFPA 70, and the American standard for intrinsic safety is ANSI/UL 913 Classification of Hazardous Locations.

Article 500 of the National Electrical Code stipulates the use of electrical apparatus in hazardous locations and defines the classification of the areas, the groups of potentially explosive material and surface temperatures.

UL 913 is specifically related to intrinsic safety and is the authority on which the standards used by the testing labs are based.

A hazardous location of Division 1 includes the corresponding Zone 0 and Zone 1. Therefore, only one intrinsic safety category is allowed with the following safety factors:

1.5	Considering the most unfavorable condition of a single fault
1	Considering the most unfavorable condition of two faults

The North American standard is equivalent to the European standard for category "ia."

The certification of apparatus, as it relates to the present danger—gas, dust, fiber—and surface temperature, follows the same concept as the European classification. The differences lie with the denomination of the groups and the subclasses of temperature.

The ignition curve for the resistive, inductive and capacitive circuits are identical to European standard EN 50020.

Design and Construction Aspects of Intrinsically Safe Apparatus

From an electrical point of view, the design of intrinsically safe apparatus must limit the maximum current and maximum voltage that can be present in hazardous locations, as a consequence of a fault or combination of faults, with values lower than the one derived by the ignition curves after applying the adequate safety factor.

From a construction point of view, devices must be used to guarantee the integrity of the components and the circuits on which intrinsic safety depends.

The standards relative to intrinsic safety mainly discuss the following aspects:

- Component-dimensioning
- Separation of conductors
- Isolation
- Human error

Component-dimensioning

An intrinsically safe system must remain intrinsically safe even during a single- or two-fault condition. Generally, an electrical fault can be caused by the deterioration of the components or by accidental short circuits.

The components, upon which intrinsic safety depends must have a fault mode so as not to decrease the safety degree and are considered "infallible" when in specific fault conditions. They are not subject to more than 2/3 of their nominal characteristics (power, current or voltage).

The components that do not satisfy these requirements must be considered as subject to fault during normal operation.

The following components are considered "infallible":

- Metal film resistors.
- Wire-wound resistors, if manufactured in such a way that the wire cannot unwind in case of an interruption
- Electro-mechanical relays and optical isolators, if approved as intrinsically safe components
- Transformers, both of power supply and signal, if manufactured and tested according to the standard. For these components, the functioning condition within 2/3 of their nominal power is not required.
- Capacitors that are highly reliable and contain at least two in a series. Tantalum and electrolytic capacitors are not allowed.
- Semiconductors, such as diodes and zeners, are used as voltage limiters and have a fault mode that is generally the short circuit, thus providing a short to safety ground. The eventuality of a fault for interruption is not to be excluded; therefore, one diode is not sufficient to guarantee an infallible state. The standard requires at least duplication and, in certain cases, triplication.

  Series-connected semiconductors that are used as current limiters must be at least duplicated and are restricted to certain applications.

  The series-connected diodes that are used to block current that otherwise would be circulating in the opposite direction from that of normal functioning can be used, but triplication is required by some standard.

The "infallible" components of an intrinsically safe circuit must be highlighted and mounted in such a way as to make it impossible to accidentally be excluded from the circuit. For this purpose, the distances in air and on the surface between the conductive parts must be in compliance with a Nationally Recognized Testing Laboratory (NRTL) standard, such as FM 3610, UL 913 or CSA C22.2, No 157.

Substitution of "infallible" components must be made by competent personnel (usually the manufacturer) using equivalent components.

Separation of Conductors

The separation of electrical conductors in intrinsically safe circuits is defined in terms of "through air distances" and "over surface distances" and is related to the maximum peak voltage existing between conductors, according to the following table from the EN 50020 standard.

Peak value of nominal voltage (V)	60	90	190	375	550	750	1000	1300	1550
Over surface distance (mm)	3	4	8	10	15	18	25	36	40
Over surface distance under coating (mm)	1	1.3	2.6	3.3	5	6	8.3	12	13.3
Minimum CTI[1]: "ia" "ib"	90 90	90 90	300 175	300 175	300 175	300 175	300 175	300 175	300 175
Through air distance (mm)	3	4	6	6	6	8	10	14	16
Distance through encapsulation (mm)	1	1.3	2	2	2	2.6	3.3	4.6	5.3

Table 4.1

Over surface distances, through air distances and distances through encapsulation

[1] Comparative Tracking Index

The "through air distance" is the shortest route in air between the conductive parts, while the "over surface distance" is the shortest route on solid surfaces.

Distances that are within 1/3 of the distance shown in the above table are considered as faults. Distances under this value cause the conductive parts to be classified as short-circuited.

In general, the surface distances are greater than the distances in air, except in cases where the separation is not sufficiently extended to be considered effective.

Figure 4.9 illustrates how to determine surface distances between conductive parts.

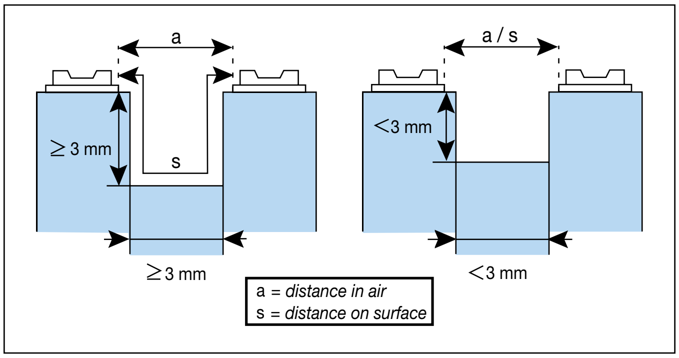

Figure 4.9

Determination of surface distances between conductive parts

Separation of less than 3 mm, but greater than 1 mm, must be considered as an eventual fault. If the separation is less than 1 mm, the surface and air distances coincide.

The characteristics of the isolating material are defined by its CTI (comparative tracking index), which represents the resistance index of the circulation of the surface current when the surface of the isolating support is contaminated in a certain way.

The separation of the connecting terminals of the external circuits must also take into account the danger represented by accidental errors or faults caused by the operator during the maintenance and inspection phases. For this reason, the required distances are greater than the distances necessary for the internal parts of the apparatus.

Intrinsically safe circuit terminals must be separated from the non-intrinsically safe terminals by a distance that is not less than 50 mm (2 inches). Alternatively, separation can be achieved with the use of isolating or metallic material (if grounded).

The adjacent intrinsically safe circuit terminals must be separated by a distance of at least 6 mm.

Isolation

According to FM 3610, UL 913 and CSA C22.2, No. 157, isolation between two different intrinsically safe circuits and between one circuit and the ground is 500 V_{rms}.

An intrinsically safe circuit can have only one grounded point; therefore, the isolation required toward ground has the function of minimizing the probability of an eventual second-ground connection of the circuit that can introduce a dangerous difference of potential between the two points, if there is no equipotential.

For functional reasons, in the application where the intrinsically safe circuit already has a grounded point, i.e., thermocouple with grounded hot junction, all the remainder of the circuit must be galvanically isolated from all other circuits.

When intrinsically safe and non-intrinsically safe circuits are contained in the same apparatus, the required isolation between the circuits must be at least 1500 volts.

Human Error

Apparatus containing circuits or parts of circuits that are intrinsically safe require an adequate protection to prevent possible interferences or errors by installation, maintenance and inspection personnel. The standard requires a protection against the input of solids larger than 12 mm for enclosures; connectors, cables and printed circuit boards cannot be exchanged with others that are similar inside the apparatus, if a dangerous situation would exist as a result.

It is obvious that absolute protection is impossible; therefore, it is necessary to have adequate documentation that includes the correct installation, maintenance and control procedures in order to minimize errors or interferences by authorized personnel.

Intrinsic Safety Barriers

Safety barriers are protection devices that function to limit the energy to the field within the minimum ignition level of the dangerous mixture.

In order to interface electrical apparatus located in a hazardous location with electrical apparatus located in a non hazardous location (associated apparatus), defined barriers must be used. Barriers can be of the following two types:

- Diode safety barriers, or "passive" barriers
- Galvanically isolated safety barriers, or "active" barriers

Passive Barriers

Intrinsic safety barriers of this type are uncomplicated from a circuital point of view (refer to Figure 4.10).

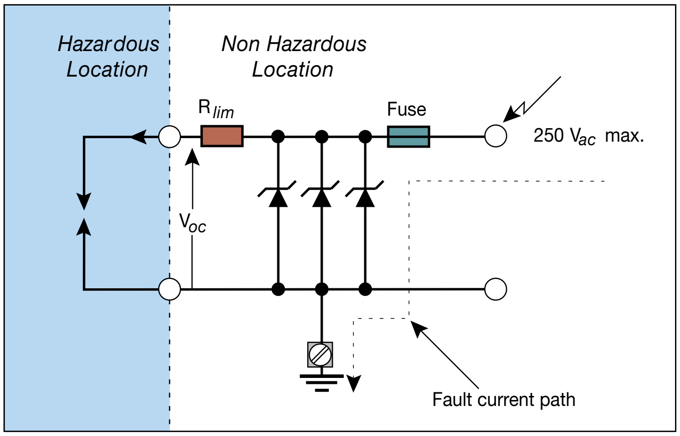

Figure 4.10

Schematic of a passive barrier

The functioning principle relating to passive barriers is based on the following: If a dangerous voltage that comes from the safe area (250 V_{ac} max.) is present, the zener barrier shunts the fault current toward ground until the fuse breaks, thereby maintaining an open-circuit "safe" voltage (V_{oc}) toward the hazardous location, while the maximum field short-circuit current is defined by $I_{sc} = V_{oc}/R_{lim}$.

The safety parameters of passive barriers are defined in the following table:

V_{oc}	Maximum open-circuit voltage
I_{sc}	Maximum short-circuit current
C_a	Maximum allowed external capacitance
L_a	Maximum allowed external inductance

The efficiency of passive barriers in limiting the maximum energy to the hazardous location substantially depends on the integrity of the barrier ground connection. U.S. installation rules require that the ground-connection resistance of the barrier must be lower than 1Ω.

The main advantages of passive barriers are:

- Lower component costs
- Uncomplicated and reliable functioning
- The possibility of transforming a standard apparatus into an intrinsically safe system
- More flexibility

The limitations of passive barriers are:

- The requirement of an equipotential ground system
- The existence of problems with current return caused by the absence of input/output isolation
- The reduction of the voltage available for the transmitter caused by the limiting resistor, and the introduction of errors when the limiting resistor is connected to resistance temperature detectors
- The introduction of errors by the limiting zener due to the leakage of current toward ground
- The requirement of active instrumentation for obtaining a signal, i.e., 4-20 mA, that is usable in non hazardous locations when used with passive sensors, such as TCs, RTDs, etc.
- The possibility of permanent damage to the barrier in the case of a fault situation or an incorrect connection

Active Barriers

Galvanically isolated active barriers are power supplies or signal conditioners that transmit or receive signals from hazardous locations in an isolated way (refer to Figure 4.11).

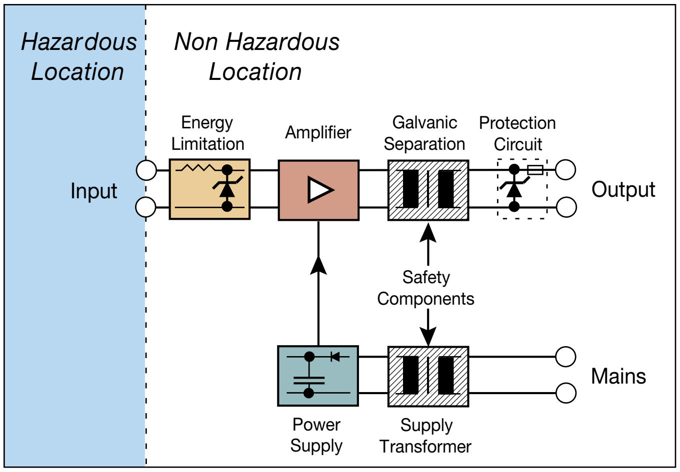

Figure 4.11

Schematic of a galvanically isolated barrier

The main difference between a passive barrier and a galvanically isolated one, or active barrier, lies in the safety components that are used to obtain the isolation between the non hazardous location and the circuit related to intrinsic safety.

This configuration does not allow the dangerous voltage (250 V_{ac} max) that is present on the terminal blocks, which are located in a non hazardous location, to be transferred to the energy-limiting circuit that must be able to tolerate, during a fault condition, the maximum voltage of the secondary side.

Since the entire circuit is floating in respect to ground, there is no possibility for the fault current, due to the 250 V_{ac}, to pass through the energy-limiting circuit; therefore, it is not necessary to ground the energy-limiting circuit.

The safety parameters for active barriers (V_{oc}, I_{sc}, C_a and L_a) are determined in a similar way to the safety parameters for passive barriers. This is due to the similarity of the intrinsically safe circuits toward the hazardous location.

The main advantages of galvanically isolated, or active, barriers are:

- A grounded system is not required
- Grounded sensors can be used
- Galvanic isolation avoids the problems of the return currents and allows a high common-mode rejection
- Better measurement accuracy is possible
- Output signals can be directly used

The limitations of galvanically isolated barriers are:

- Higher component costs, although installed costs are more comparable
- Designed for specific applications, so they are less flexible

Section 5
Intrinsically Safe Systems

Intrinsically safe apparatus never stand alone (unless they are battery operated). Generally, it is part of a system in which the certified components are used to guarantee the safety of the system.

The simplified schematic of an intrinsically safe system is shown in Figure 5.1.

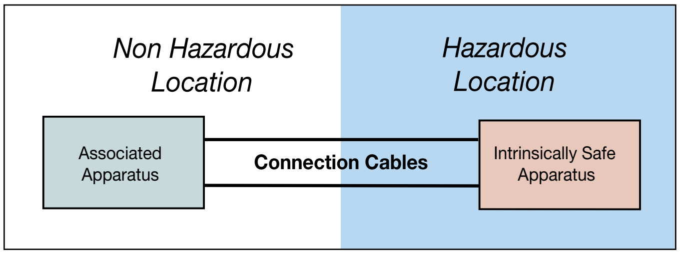

Figure 5.1

Simplified schematic of an intrinsically safe system

As can be seen, the system includes:

- Electrical apparatus located in a hazardous location
- Electrical apparatus located in a non hazardous location
- The wiring between the two apparatus

The analysis of an intrinsically safe system follows criteria that verify that the maximum energy, electrical and thermal, released in a hazardous location is lower than the ignition limit of the potentially explosive air/gas mixture, during normal or fault conditions.

Each intrinsically safe apparatus must have a control drawing that specifies parameters for the selection of the associated apparatus. V_{max} and I_{max} parameters are assigned to each input. The associated apparatus connected to each input must not have a maximum output voltage V_{oc} greater than V_{max}. Similarly, the associated apparatus must not have a maximum output current I_{sc} greater than I_{max}.

The procedure for analyzing the safety of a system is as follows:

1. Determine the maximum open-circuit voltage V_{max} and the corresponding short-circuit current I_{sc}. Using the resistive circuit ignition curve, verify that when:

   $$V = V_{max}, \text{ then } 2/3\ I \le I_{sc}$$

2. From the capacitive circuit curve, determine the maximum allowed capacitance value for:

   $$V = V_{max} \times 1.5$$

3. From the inductive circuit curve, determine the maximum allowed inductance value for:

   $$I = I_{sc} \times 1.5$$

4. Evaluate the temperature class based on the maximum energy that can be dissipated in a hazardous location

In practice, all the possible fault conditions (e.g., eventual short-circuiting, opening or grounding of the connecting cables) must be considered in order to determine which one is the most dangerous.

A simple system, as illustrated in Figure 5.1, is easy to evaluate because the fault combinations are few, and the knowledge of the apparatus' safety parameters and the cable characteristics are sufficient to verify the safety of the system.

A more complex system (e.g., combinations of barriers or the use of multiple cables) requires a more detailed analysis because the fault combinations are numerous and not always obvious.

Hazardous-Locations Apparatus

Apparatus that are certified for use in hazardous locations are of two types—simple apparatus and intrinsically safe apparatus.

Simple apparatus

Simple apparatus are those devices in which none of the following values are exceeded: 1.5 V, 0.1 A or 25 mW. Practically speaking, simple apparatus are not able to generate or store energy sufficient to ignite a dangerous mixture.

Thermocouples, resistance temperature detectors (RTDs), contacts, light-emitting diodes (LEDs) and photocells are part of this category and, due to their nature, do not require certification.

Intrinsically safe apparatus

The intrinsic safety of the apparatus must be guaranteed. This is accomplished by not permitting high energy levels, coming from connected apparatus or other circuits located in the same area, to be present in the hazardous location.

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Worldwide Headquarters web: www.pepperl-fuchs.com phone: +49 621 776-0 • email: pa-info@de.pepperl-fuchs.com
Asia Pacific Headquarters web: www.pepperl-fuchs.com phone: +65 67799091 • email: sales@sg.pepperl-fuchs.com

The certification exemption cannot be applied to reactive circuits due to their capability of storing energy. Inductive components, relay coils or solenoid valves often can operate with energy levels much lower than the limits for intrinsic safety, but the energy released when the circuit is open can cause the ignition of the dangerous mixture. In the same way, a capacitive circuit can cause ignition during discharge of the capacitor. Those types of apparatus must be equipped with devices to reduce the released energy to safe levels.

The solution for making an inductive component safe is to parallel-connect a semiconductor diode to the coil so that released energy can be absorbed. For capacitive components, a resistor must be series-connected to reduce the discharged current to a safe level.

The standards permit the use of components—diodes and resistors—that are considered "infallible," where working conditions are concerned. Diodes must be duplicated and mounted so that a possible fault will not disconnect them from the coil. The resistor must be of metal film or wire-wound and of the necessary power rating. It must also be wired so that it will not short circuit during fault status.

Parameters for intrinsically safe apparatus in hazardous locations

Electrical apparatus for hazardous locations must be approved as intrinsically safe and have the following parameters that are adequate for the type of hazardous atmosphere in which the intrinsically safe apparatus will be used:

V_{max}	Maximum voltage applied to apparatus
I_{max}	Maximum current applied to apparatus
C_i	Internal unprotected capacitance
L_i	Internal unprotected inductance

Non Hazardous Location Apparatus

Associated electrical apparatus, which are located in a non hazardous location, consists of electrical circuits related to intrinsic safety and can be designed to limit the energy toward the hazardous location to the required level.

Associated apparatus can be of the following three types:

1. Apparatus receiving signals from the field
2. Apparatus sending command signals to the field
3. Intrinsically safe interfaces

Instrumentation devices that receive signals from a hazardous location do not supply power to the field devices during normal functioning. Intrinsic safety is accomplished by limiting the energy in the case of a fault.

Instruments that send signals are designed so that the dangerous energy level is never exceeded during normal operation or under fault conditions.

Intrinsically safe interfaces (e.g., passive barriers) prevent the transfer of dangerous energy coming from the uncertified instrumentation in non hazardous locations.

North American parameters of associated apparatus

Associated electrical apparatus must be certified as intrinsically safe, based on the maximum energy that can be transferred to the hazardous location, and have the following parameters:

V_{oc}	Maximum open-circuit voltage
I_{sc}	Maximum short-circuit current
C_a	Maximum allowed capacitance
L_a	Maximum allowed inductance

These parameters are very important for the intrinsic safety of a system. If the parameters are respected, ignition of the dangerous mixture will be prevented, both during normal operation or under fault conditions (i.e., accidental short-circuiting, opening or grounding of the connecting cable).

For European applications, the parameter L/R (maximum inductance/resistance ratio) must also be considered.

Connecting Cables

The length of cable connecting intrinsically safe equipment with associated equipment may be limited because of the energy-storing characteristics of the cable. The control drawing provides guidance on determining the maximum allowed capacitance and inductance.

The electrical parameters of an associated apparatus determine the maximum allowed inductance and capacitance values of the connected circuit; therefore, not only must the reactive part of the field devices be considered, but also the part related to the interconnecting cables. It is possible to limit or suppress the stored energy for field and non hazardous location apparatus; however, because the total inductance and capacitance of the cable are distributed along its length, it is not possible to limit or suppress the stored energy for the connecting cable (refer to Figure 5.2).

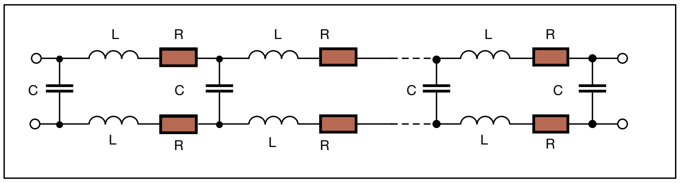


Figure 5.2

Equivalent schematic of a connecting cable

The capacitance, inductance and resistance to length ratio parameters are usually supplied by the cable manufacturer and rarely cause a problem for the user. Particular attention must be given to the cable parameters because the manufacturer's data is not related to the possible fault situations covered by intrinsic safety. The fault combination that deterrnines the worst condition must be verified.

For a 2-conductor cable, the manufacturer's data is sufficient. For shielded or multiconductor cables, the analysis is more complex. In these cases, it is advisable to: (1) measure the capacitance and inductance values on a sample cable, using an alternative current-measuring bridge and (2) consider the worst possible condition. Consequently, by determining the length of the sample cable, it is possible to determine C and L parameters for the required connecting distance.

For European applications, the most important cable characteristic is the ratio of inductance to resistance (L/R), taking into consideration the fact that the longer the cable, the greater the resistance. It can be demonstrated that the maximum energy that can be stored by the cable is related to ratio L/R and is independent from the cable's length. Since the energy stored by the cable's inductance is related to the circulation of the current ($1/2\ LI^2$), it follows that a cable of infinite length has infinite resistance, and because the current is zero, the stored energy will also be zero. The maximum energy exists at the point where the cable's resistance has the same value as the resistance from the supplied source (refer to Figure 5.3).

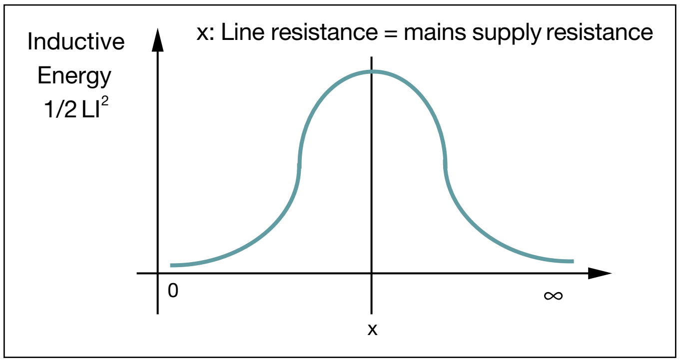


Figure 5.3

Relationship between cable length and stored inductive energy

Inductance/resistance (L/R) parameter for associated apparatus

The L/R parameter, specified by the associated apparatus, is calculated and/or tested in a maximum energy-transferring condition. This is represented by the following equation:

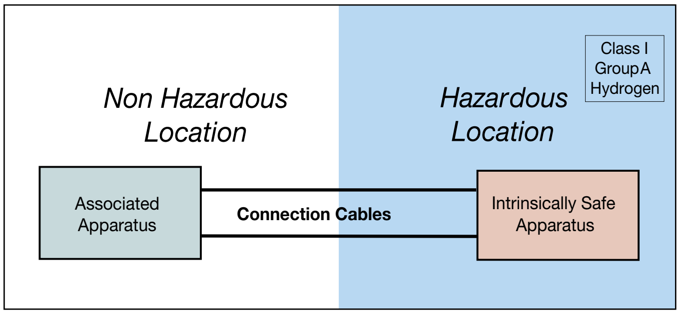
$$L/R = 4\ L_{a/r}$$

where L_a = (inductance recovered from the current I_{sc} ignition curve) multiplied by 1.5; and $r = V_{max} / I_{sc}$ (resistance of the equivalent source), which is determined by the open-circuit voltage divided by the short-circuit current.

Ratio L/R, normally specified in μH/Ω, can be an alternative to the cable inductance value. This value permits more flexibility in cable installation because it is not bound to the length limit.

Analysis of Intrinsically Safe Systems

An intrinsically safe system can be completely analyzed by referring to Figure 5.1 and by using the data shown in Figure 5.4.



Associated Apparatus	Cable Interconnections	Intrinsically Safe Apparatus
V_{oc} = 28 V I_{sc} = 93 mA C_a = 0.13 μF L_a = 4.2 mH L/R = 55 μH/Ω	C = 100 pF/m L = 1 μH/m R = 39 Ω/Km	V_{max} = 30 V I_{max} = 100 mA C_i = 0.01 μF L_i = 3.5 mH

Figure 5.4

Example of an intrinsically safe system and its parameters

The steps for analyzing an intrinsically safe system are:

1. Intrinsically safe apparatus must be adapted to the hazardous-location classification:
   - In North America, all intrinsically safe apparatus must be suitable for Division 1 and 2 installations (the "ib" category is not recognized).
   - In Europe, the "ia" safety category is required for Zone 0, and the "ib" safety category can only be used for Zones 1 and 2.
2. Intrinsically safe apparatus must be certified for the type of dangerous atmosphere present.
3. Associated apparatus (i.e., passive or active barriers) must be certified for the type of hazardous location in which they receive or send signals.
4. The electrical voltage and current parameters of the two apparatus must be matched, according to the following relationships:

   $$V_{oc} \leq V_{max}$$
   $$I_{sc} \leq I_{max}$$

   Both relationships must be in compliance for safety to be guaranteed.
5. Verify that the reactive parts of the system—capacitance and inductance—are within the safety limits, according to the following relationships:

   $$C_{cable} \leq C_a - C_i$$
   $$L_{cable} \leq L_a - L_i$$

Associated apparatus C_a and L_a parameters must not be exceeded by the connected circuit, taking into account not only the field device, but also the connecting cable. In this case:

$$C_{cable} = C_a - C_i = 0.13\ \mu F - 0.01 \mu F = 0.12\ \mu F \text{ max.}$$

$$L_{cable} = L_a - L_i = 4.2\ mH - 3.35\ mH = 0.7\ mH \text{ max.}$$

The maximum length of the connecting cable, specified by its capacitance and inductance, is the lesser of the following two relationships:

$$\text{Length} = (0.12\ \mu F/100\ pF/m) = 1200 \text{ meters}$$

$$\text{Length} = (0.7\ mH/1 \mu H/m) = 700 \text{ meters}$$

In Europe, the inductance/resistance ratio of the cable can be used as an alternative to the inductance value if it is lower than the maximum value of L/R permitted by the associated apparatus. In this case, the cable has an L/R ratio equal to:

$$L/R_{cable} = (1 \mu H/m\ /\ 39 \Omega/Km) = 25.6\ \mu H/\Omega$$

This value is lower than the L/R ratio permitted by the associated apparatus; therefore, the inductive effect of the cable can be ignored, and the cable distance can be up to 1200 meters.

The connecting cables rarely present a problem. The most limiting factor is the maximum permitted capacitance that can reduce the connecting distance in those cases where the open-circuit voltage is approximately 25-30 V, and the hazardous atmosphere is classified as Class I, Group A. With lower voltages, the capacitance value notably increases; for less dangerous gas groups such as Class I, Groups C and D, the capacitance value can be, respectively, 3 or 8 times the one specified.

The procedure shown in the above paragraph demonstrates how a simple system analysis can be performed by using the apparatus and cable parameters and not using the ignition curve.

Combination Barriers

The evaluation of a system containing more than one barrier is relatively complex because there can be many fault combinations. The barrier equivalent circuit illustrated in Figure 5.5 can be used for analysis.

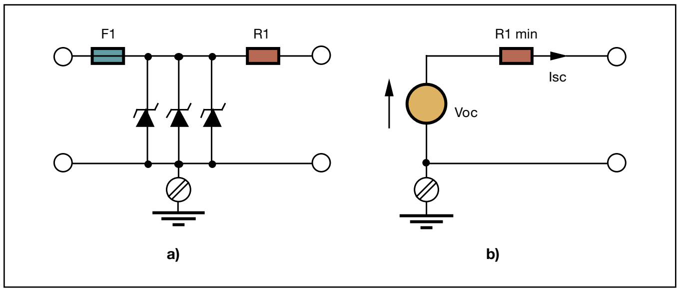


Figure 5.5

(a) Barrier electrical schematic
(b) Equivalent circuit

For the equivalent circuit, V_{oc} is the maximum voltage on the output of the barrier, while R1 is the minimum limiting resistor that determines the maximum short-circuit (I_{sc}) to the hazardous location.

There are three types of barriers, as follows:

Positive	Zener diodes are installed as shown in Figure 5.5 (a).
Negative	Zener diodes are installed with the polarity inverted.
Non-polarized	Zener diodes have the same characteristics, regardless of polarity. V_{max} can be either positive or negative.

One of the most widely used applications is the combination of two identical channels without ground return (refer to Figure 5.6, which was configured using the equivalent circuit).

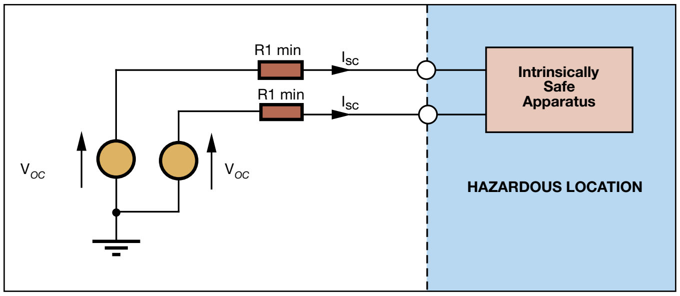


Figure 5.6

Equivalent circuit for two identical channels without ground return

The safety parameters toward the apparatus that is located in a hazardous location are dependent upon the type of barrier used. The following is an explanation of possible cases:

1. For two channels of the same polarity, the maximum open-circuit field voltage (V_{oc}) cannot be greater than V_{max}; and the corresponding short-circuit current is $I_{sc} = V_{oc} / R1_{min}$.
2. For two channels of opposite polarities, the maximum field voltage is 2 times V, while the short-circuit current remains I_{sc}.
3. For two non-polarized channels, the same parameters as in Figure 5.5 (b) are valid.

Note the changes to an equivalent circuit when the circuit has a ground return (refer to Figure 5.7).

Now, a current return by means of the grounded conductor is possible. The three cases previously examined for an equivalent circuit without ground return follow, but they have been revised to reflect the changes that occur when examining an equivalent circuit with ground return.

1. For two channels of the same polarity, the maximum open-circuit voltage remains V_{oc} ; while the current on the return conductor, in the case of a fault toward ground of the field conductors, is equal to the sum of the current of each channel (2 I_{sc}).
2. For two channels of opposite polarities, the maximum field

voltage is 2 times V_{oc}, and the current is I_{sc}, because a sum of the current never exists.

3. For two non-polarized channels, a combination of the two previous situations is present (2 times V_{oc} and 2 I_{sc}).

In both of the above configurations (with or without ground return), the voltage and current parameters of a system are possibly higher when compared to the parameters of a single channel. This implies that there is a reduction in the maximum capacitance and/or maximum inductance permitted. Verify a few values for V and I on the circuit ignition curve after applying the safety coefficient to determine the group or dangerous mixture that the system can be assigned.

The examples that follow highlight these concepts. Each example is based on the equivalent circuits illustrated in Figures 5.6 and 5.7, and each channel has the following safety parameters, except where noted:

V_{oc} = 21.2 V; I_{sc} = 143 mA; Class I, Groups A or B; C_a = 0.25 μF; L_a = 1.6 mH; L/R = 47 μH/Ω.

Example 1

For two channels with the same polarity

without ground return: V_{oc} = 21.2 V; I_{sc} = 143 mA; Class I Groups A or B; C_a = 0.25 μF; L_a = 1.6 mH; L/R = 47 μH/Ω.

with ground return: V_{oc} = 21.2 V; I_{sc} = 286 mA.

On the resistive circuit ignition curve, for a current I = 1.5 x 286 mA = 429 mA, the gas group in which V_{oc} = 21.2 V, and for which ignition is impossible, is Class I, Group C. The maximum allowed capacitance is C_a = 3 x 0.25 μF = 0.75 μF.

On the inductive circuit curve, for a current I = 1.5 x 286 mA = 429 mA, refer to Class I, Group C. The maximum allowed inductance is L_a = 2 mH.

The resistance of the equivalent circuit source is R = 21.2 V/286 mA = 74.13Ω; therefore, the ratio L/R = 4 x 2 mH/74.13Ω = 107.9 μH/Ω.

Example 1 safety parameters:

V_{oc} = 21.2 V;

I_{sc} = 286 mA;

Class I, Group C;

C_a = 0.75μF;

L_a = 2mH;

L/R = 107.9 μH/Ω.

Example 2

For two channels with opposite polarities

with or without ground return: V_{oc} = 42.4 V; I_{sc} = 143 mA.

On the resistive circuit ignition curve with a current I = 143 x 1.5 = 214.5 mA and V_{oc} = 42.4 V, the gas group is Class I, Group D.

For 42.4 x 1.5 = 63.6 V, the maximum allowed capacitance is C_a = 8 x 0.05 μF = 0.4 μF.

The maximum allowed inductance for Class I, Group D with I = 143 x 1.5 = 214.5 mA is L_a = 14 mH.

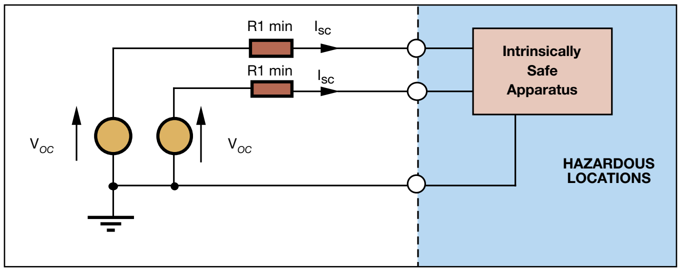


Figure 5.7

Equivalent circuit for two identical channels with ground return

The source resistance is R = 42.4 V/143 mA = 296.5Ω; therefore, the ratio L/R = 4 x 14 mH/296.5Ω = 188.9 μH/Ω.

Example 2 safety parameters:

V_{oc} = 42.4 V;

I_{sc} = 143 mA;

Class I, Group D;

C_a = 0.4 μF;

L_a = 14 mH;

L/R = 188.9 μH/Ω.

Example 3

For two non-polarized channels

without ground return: V_{oc} = 42.4 V; I_{sc} = 143 mA; Class I, Group D; C_a = 0.4 μF; L_a = 14 mH; L/R = 188.9 μH/Ω.

with ground return:
The maximum open-circuit voltage is V_{oc} = 42.4 V.
For the short-circuit current, there are two situations:

I_{sc} = 143 mA with 42.4 V; Class I, Group D

I_{sc} = 286 mA with 21.2 V; Class I, Group C

Class I, Group D combination is the more dangerous of the two; therefore, the allowed inductance for I = 1.5 x 286 mA = 429 mA is L_a = 3.6 mH.

Example 3 safety parameters:

V_{oc} = 42.4 V;

I_{sc} = 286 mA;

Class I, Group D;

C_a = 0.4 μF;

L_a = 3.6 mH.

For the L/R ratio, the more unfavorable situation of the two must be considered (refer to Figure 5.8).

The least favorable L/R ratio is 188.9 μH/Ω and is due to the first condition. Note that the maximum allowed L/R ratio of the system does not necessarily coincide with the maximum current circuit condition. This stresses the importance for examining all of the possible fault combinations in order to determine, for the worst condition, the corresponding safety parameters.

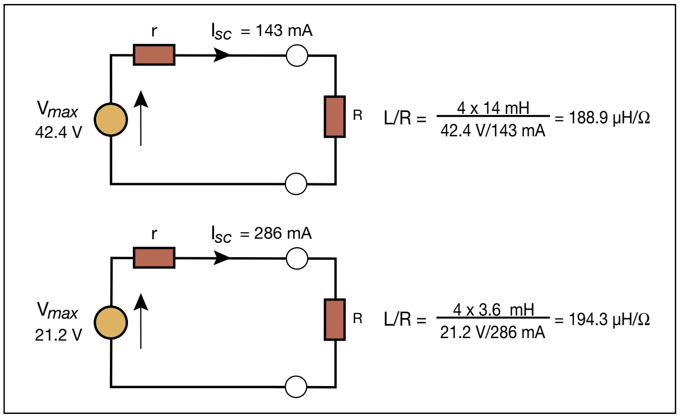


Figure 5.8

L/R ratios for short-circuit current

The Use of Multiconductor Cables

The use of multiconductor cables for connecting field devices is widespread and is accepted by the standard, if in the safety analysis of a system the opening, short-circuiting and grounding of the cable are not considered as fault conditions.

In the example shown in Figure 5.9, the multiconductor cable includes different intrinsically safe circuits. Over time the cable could be damaged and cause wires of different circuits to short circuit; therefore, voltages can be present or current can circulate in hazardous locations, both of which are larger than those for each single circuit.

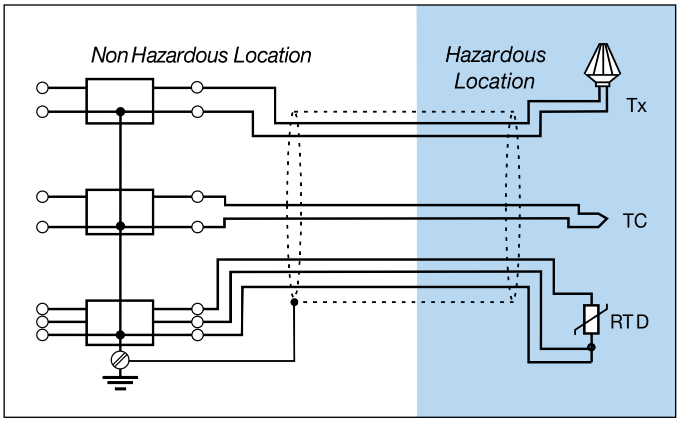


Figure 5.9

Example of a connection with multiconductor cables

The analysis of the effect of accidental contacts is similar to the analysis that is used in evaluating barrier combinations.

Section 6
Installation of Intrinsically Safe and Associated Apparatus

In the United States installation of intrinsically safe and associated apparatus must conform to Article 504 of the National Electrical Code and ANSI/ISA-RP12.06.01. For Canada the Canadian Electrical Code, Part I, C22.1 applies. These standards require that intrinsically safe wiring be separated from non intrinsically safe wiring, and that intrinsically safe wiring, terminals and raceways be clearly labeled. Other considerations such as grounding and shielding requirements are also considered.

The installation of intrinsically safe and associated apparatus must be handled with particular care in order to prevent any intrusion in the intrinsically safe circuits from apparatus and conductors that are not intrinsically safe circuits, if these intrusions could reduce or eliminate the intrinsic safety of the system. To achieve this, it is important to understand the concepts of segregation, separation and clear identification of the intrinsically safe components. In particular:

1. The terminals of the intrinsically safe circuits must be placed at a distance of at least 2 inches (50 mm) from the terminals of the non intrinsically safe circuits, or adequate separators (e.g. grounded metal partitions) must be used.
2. The different types of intrinsically safe circuits do not have to be electrically connected, unless such connection has been specified in the control drawing.
3. The intrinsically safe circuits cannot be metallically connected to apparatus which may have an overvoltage that has been transmitted from power lines or any source of electrical energy. Such a connection is permitted only if it is specified in the control drawing. When different types of intrinsically safe circuits end at the same marshaling terminal, it is advisable to maintain a distance between the relative terminals that is much greater than the 6 mm required by the standard, unless it can be demononstrated that the interconnection between the different types of circuits will not introduce a dangerous energy situation.
4. The properties of intrinsically safe circuits are different if the circuits:
   - Operate at different voltages or polarities
   - Have different barrier grounding points
   - Are certified for different categories or for different gas groups

For the intrinsically safe circuit, installation must be performed so that the maximum allowed value for current and voltage can never be exceeded because of external electric or magnetic fields. For example, proper installation in this case requires the use of cables that are adequately shielded and are separated from the cables of other circuits.

The connection elements—terminal block housing, protective enclosures for cables, the external enclosures for single conductors, and the wiring between intrinsically safe apparatus and associated apparatus—must be clearly marked and easily identified. If a color is used for this purpose, the color must be light blue.

The types of information that must appear, clearly and permanently marked, on the required label for each of the intrinsically safe components are: (1) the identification of the apparatus and (2) all the requirements necessary to maintain the intrinsic safety of the system (or the essential elements of the design document containing such requirements must be clearly marked).

For devices such as terminal blocks and switches, additional certification or specific marking is not required.

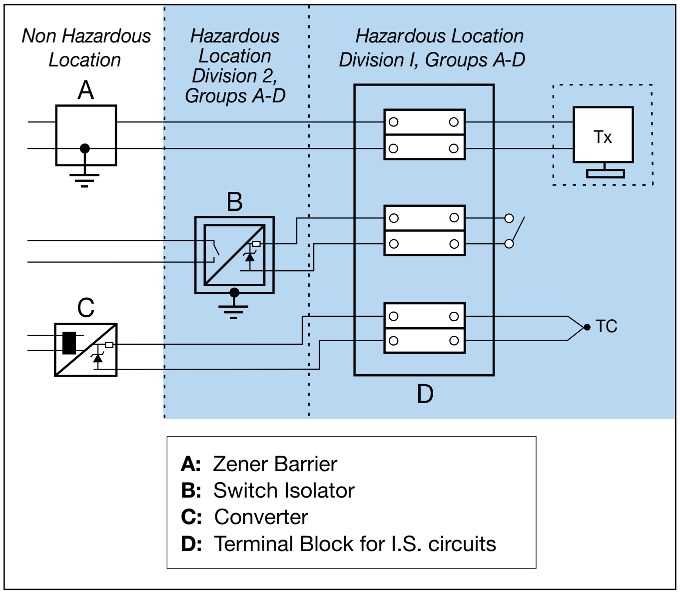


Figure 6.1

Example of different types of intrinsically safe circuits

Protection Ratings for Enclosures

Indoor enclosures

Required by the standards for enclosures of intrinsically safe and associated apparatus, Type 1 is the minimum degree of protection for enclosures that are installed in indoor and/or protected areas. (refer to the *Additional Information* section for a detailed presentation of Type protection ratings).

Outdoor enclosures

For outdoor enclosures, a protection degree of Type 4 or 4X is required. It is important to consider protection ratings of enclosures for intrinsically safe and associated apparatus in the context of the overall functionality and safety of the plant.

The *Additional Information* section presents the European enclosure protection rating system.

Cable Capacitance and Inductance

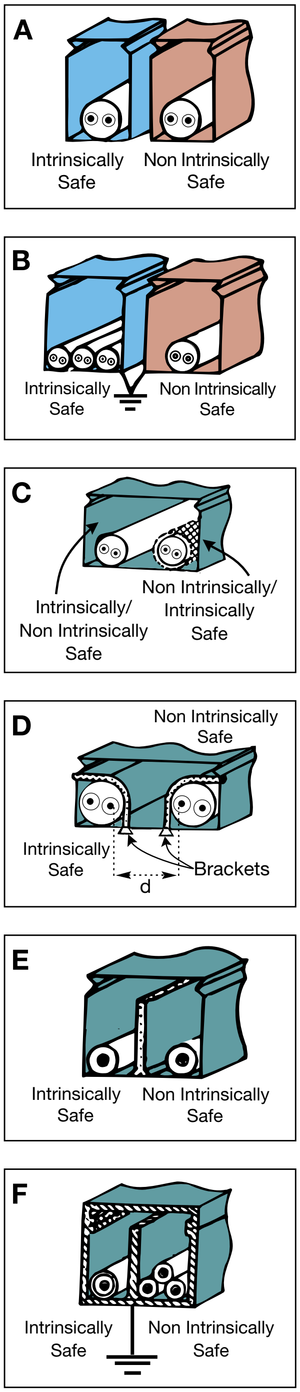
When designing and installing intrinsically safe systems, keep in mind that capacitance and inductance parameters of the connecting cables are important factors, even if they are not always determining factors.

The capacitance and inductance values of the cable (generally, given in pF/m and μH/m) should be easily available from the cable manufacturer. However, if there are difficulties in obtaining this data, the following values can be hypothesized (but only in an extreme situation).

Capacitance: 60 pF/ft (200 pF/m) - Inductance: 0.2 μH/ft (1 μH/m)

As an alternative to the inductance, another characteristic of the cable, the inductance/resistance ratio (L/R), can be used and is normally given in μH/Ω. This parameter permits more flexibility in the cable installation process.

Refer to Figure 6.2 for examples of cable installation and to Figure 6.3 for examples of wiring in small enclosures containing associated apparatus.



A: The cable of the intrinsically safe circuits and the cable of the non intrinsically safe circuits are installed in two different isolated trays.

B: The cable of the intrinsically safe circuits and the cable of the non intrinsically safe circuits are installed in two different metallic grounded trays.

C: The cable of the intrinsically safe circuits and the cable of the non intrinsically safe circuits are installed in the same tray; one of the cables is protected by a grounded shield capable of carrying fault current to ground.

D: Installation as above, but the cables are separated by anchor brackets. The distance "d" must conform to the standards with a minimum of 50 mm.

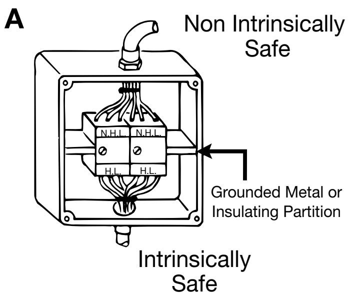
E: Installation as above, but the tray must have an isolated intermediate separator.

F: Installation as above, but the tray and the separator are metallic and grounded.

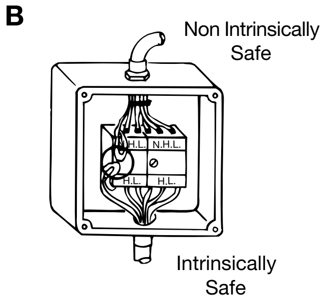
Figure 6.2

Examples of cable installation

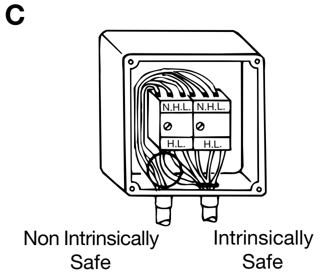
USA Headquarters web: www.am.pepperl-fuchs.com
phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com
Worldwide Headquarters web: www.pepperl-fuchs.com
phone: +49 621 776-0 • email: pa-info@de.pepperl-fuchs.com
Asia Pacific Headquarters web: www.pepperl-fuchs.com
phone: +65 67799091 • email: sales@sg.pepperl-fuchs.com



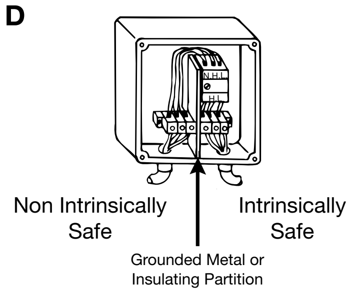
Correct:
When installing the wiring as shown, the minimum required distance between intrinsically safe and non intrinsically safe conductors is guaranteed.



Incorrect:
Several conductors are of excessive length.



Incorrect:
A separation does not exist between intrinsically safe and non intrinsically safe conductors.



Correct:
The maximum distance between the lid and the separator must be less than 1.5 mm; or the separator must guarantee a distance in air around the lid of at least 50 mm between the terminals of the intrinsically safe circuit and the non intrinsically safe circuit.

Figure 6.3

Examples of wiring in small enclosures containing associated apparatus

Grounding of Intrinsically Safe Plants

Intrinsic safety standards require that certain points of the system must be grounded and others must be isolated from ground. Generally, the grounding of intrinsically safe circuits is required to prevent or even to reduce the probabilities that excessive energy levels can be generated in the hazardous location.

The isolation from ground of parts of the circuit is required to prevent the possibility of having two grounded points with a different potential and the possible circulation of a high current.

It is also a requirement of intrinsic safety that only one point can be grounded, while the rest of the circuit must be isolated from ground (500 V_{ac} min).

The grounding of intrinsically safe circuits must be accomplished with a conductor that is isolated from any other plant grounds and connected to the reference ground system.

ANSI/ISA-RP12.06.01 has become the authority in the United States on the installation of intrinsically safe equipment. Refer to the applicable standards for grounding practices in other countries.

Grounding of Passive Barriers

From an intrinsic safety point of view, the effective functioning of passive barriers is linked to their capability of diverting to ground the dangerous energy coming from the non hazardous instrumentation devices on which they are connected.

For this reason, it is very important that the ground connection of the passive barrier is made to an equipotential ground system (refer to Figure 6.4).

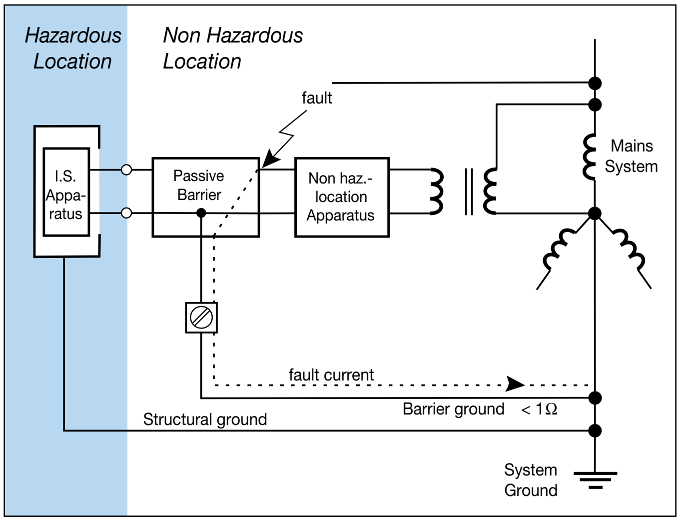


Figure 6.4

Schematic of a grounded passive barrier

The ground connector must be mechanically and electrically reliable and be able to reduce the fault current or the sum of the fault currents, if more barriers are connected to a single-ground bus.

The connecting cable used in grounding the barriers must be at least No. 12 AWG (American Wire Gauge).

The allowed resistance between the ground terminal of the most distant barrier and the isopotential ground point must be less than 1Ω.

Barrier ground connections must be separated from any other plant grounds and must be connected to a ground system at only one point.

The required condition of the only ground point implies that a passive barrier cannot be used on interfacing sensors or hazardous location apparatus containing grounded or poorly isolated circuits (i.e., thermocouples with grounded junctions or non isolated transmitters).

The generally accepted practice differs, however, because an equalization conductor (bonding) of the ground potential is usually found in a hazardous location, as shown in Figure 6.5.

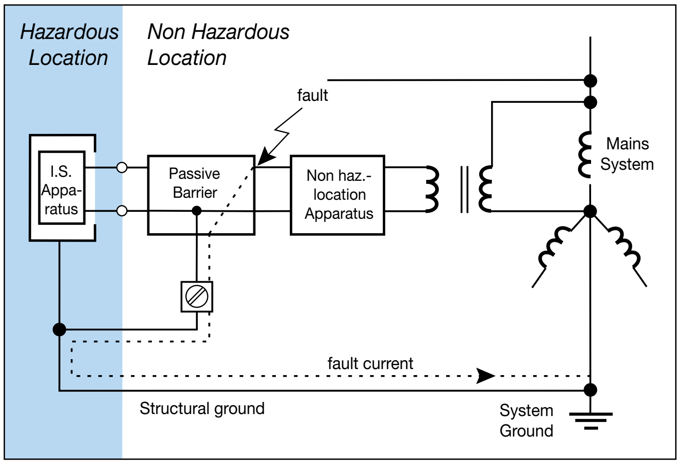


Figure 6.5

Schematic of a ground connector for a passive barrier (used only in Germany)

The fault current, following the route shown, can increase the ground potential of the hazardous location circuits in comparison to the one of the reference ground system. This does not represent a dangerous situation because all of the metallic structures in a hazardous location are connected to the equalization conductor, resulting in an isopotential state. This type of connection is permitted for Zones 1 and 2 in Germany. For Zone 0 applications, the use of galvanic separation, independent from the degree of isolation of the hazardous-location apparatus, is mandatory.

Grounding of Shielded Cables

The use of shielded cables for connecting the hazardous location sensors or transmitters with the non hazardous location control and measurement apparatus is widespread.

From a functional point of view, the shield's purpose is to create an equipotential zone around the conductor's capacitive coupling with that of other conductors. This is only true if the shield is connected to a grounded reference potential.

The shield should be grounded at only one point—preferably, at the system's ground point. If the shield is grounded at two non equipotential points, the current could circulate in the shield, preventing functionality. Therefore, a shielded cable must be provided with an extra isolating coat above the shield to prevent accidental ground contacts.

For intrinsically safe apparatus, the shield acts as another conductor between the hazardous and non hazardous locations and could become the fault current route if the cable is damaged. From this point of view, the principle of isolating the circuit in hazardous locations and grounding it in non hazardous locations can also be applied to the shield.

For passive-barrier applications, the shield can be locally grounded if the galvanic isolation is not damaged by this connection. This means that the two shields at the two sides of the isolation device must not be interconnected.

For applications where shielding is part of the segregation technique between different types of intrinsically safe circuits (i.e., multipolar cables), the reference ground connection of the shields must be the same as the ground connection of passive barriers (refer to Figure 6.6).

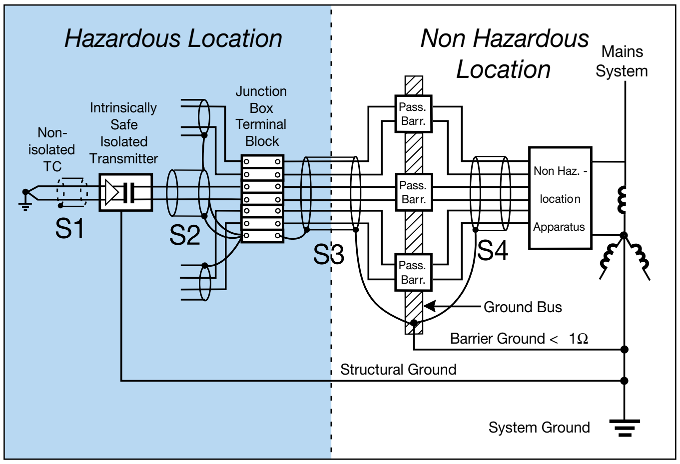


Figure 6.6

Example of shield ground connections

For functional reasons, the S1 shield is connected to the same grounding point as the measuring circuit. This must not be connected to the transmitter's metallic parts in order to prevent the second-circuit ground connection, which is not permitted by the intrinsic safety protection method.

Since the purpose of the field transmitter is to galvanically isolate the thermocouple's circuit from instrumentation in non hazardous locations, there must be no connection between shields S1 and S2.

Shields S2 and S3 provide the shielding of the connection between the transmitter and the barrier. They are interconnected in an isolated point of the junction box terminal block.

S3 is also connected to the barrier's ground bus that, by means of a separate conductor, is connected to the reference ground point.

Shield S4 completes the shielding of the system and is not very important from a safety point of view. It is connected to the shield's reference point, which is represented by the ground bus.

For this type of connection, it is necessary that Shield S2 be properly isolated from the transmitter's metallic structure; otherwise, a situation as shown in Figure 6.7 can occur.

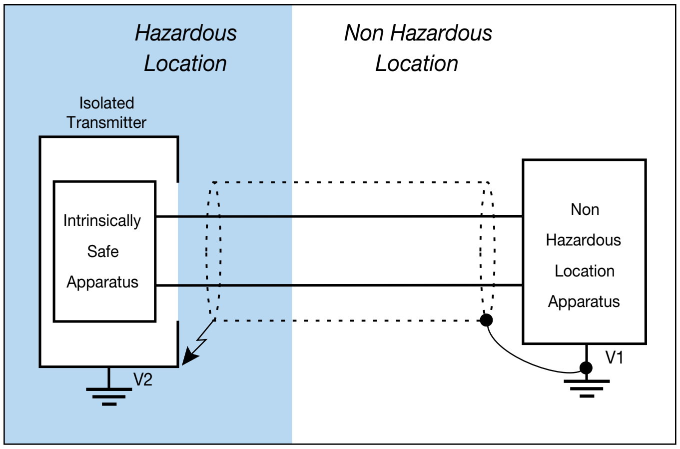


Figure 6.7

Possible dangerous situation for grounding of non hazardous-location shields

When isolation no longer exists between the shield and the transmitter's enclosure, an excessive energy level could be present in a hazardous location if ground potential V1 is different from V2. Since the fault current is limited only by the resistance of the shield and the one existing between V1 and V2, the generated spark could ignite the surrounding potentially dangerous atmosphere.

This situation can be prevented by grounding the shield in the hazardous location; therefore, a spark could occur in the non hazardous location without causing a fire or explosion.

Section 7
Maintenance of Safe Plants

No method of protection is completely safe and human-error proof. Proper maintenance that includes a rigorous initial inspection, verification, and subsequent periodic inspections and repairs is extremely important for the safety and economical management of any instrumentation plant, and becomes fundamental in plants where the danger of fire or explosion exists.

To reduce the risk of catastrophic human errors, it is also important to permit only authorized and competent personnel to repair explosionproof apparatus—as equipment must not be serviced under power. The following maintenance criteria are presented to give the reader a general understanding of what is involved in order to maintain an industrial facility relative to safety. This material is not intended to replace the applicable safety standards.

After the installation and completion of each plant, it is necessary to perform the following three types of inspection/maintenance activities:

1. Initial inspection
2. Programmed maintenance (periodic inspections and repairs)
3. Apparatus failure and repairs

Initial Inspection

Prior to acknowledging and classifying the presence of flammable mixtures and performing the startup of a newly completed, modified or expanded plant containinig hazardous locations, a complete inspection of the plant by qualified personnel must be carried out. An inspection must also be performed if the classification of the hazardous location has been modified. The inspection personnel must provide documentation that verifies the following:

- The adequacy of the entire plant
- The adequacy of all the field elements
- The adequacy of all the associated apparatus
- The agreement between safety parameters and the inter-connected apparatus

Adequacy of the Entire Plant

It is necessary to verify that the protection methods used, in their entirety, are compatible with the hazardous locations and the gas groups present and that the technical rules of each protection method have been strictly followed.

Explosion-proof installations

Specifically, for an explosion-proof installation, verify that:

1. All of the plant's components and electrical lines located in a hazardous location are of an explosion-proof type, with continuity, up to the exit point of the hazardous location or are directly protected with other authorized methods that are properly installed.
2. The apparatus are correctly anchored and do not exert force on the connecting pipes, causing cracks or deformation near the connection points.
3. The locking joints conform to the standard and are properly tightened and sealed.
4. The conductors leading into the junction boxes are firmly anchored but do not risk abrasion or cuts in the isolation.
5. There is no formation or accumulation of condensation in the pipes and/or the enclosure of the apparatus.
6. The explosion-proof enclosures have a reliable external ground connection.
7. If mixed protection methods are used, these methods must be authorized for the specific type of hazardous location and groups of gases and must be properly installed.
8. Adequate space has been allowed for easy removal of the lid during maintenance activities.

Intrinsically safe installations

For intrinsically safe installations, verify that:

1. All of the electrical conductors that route, even marginally, into a hazardous location and are not protected with explosion-proof pipes, and pertain exclusively to intrinsically safe circuits (or, where permitted, increased safety), are properly protected for the respective hazardous locations and gas groups and are installed in conformity with the installation standard.
2. None of the intrinsically safe circuit conductors are mixed with the non intrinsically safe circuit conductors (e.g., multiconductor cables) without respecting, along the entire route, the safety distance and segregation from other conductors and/or terminal blocks, and also its identification as an intrinsically safe circuit.

3. Conductors of different types of intrinsically safe circuits (especially ones with different safety parameters) are properly separated and isolated from each other.
4. If diode safety barriers (passive or non isolated) are used, there exists an isopotential system with plant grounds conforming to the applicable standard, and that the continuity toward ground is guaranteed for each apparatus.
5. Non hazardous-location apparatus that are directly powered with voltages larger than 250 V are not present, unless they are protected and certified for that use.
6. Shields of conductors associated with diode safety barriers are connected to the isopotential ground.
7. The reciprocal and toward-ground isolation, where required, of all intrinsically safe circuits conform to the standard. (Use a test instrument that does not generate more than 1.2 V and 0.1 A, or 25 mW if there is a presence of flammable mixtures in the plant, or shut down the plant and be sure that flammable mixtures are not present.)
8. The markings that specifying different measuring and/or regulation loops are clear and avoid confusion between different types of barriers with different parameters.
9. The barrier input terminals are not confused with the output terminals.
10. Installation conforms to the manufacturer's control drawing.

Adequacy of all the Field Elements

Demonstrate that all of the apparatus installed in hazardous locations are free from the risk of fire or explosion by:
(1) verifying that the apparatus are connected with simple devices ($V_{max} \leq 1.2$ V; $I_{max} \leq 0.1$ A; $P_{max} \leq 25$ mW), or (2) verifying that a protection method is being used that is authorized for the specific installation zone and compatible with the gas groups and temperature class.

Explosion-proof apparatus

Specifically, for explosion-proof apparatus, verify that:

1. All of the apparatus are installed in Division 2, or Division 1 with certain restrictions. (In Europe Zone 1 or Zone 2; Zone 0 does not permit the installation of electrical apparatus using only the explosion-proof protection method.)
2. Certification is compatible with the gas group and surface temperature class of the flammable mixture present.
3. None of the explosion-proof points have been damaged during transport or installation.
4. All of the openings toward the outside of the enclosure have been used (flame break joint, conduit [pipe] joint) or properly sealed with explosion-proof caps that are properly tightened.
5. All of the removable lids are integral, closed and tight (lid bolts all present and tight; screw-type lids tightened completely and equipped with devices against accidental unscrewing).
6. All of the threaded junctions are integral and protected against corrosion.
7. Each enclosure has an external ground connection properly tightened and efficient.
8. Warnings stating that the power should be shut down before opening are always present on the lids and/or the labels.

Intrinsically safe apparatus

For intrinsically safe apparatus or for simple electrical devices, verify that:

1. They have, where required, a type of certification that is suitable for their hazardous location and the gas groups corresponding to the flammable mixtures present.
2. They have, where applicable, a surface temperature classification compatible with the flammable mixture present (e.g., T6).
3. They are exclusively connected to intrinsically safe circuits, in the manner specified by the certification documents, especially for the eventual connection to alarm safety apparatus, and that the safety parameters of the connecting cables have been respected.
4. They are, where applicable, powered or interconnected with associated apparatus having safety parameters compatible with the apparatus and the proper protection method.
5. They have a grounded enclosure, or if a plastic enclosure is used, that the risk of electrostatic discharge is not present (warning labels, etc.) and, if required, that they are installed with the proper environmental protection.
6. They do not have points of the circuit grounded or poorly isolated toward ground, only if connected with diode safety barriers without galvanic isolation, with the exception of the equipotential ground connection on the barrier.
7. The eventual loosening of cable clamps or conductor input joints does not jeopardize the tightness of the enclosure against water and corrosive atmospheric elements.

Adequacy of all Associated Apparatus

For the adequacy of the associated apparatus, verify that:

1. They have been exclusively installed in a protected non hazardous location, unless other protection methods that are suitable for the hazardous location have been used.
2. The type of certification is compatible with the intrinsically safe circuit to which they are connected, according to the hazardous location and the gas group.
3. They have safety parameters that are compatible with both the connection cable and the intrinsically safe apparatus to which they are connected.
4. Separation and identification of the intrinsically safe circuit exists along the entire connection route, as required by the standards.
5. They have correctly rated and installed internal fuses and that an external protection device (i.e., isolator breaker) is present on the main power line.

Agreement between the Safety Parameters and the Associated Apparatus

Any apparatus that is certified or recognized as safe can become unsafe if they are used in connection with other apparatus, even if these apparatus are certified as safe. Therefore, use the interconnected apparatus documentation to verify that the entire connections are specified and permitted by the certification, and that parameters derived by the interconnection, remain compatible with values that are characteristic of the cable and the field elements connected.

Programmed Maintenance

Programmed maintenance prevents the deterioration of apparatus, both functionally and from a safety point of view. It includes the periodic inspection and the repairs (if any) which are made as a result of the inspection. A record must be kept of the type of maintenance performed, the date and the results.

Periodic Inspection for Explosion-proof Apparatus

To perform a periodic inspection to determine the safety of explosion-proof apparatus, verify that:

1. All of the explosion-proof lids are tightly screwed or bolted, depending on the type. If bolted, all of the bolts must be fitted properly and tightened.
2. Signs of deformations, cracks or corrosion in the flanged joint, tightening lid thread and pipe union are not present.
3. The enclosure's external grounding terminals are tightened, and that the grounding conductor is integral and guarantees a good ground connection.

Calibration Verification: Prior to performing calibration verification on an explosion-proof enclosure, the power supply must be turned off, or ensure that there are no flammable mixtures present around the enclosure. Turning off the power supply makes it impossible to verify the proper functioning of the apparatus; therefore, it is preferable to eliminate the presence of flammable mixtures and perform the calibration with the power on. (This can be determined by on-site testing with a combustible gas detector.)

1. During all of the subsequent operations, continuously verify with the gas detector the absence of flammable mixtures.
2. Turn off the power to the apparatus, and open the cover to access the input/output connection and calibration regulations.
3. Connect the calibration instrument to the input/output connection, according to the instructions on the apparatus. With the combustible gas detector, verify the absence of flammable mixtures and restore the power.
4. Following the manufacturer's instructions, verify the calibration and adjust it if necessary.
5. Turn off the power and reconnect the original connections.
6. Close the lid and verify its tightness.
7. Restore the power for normal functioning.

Periodic Inspection for Intrinsically Safe Apparatus

For intrinsically safe apparatus, certain inspections can be performed without a plant shutdown. For each inspection, however, verify that situations of real or potential dangers are not generated for the following reasons:

1. The instruments or verification connections do not cross the hazardous (I.S.) and non-hazardous terminals of the barriers.
2. The ground connections are not interrupted while the intrinsically safe circuits are powered or are connected to other powered circuits.
3. The apparatus, used for the test, are certified and suitable to operate in a hazardous location with explosive mixtures present.
4. The apparatus used for the test do not introduce dangerous voltages or currents in the circuit. This is not necessary in order to test apparatus according to the standard.
5. The conductors, temporarily disconnected for the test, do not remain free to cause unwanted contacts, but are clearly identified and firmly anchored to an electrically safe point (e.g., isopotential grounded system).

When possible, verification of apparatus should be performed by removing them from the plant (substitution is advisable if spares are available) and safely testing them in a lab that is located in a non hazardous location. This procedure is greatly simplified if the apparatus are equipped with plug-in type connectors that allow removal of the card without touching the cable connections.

Hazardous locations

Generally, the maintenance procedure in a hazardous location should be limited to the following:

1. The disconnection and removal (or substitution) of apparatus and part of the connections
2. Calibration adjustment of the apparatus
3. The use of permitted and specified test apparatus
4. Other permitted or specified maintenance activities

Non hazardous locations

Although it may appear that there is less danger when inspecting or repairing apparatus in a non hazardous location, this is not the case. In fact, a more dangerous situation could develop due to the fact that often, less care is taken because of the non hazardous classification. It is difficult to realize that an erroneous operation in a non hazardous location can generate an explosion in a hazardous location by means of the interconnected circuit.

Passive barriers in non hazardous locations

Therefore, for circuits protected by diode safety barriers, verify that:

1. The ground conductor of each barrier is properly tightened and maintains a total resistance up to the isopotential ground point less than or equal to 1Ω.
2. The safety circuits (measured by non repetitive samples) are isolated from other ground points, and the isopotential point to which they are connected is according to the standard.
3. The separating distances of safety terminal blocks and conductors are respected.

Active barriers in non hazardous locations

For circuits protected by galvanic isolation barriers, verify that:

1. The separating distances of safety terminal blocks and conductors are respected.

Calibration Verification: As previously stated, intrinsically safe circuits have the advantage of permitting maintenance activities to be performed while the power is on (usually the maximum voltage present is 28 V). However, with circuits protected by barriers, the possibility always exists that the barrier could be permanently short-circuited. This could cause the fuse to blow, rendering the barrier useless. In other apparatus, the risk of accidental improper contact remains. Therefore, when possible, it is advisable to remove the apparatus (this is particularly easy with instruments with plug-in type connectors) and proceed with verification in a lab. Where it is impossible to remove the apparatus from the installation, the following must be performed:

1. Disconnect the input/output conductors and, after identifying them, connect them temporarily to the isopotential ground; or, if already grounded, keep them isolated and anchored to the free terminals of a supporting terminal block.
2. Connect a calibrator to the input and a calibration indicator to the output. Both must be certified for the division and gas group in which they are used.
3. After completing the verifications and calibrations, restore both the input and output conductors with extreme care.

Apparatus Failure and Repairs

Repair of Explosion-proof Apparatus

When there are functioning abnormalities in an explosion-proof instrumentation plant, the following must be performed in the shortest time possible:

1. Determine the cause of the apparatus failure, or abnormality.
2. Isolate and determine the anomalous part of the plant.
3. Substitute, if possible, the malfunctioning components with spares.
4. Repair the malfunctioning components in order to regain proper functioning.

Reducing the time that a plant is shut down for repairs is the key to reducing maintenance costs. Quick and precise determination of the causes and identification of the malfunctioning apparatus become very important when viewed in this way. This can be made easier if precautionary measures that render safe and quick substitution of the components were taken during the design phase.

Using this concept, the best solution can be obtained from the use of:

1. Field and control room instrumentation of the modular and plug-in type, making it easier to remove the instrument without altering the wiring
2. Adequate inventory of spare components that permit immediate substitution

The determination of the causes of malfunction or failure and the identification of the failed apparatus in explosion-proof plants follow the same general rules as trouble-shooting in standard instrumentation plants. In this case, however, there is a danger of fire or explosion; therefore:

1. Do not perform connections that are not shown in the plant's schematic, unless the risks relative to safety have been analyzed.
2. Do not use test instruments that are not certified for use in the same hazardous location and gas group that the circuits to be analyzed are.
3. Isolate the part of the plant in which the repairs must be performed, and consider the effect of the performed tests on the interconnected circuits.
4. Most importantly, do not cross or eliminate the safety protections that are present in the safety barriers and in other parts of the plant.

The block substitution of the malfunctioning apparatus can be performed without a great deal of risk if the certainty of the correct apparatus insertion in its enclosure exists and eventual polarization keys, purposely placed on the insertion elements to prevent insertion of erroneous modules on a given apparatus, are not altered or forced.

Repair of Intrinsically Safe Apparatus

The repair of defective intrinsically safe apparatus, besides restoring the operative functionality, does not have to compromise in any way the characteristics of intrinsic safety. The most frequently used ways of ensuring that apparatus are intrinsically safe are:

1. Surface distances between the main line and the intrinsically safe circuit
2. Surface distances between two different types of intrinsically safe circuits
3. Protective coats which increase the isolations that are unobtainable with distances only
4. Protective fuses on main and signal transformers, and output circuit barriers
5. Signal and main transformers with dielectric rigidity that has been individually tested, and with distances and isolating materials that are guaranteed
6. Barrier resistors with construction techniques, nominal powers, values and tolerance as per the certification documentation
7. Diode or zener barriers with nominal voltage, tolerance, nominal power and assembly polarity well-defined
8. Optoelectronic coupler that has been certified as a component having surface and internal distances and approved construction techniques
9. Electromagnetic relays that have been certified with guaranteed surface distances between the coil circuits and the contacts and/or terminals for armor ground connections
10. Functional modules, encapsulated or not, that have been certified as components which are compatible with the concept of intrinsic safety

There are many other items that could be added to this list, but they are used less frequently and are too numerous for purposes of this discussion.

None of these protection characteristics can be substituted indiscriminately without having complete documentation and a great deal of knowledge about the concept and possible problems of intrinsic safety and the way in which intrinsic safety has been used in any particular apparatus.

USA Headquarters web: www.am.pepperl-fuchs.com
phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com
Worldwide Headquarters web: www.pepperl-fuchs.com
phone: +49 621 776-0 • email: pa-info@de.pepperl-fuchs.com
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For the manufacturer of the apparatus, however, it is often impossible to supply all of the documentation necessary for an average maintenance technician to perform, without risk, repairs on intrinsically safe apparatus.

The safer and sometimes less costly solution is to keep a series of spare cards or modules that permit an immediate substitution of the faulty unit. The faulty unit can then be sent to the authorized service dealer where it can be repaired or replaced.

Repair of intrinsically safe apparatus in emergency apparatus

If an intrinsically safe apparatus must be repaired in an emergency situation, give particular care:

1. Not to modify the air and surface distances of the barriers and their components
2. Not to substitute any component that determines its intrinsic safety (usually, these components are marked with shading on the silk screen of the printed circuit boards and on the schematics)
3. Not to substitute the fuses, unless they are substituted with others of identical type (rapid, medium lag, etc.) and nominal current
4. Not to substitute main or signal transformers, unless the substitution is made with identical components that are supplied by the manufacturer of the apparatus
5. Not to substitute certified modules, unless the substitution is made with identical modules that are supplied by the manufacturer
6. In reciprocal positioning of the components and in repositioning eventual isolators or spacing collars that are placed on the component terminals in order to distance them from the printed circuit board
7. In verifying the repaired card or component, to be certain of the complete efficiency of all the intrinsically safe protection
8. In performing an accurate washing of the printed circuit board and restoring eventual protective coatings

Section 8
Applications

Passive Zener Barriers

Intrinsically safe passive barriers use zener diodes to limit the voltage to the hazardous (classified) location and fused "infallible" resistors to limit the current.

An equipotential ground system, separated from the plant ground and safely connected to a single ground point, must be present in order to use zener barriers.

The resistance of the intrinsically safe circuit's ground connection must be lower than 1Ω (refer to Figure 6.6).

If an equipotential ground system is not available, zener barriers cannot be used.

Hazardous-location devices, such as thermocouples, resistance temperature detectors (RTDs), transmitters, contacts, electropneumatic converters, electrovalves, etc., must be isolated from ground (at least 500 V_{ac}), or these devices cannot be used.

The current leakage of zener diodes can introduce an error on the lower level of the signal.

The series resistance of barriers reduces the field voltage that is available to transmitters or converters, therefore, limiting their use.

Even if accidental, a short circuit can cause a fuse to blow.

Advantages: Zener Barriers

1. Low cost
2. Small size

Limitations: Zener Barriers

1. The requirement of an "infallible" equipotential ground system
2. The requirement of hazardous-location devices that are isolated from ground
3. Voltage drop on the series resistance
4. Unprotected against short circuits
5. The occurrence of possible errors, when measuring, due to the current leakage of the zener diodes

Loop-powered Isolated Barriers

The following three types of loop-powered isolated barriers are available:

1. Isolated current repeater for transmitters
2. Isolated current repeater for electropneumatic converters
3. Electrovalve drivers

The first two use a 4-20 mA signal that is present on the instrument loop circuit as their power supply. All of them use DC/AC conversion, an isolation transformer and the AC/DC reconversion in order to obtain the galvanic separation between the hazardous location and the non hazardous location circuits.

This type of barrier is most often used when an isopotential ground system is not available or the field elements are not isolated from ground, without using powered barriers and a power supply voltage able to overcome the major internal drops in voltage.

Advantages: Loop-powered Isolated Barriers

1. No requirement of an isopotential ground system due to input/output galvanic separation
2. The use of non isolated field elements permitted
3. Electrovalve drivers always safe, even during the fluctuations of the coil resistance due to ambient temperature variations
4. Short-circuit protection
5. Insertion or removal from the loop without turning off power.

Limitations: Loop-powered Isolated Barriers

1. Higher internal voltage drops than with passive barriers
2. Higher cost than that of passive barriers

Powered Isolated Barriers

Powered isolated barriers are available for a broad range of input/output interface types, which includes nearly all of the instrumentation applications.

Both DIN rail-mounting or as plug-in version are available.

They are individually powered, guaranteeing the galvanic separation between the intrinsically safe circuits connected to the hazardous location and the non intrinsically safe circuits that are located in a non hazardous location.

Barriers of this type require neither isolated sensors nor an isopotential ground system.

Intrinsic safety cannot be compromised by a fault in the isolation and does not depend on the integrity of the ground connection.

Powered isolated barriers permit direct interfacing with thermocouples, resistance temperature detectors, transmitter potentiometers, signal transmitters, strain gauge bridges, PH or conductivity electrodes, contacts, proximity switches, electropneumatic converters, electropneumatic positioners, solenoid valves, magnetic pickups, etc.

For the plug-in version, these barriers can be inserted or removed while the power is on. This allows repairs to be made quickly without compromising the intrinsic safety of the system.

Without exception, powered isolated barriers are technically suitable for all of the intrinsic safety applications.

Advantages: Powered Isolated Barriers

1. No requirement of an isopotential ground system due to input/output galvanic separation
2. The use of non isolated field elements permitted
3. High-voltage signal levels available in the field, independent of voltage supply
4. Short-circuit protection
5. Provide a standardized high-level isolated output signal (usually 4-20 mA)
6. For the plug-in version, quick substitution possible without shutting down the power supply
7. Suitable for all intrinsically safe applications, without exception

Limitations: Powered Isolated Barriers

1. Higher cost than passive or loop-powered barriers

Barrier Choice Criteria:

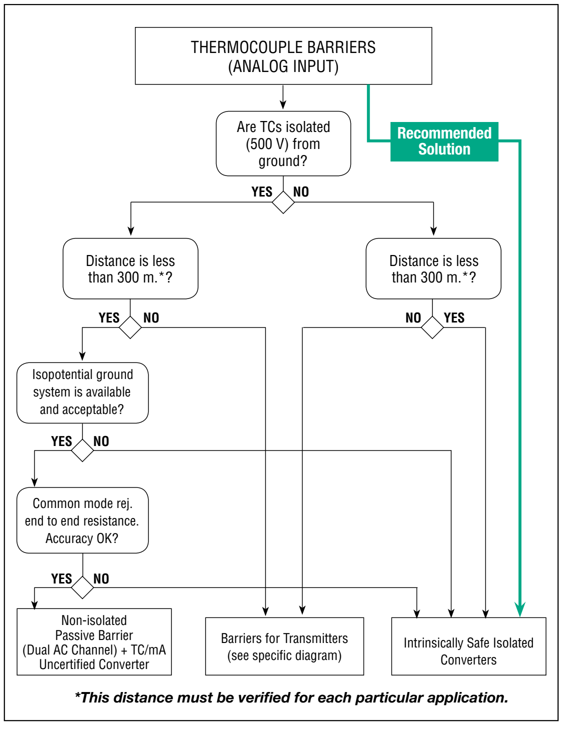

Figure 8.1

Choice criteria for thermocouple detector barriers

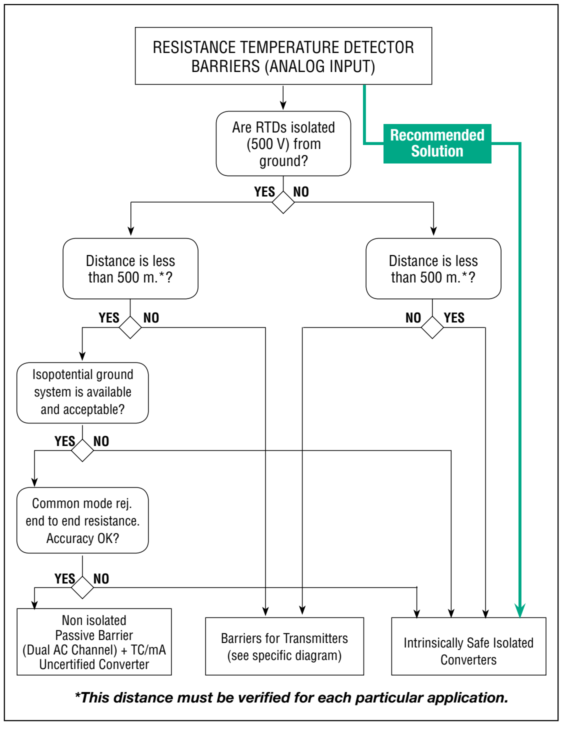

Figure 8.2

Choice criteria for resistance temperature detector barriers

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Worldwide Headquarters web: www.pepperl-fuchs.com
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Asia Pacific Headquarters web: www.pepperl-fuchs.com
phone: +65 67799091 • email: sales@sg.pepperl-fuchs.com

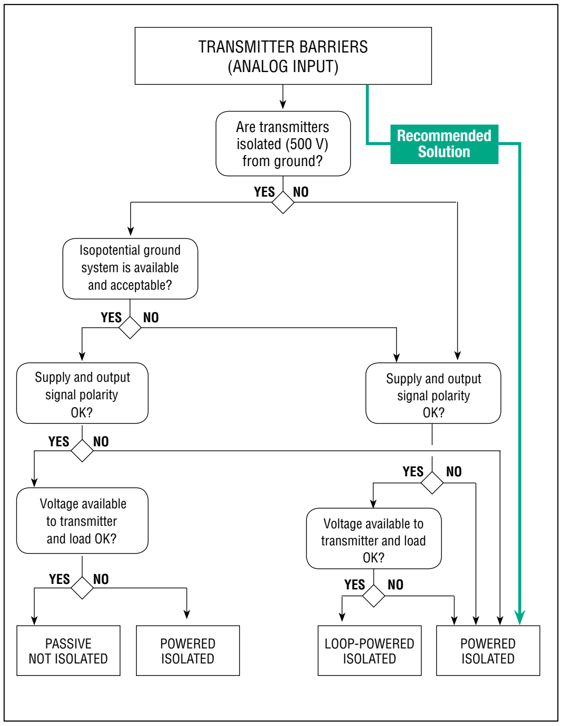

Figure 8.3

Choice criteria for transmitter barriers

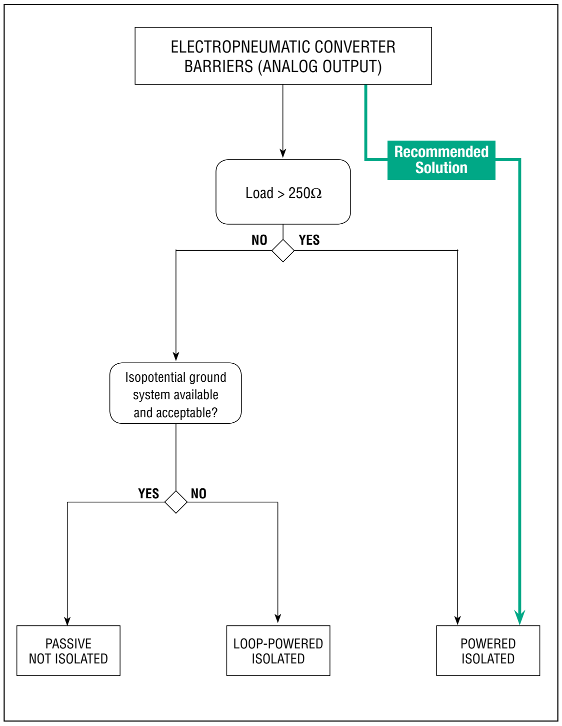

Figure 8.4

Choice criteria for electropneumatic converter

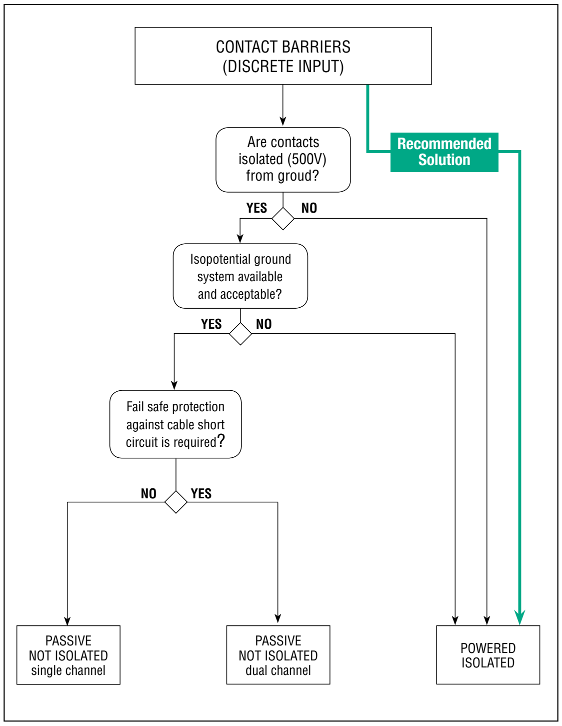

Figure 8.5

Choice criteria for contact barrier

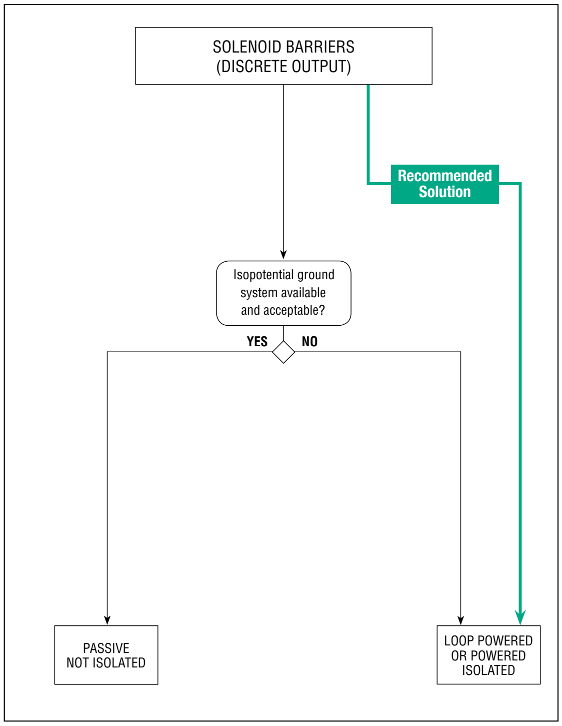

Figure 8.6

Choice criteria for solenoid barrier

Application Examples:

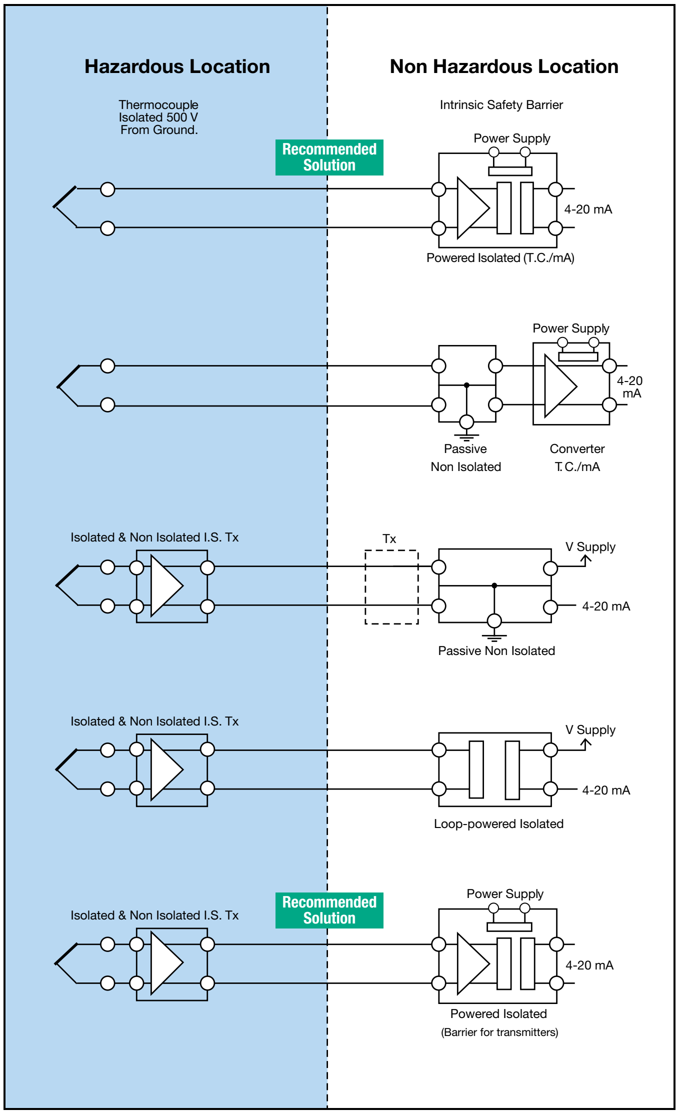

Figure 8.7

Application examples for thermocouples isolated 500 V from ground

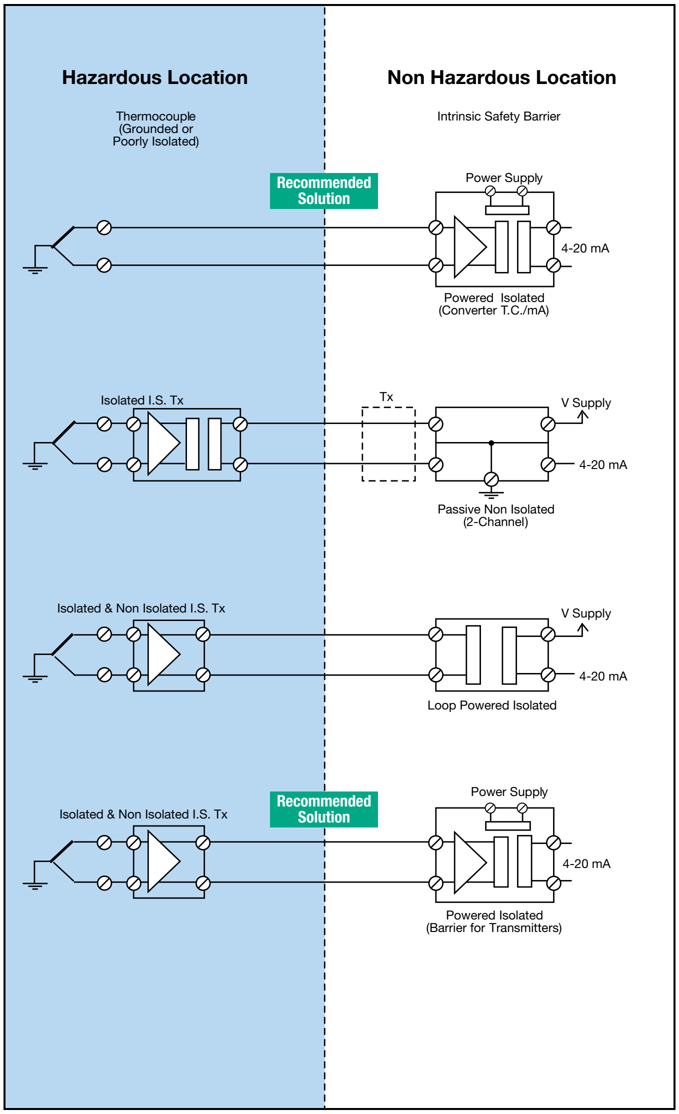

Figure 8.8

Application examples for grounded or poorly isolated thermocouples

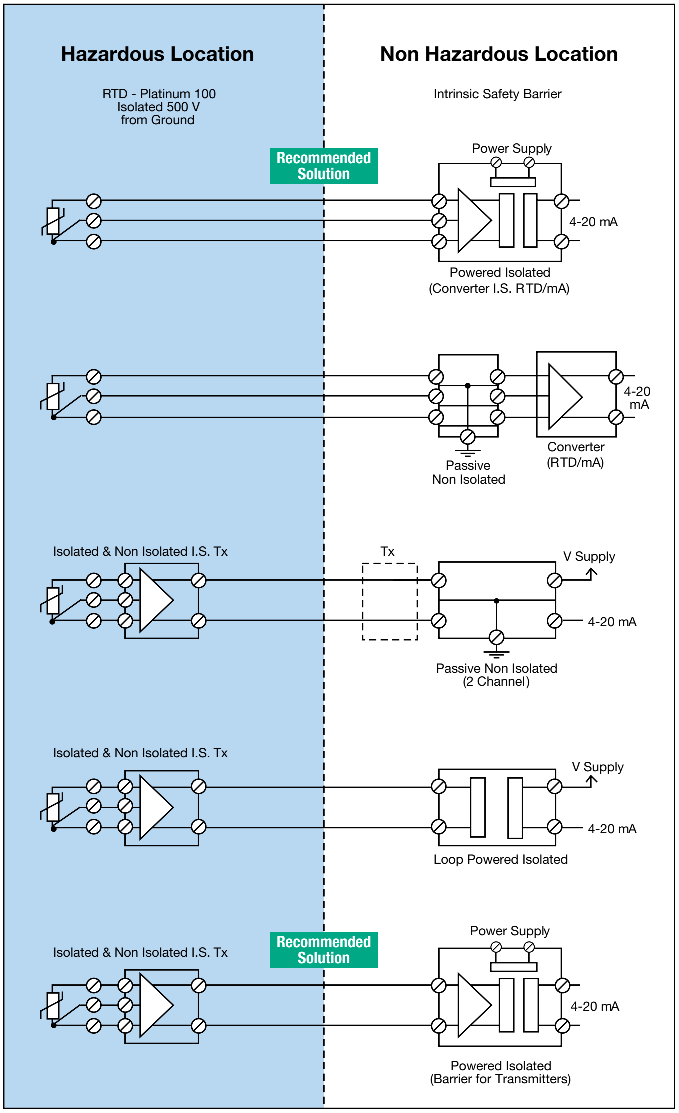

Figure 8.9

Application examples for resistance temperature detectors isolated 500 V from ground

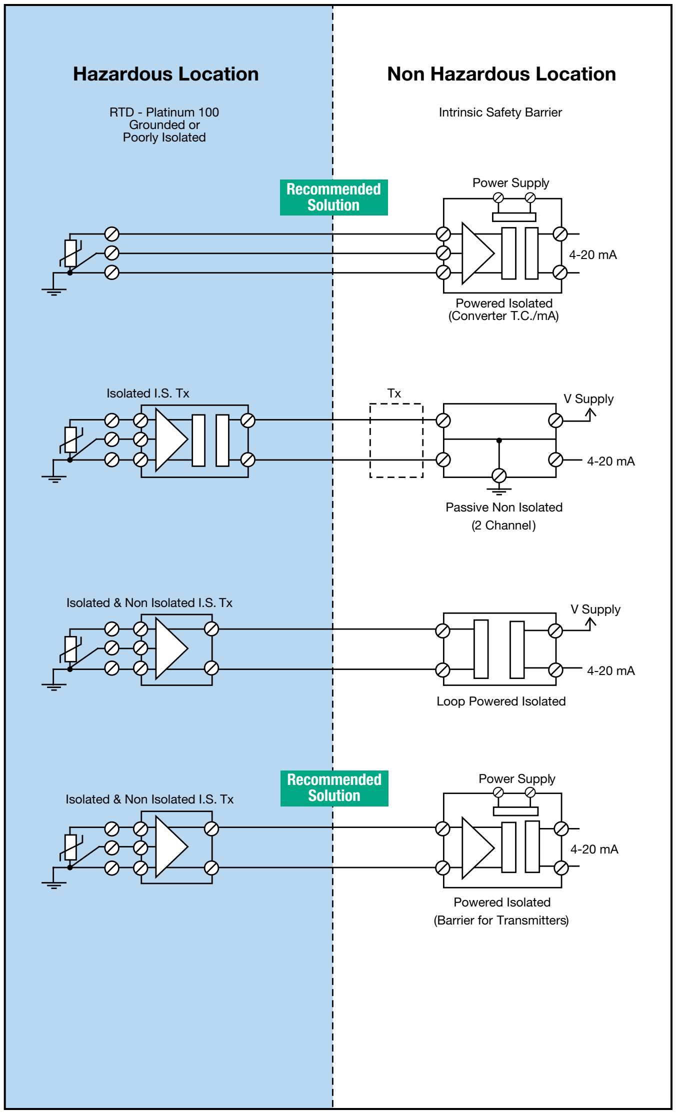

Figure 8.10

Application examples for grounded or poorly isolated resistance temperature detectors

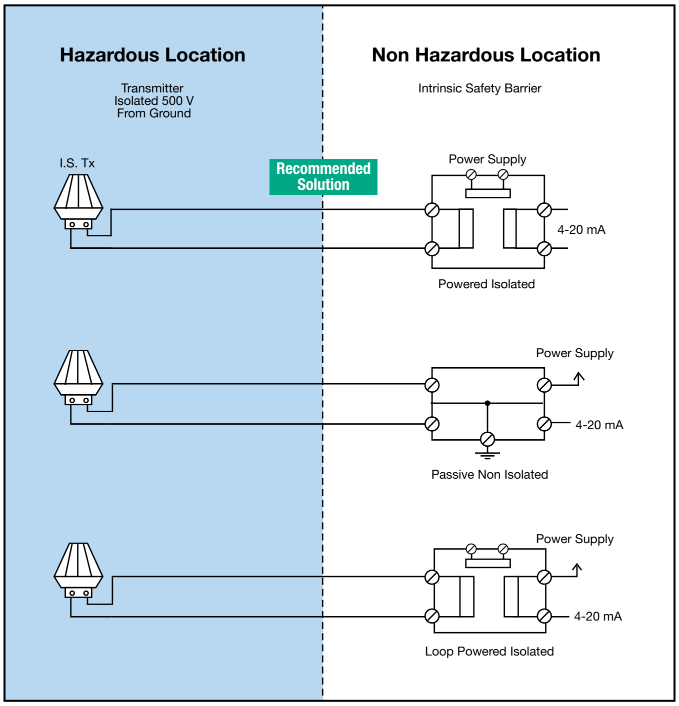

Figure 8.11

Application examples for transmitters isolated 500 V from ground

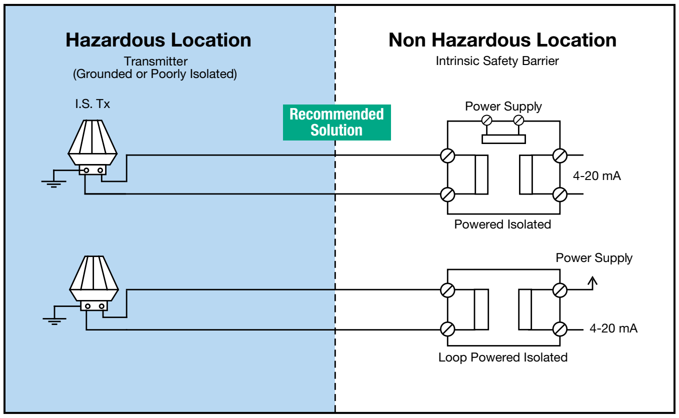

Figure 8.12

Application examples for grounded or poorly isolated transmitters

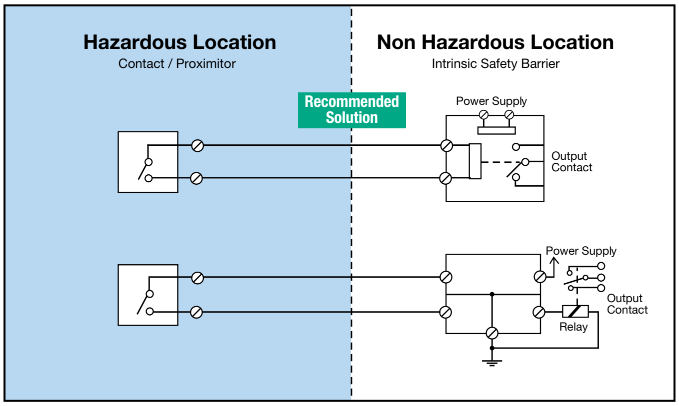

Figure 8.13

Application examples for contacts/proximitors

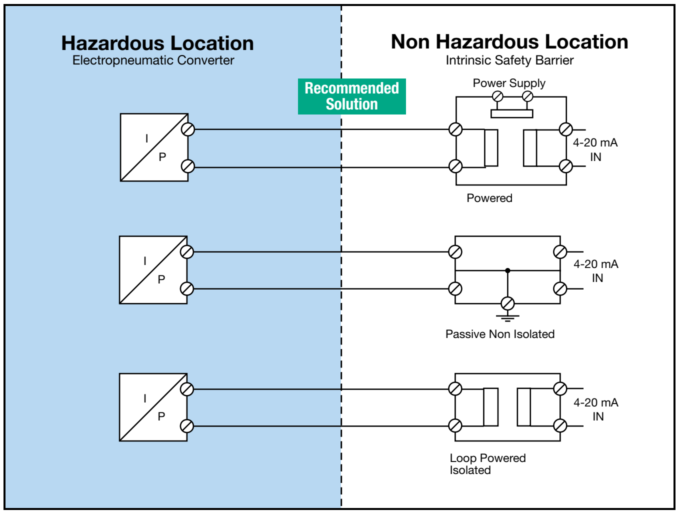

Figure 8.14

Application examples for electropneumatic converters

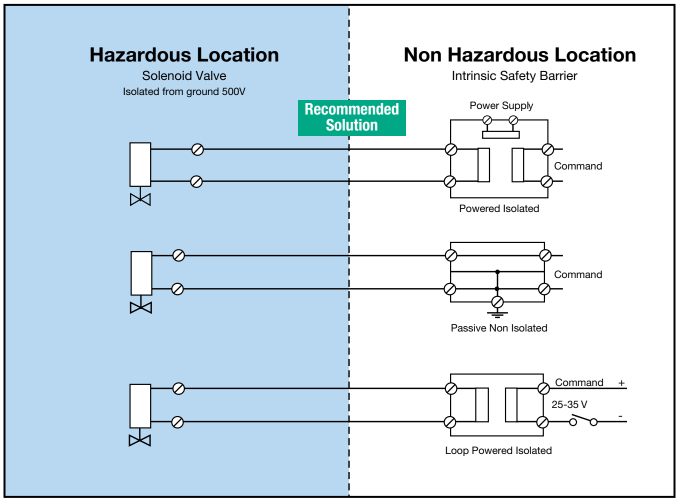

Figure 8.15

Application examples for solenoid valves

Section 9
Practical Solutions

Intrinsic safety barriers are the core of Pepperl+Fuchs product portfolio. We offer the widest selection of products for protection of electrical signals located in hazardous (explosive) areas. This guide presents common hazardous area applications involving intrinsic safety barriers to assist in selecting the correct barrier for your application.

By far, our most popular intrinsic safety barrier is the flexible, DIN rail mounted K-System isolator. This product line consists of over 150 different functional designs to meet the demands of today's factory and process automation industries. The unique design allows simple expansion with no additional wires, and can be easily designed for several redundant power configurations. K-System components meet SIL IEC61508 ratings to ensure conformity to international safety standards for systems and processes.

Zener diode barriers are the most economical hardware method available to solve a hazardous area barrier/intrinsic safety application. Our SafeSnap series of zener barriers has over 85 unique versions to solve your intrinsic safety application. SafeSnapPlus barriers contain a removable fuse that eliminates disassembly, disconnection of wiring or disposal of an entire barrier in the event of a fault.

In addition to the intrinsic safety barriers presented in this application guide, Pepperl+Fuchs also offers HiD2000, our line of backplane mounted isolated barriers. This innovative product is ideal for applications requiring tight DCS or system integration. The powerful motherboard system is available in a wide range of termination assembly versions that can be installed easily. The intrinsic safety modules simply plug into the motherboard, so wiring is never an issue on the barrier itself. Plus, HART multiplexers can be integrated easily into a HiD2000 system once the proper module is installed on the motherboard.

Also available is our µZ range of zener diode barriers that combines outstanding features and performance in a compact housing. Its thin width and low profile—the lowest profile zener on the market—make it perfect for those hard-to-reach areas of a cabinet or an enclosure. Plus, µZ comes with many of the great features found in our full line SafeSnap product.

At Pepperl+Fuchs, we build and support quality products that meet the demands of our customers and take intrinsic safety well into the 21st century.

Switches and NAMUR Sensors

Zener Diode Barriers

The following illustration shows a standard method of transferring the switch status. Zener diode barriers in the "quasi-floating" configuration enable a load to operate in either leg of the power supply.

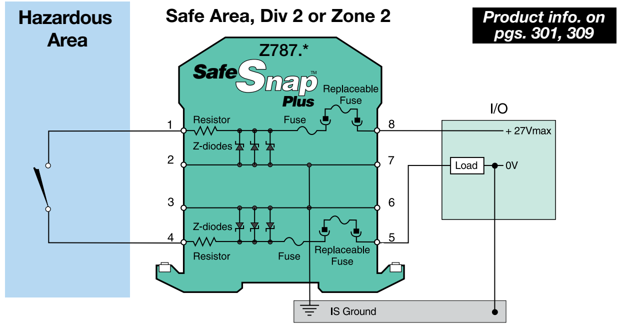

Figure 9.1

This illustrates an alternate method of providing mutlitple channels in a "quasi-floating" configuration. The first channel of the Z787.* (or Z787.H.*) is used as the field power supply while each diode return channel is isolated from ground.

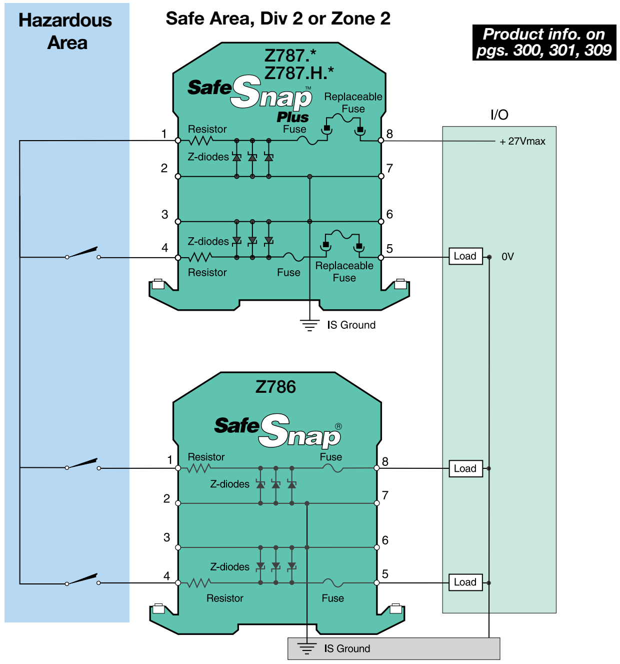

Figure 9.1

Note: *SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.*

Isolated Barriers

The barriers shown in the following diagrams are galvanically isolated switch repeaters. These units are provided with an amplifier that transfers discrete signals (NAMUR proximity sensors/mechanical contacts) from a hazardous area to a safe area. The proximity sensor or mechanical contact will initiate a safe area control mechanism in the barrier such as a relay contact or transistor. All of these barriers can be used in SIL 2 applications according to IEC 61508 and in SIL 3 applications when installed in a redundant structure. The following illustrations show several of the possible configurations.

Single Channel AC

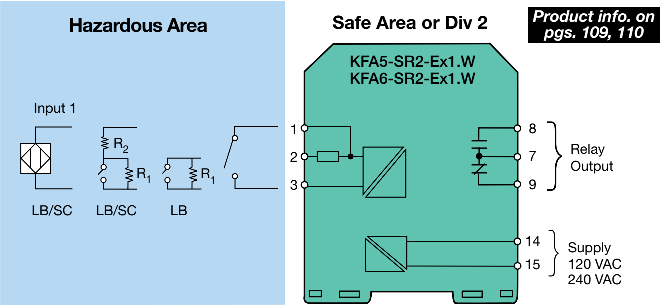

Figure 9.3

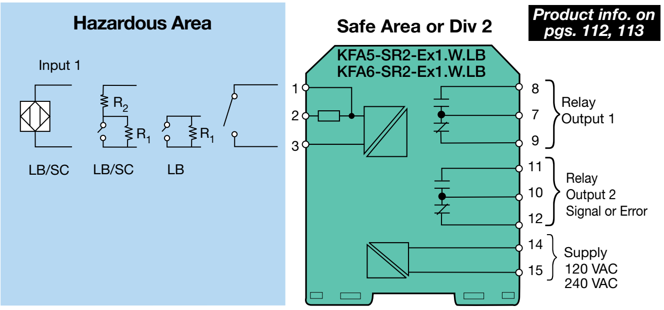

Figure 9.4

Dual Channel AC

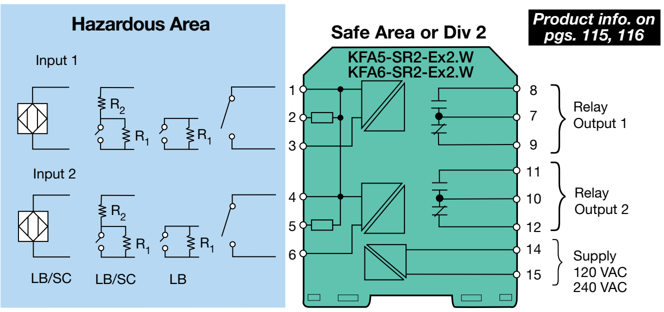

Figure 9.5

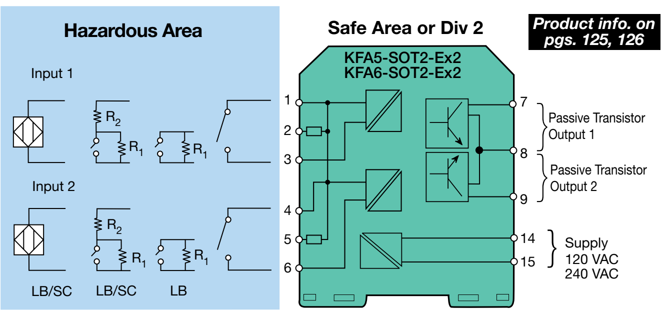

Figure 9.6

Single Channel DC

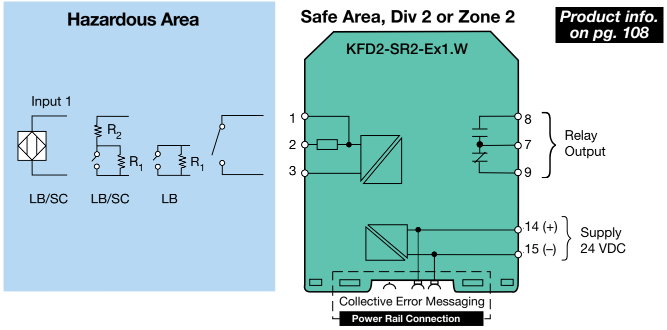

Figure 9.7

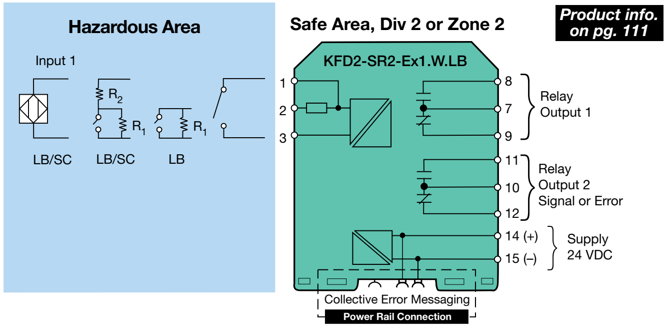

Figure 9.8

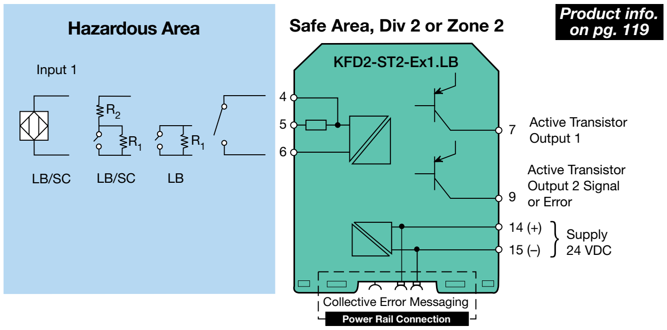

Figure 9.10

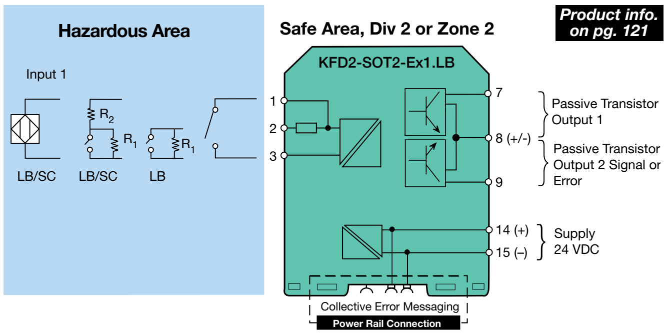

Figure 9.11

Dual Channel DC

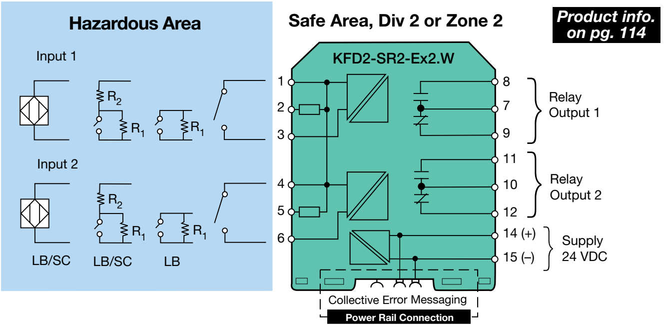

Figure 9.12

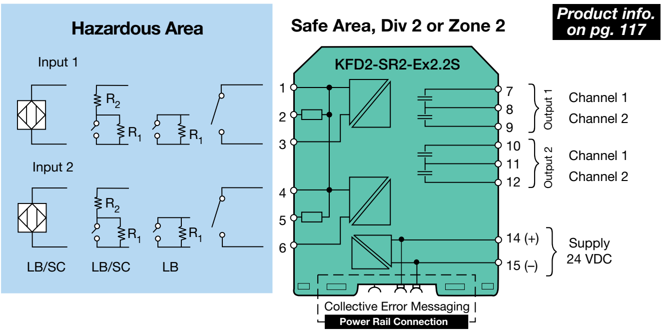

Figure 9.13

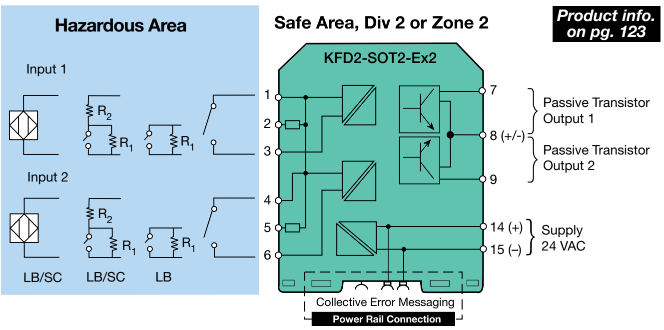

Figure 9.14

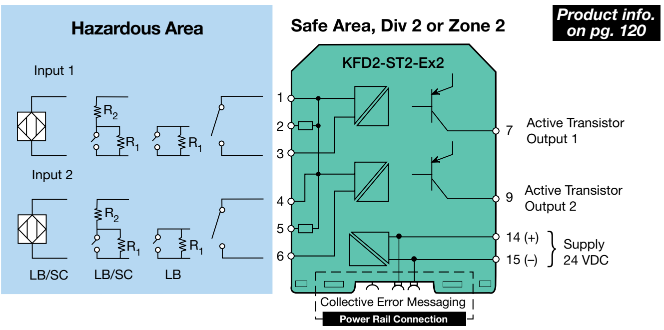

Figure 9.15

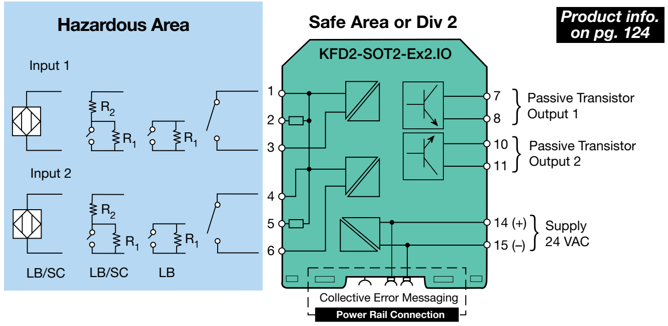

Figure 9.16

Quad Channel DC

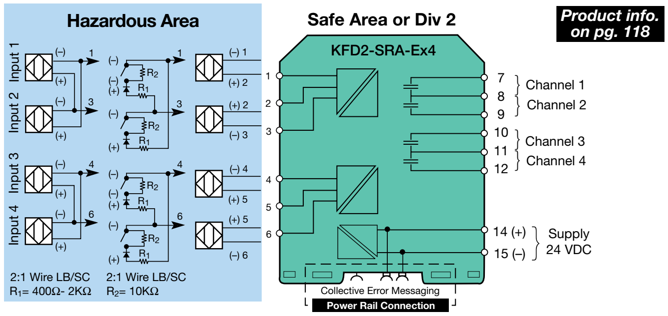

Figure 9.17

Transmitters

Zener Diode Barriers

This is the most common method of connecting a 2-wire transmitter to a zener barrier. Due to the "quasi-floating" configuration of this barrier, multiple I/O channels are not required to be isolated from one another.

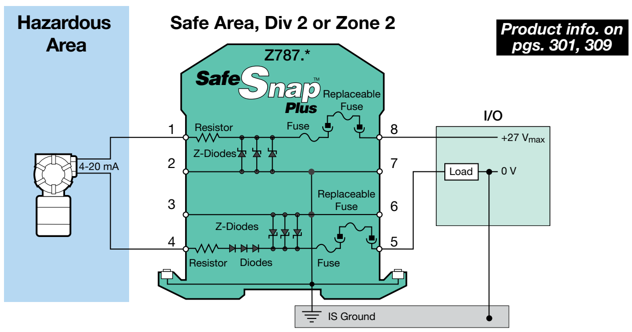

Figure 9.18

The figure below shows the most efficient method of connecting 2-wire transmitters providing the power supply for each I/O channel is individually isolated from one another or the measurement load is attached to the positive leg of the supply as shown.

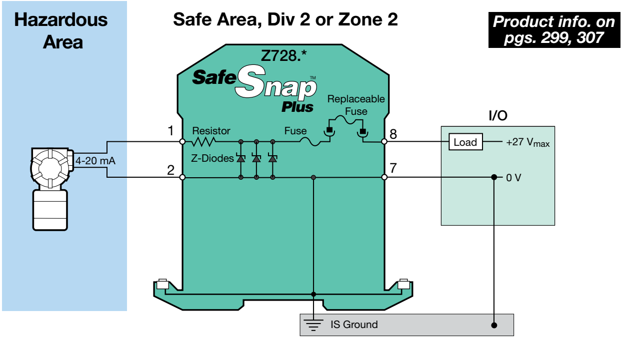

Figure 9.20

Note: *SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.*

If the I/O system requires a 1-5 V input, the Z788.R contains a precision 250 Ω resistor internally connected between Terminals 3 and 4 to facilitate the 1-5 V output from a 4-20 mA transmitter.

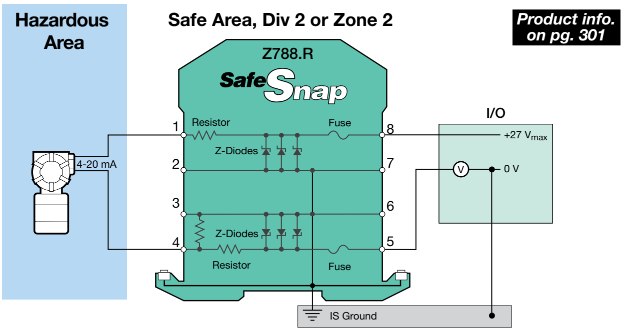

Figure 9.21

Note: *If additional voltage is required for the transmitter, the Z788.R.H can provide the necessary increase. The entity parameters must, however, be verified.*

Isolated Barriers

Dual Channel Isolated Transmitter Power Supply

This dual channel galvanically isolated transmitter power supply provides 3-way isolation between power, input and output for optimal signal intergrity. This isolator powers a 2-wire tranamitter within a hazardous area and transfers the anlog 4-20 mA signal from the hazardous to the safe area. These barriers are suitable for SIL 2 applications according to IEC 61508.

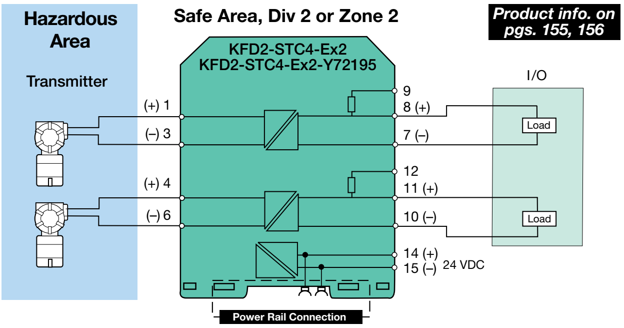

Figure 9.22

Isolated Transmitter Power Supply

This galvanically isolated transmitter power supply provides 3-way isolation between power, input and output for optimal signal integrity. This intrinsic safety barrier can be used for 2 or 3-wire transmitters (0/4-20 mA) and will source current to a 800 Ω load in the safe area with an accuracy of ≤10 μA. This barrier is suitable for SIL 2 applications according to IEC 61508.

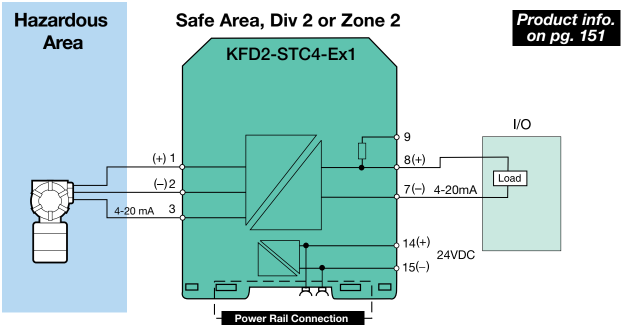

Figure 9.23

Isolated Transmitter Power Supply

This figure shows a galvanically isolated transmitter power supply similar to Figure 9.23, except the safe area output sinks the current from the I/O device. This barrier is suitable for SIL 2 applications according to IEC 61508.

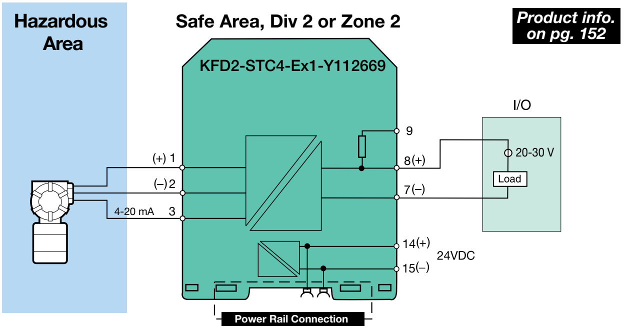

Figure 9.24

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Isolated Transmitter Power Supply

This figure illustrates a galvanically isolated transmitter power supply similar to Figure 9.23, except the safe area output is equipped with 2 isolated outputs. These barriers are suitable for SIL 2 applications according to IEC 61508.

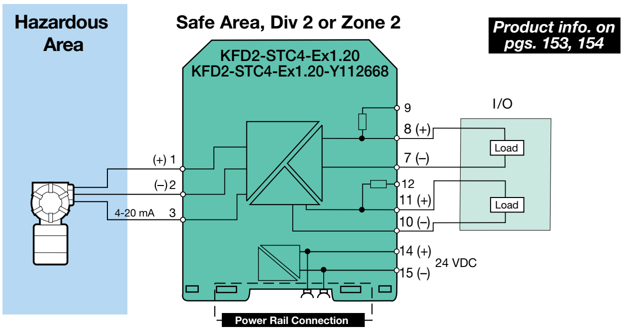

Figure 9.25

Note: *The KFD2-STC4-Ex1.20-Y112668 has sink mode outputs.*

SMART Transmitters

Zener Diode Barriers

For bidirectional digital communication between the safe and hazardous locations, the Z787.* is the most common zener barrier used for SMART transmitter applications. The communicator can be connected as shown, however other configurations are possible.

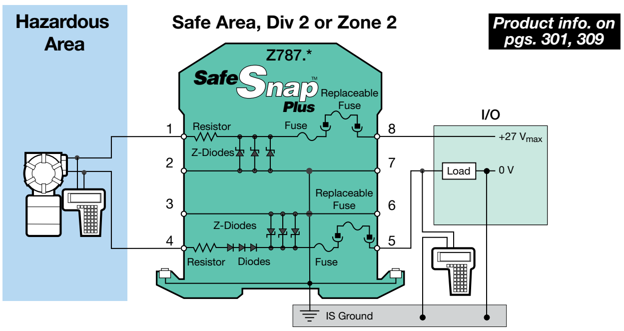

Figure 9.26

The figure below shows an alternate method of achieving bidirectional SMART communication through a zener diode barrier. The circuit implementing the Z728.* zener barrier must be individually isolated from each I/O channel or must have the measurement load attached to the positive leg of the supply for proper analog/digital communication to occur.

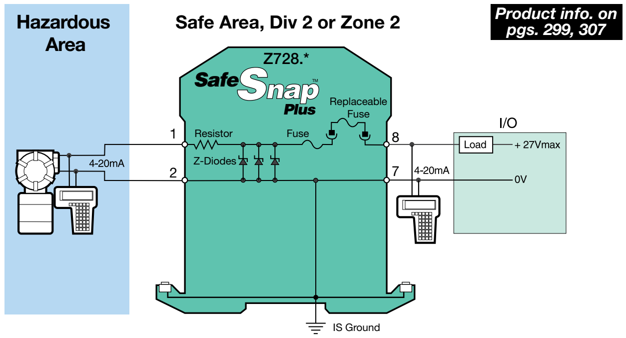

Figure 9.27

Note: *When using zener barriers with SMART Transmitters, the over-all resistance for the loop must be considered to ensure correct operation. SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.*

Isolated Barriers

Isolated SMART Transmitter Power Supplies

The following illustrations identify wiring diagrams for P+F's galvanically isolated SMART transmitter power supplies. This group of barriers provides signal isolation between the hazardous and safe areas while providing the necessary voltage for 2-wire SMART transmitters. Nearly all field device manufacturers have been successfully tested with P+F isolators. It must be noted that some high frequencies used for communication require the KFD2-STC3-Ex1 to be used since this isolator is rated for frequencies up to 40 kHz. The transfer characteristics of these units is ≤ 10 µA. The STC4 version barriers are suitable for SIL 2 applications according to IEC 61508 and SIL 3 applications when installed in a redundant structure.

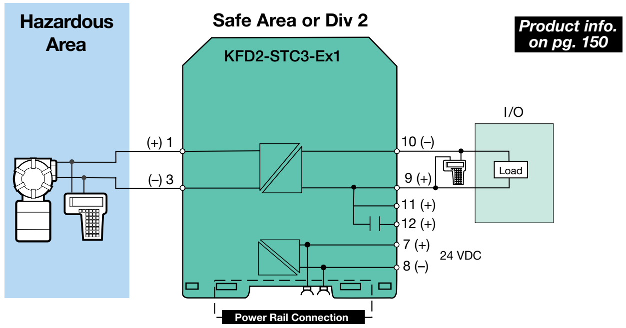

Figure 9.28

Note: *Depending on calibrator design, connection can be made across Terminals 9 and 10 in the safe area.*

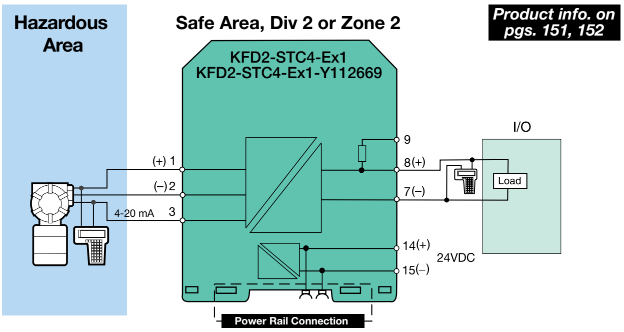

Figure 9.30

Note: *The KFD2-STC4-Ex1.20-Y112669 has sink mode outputs.*

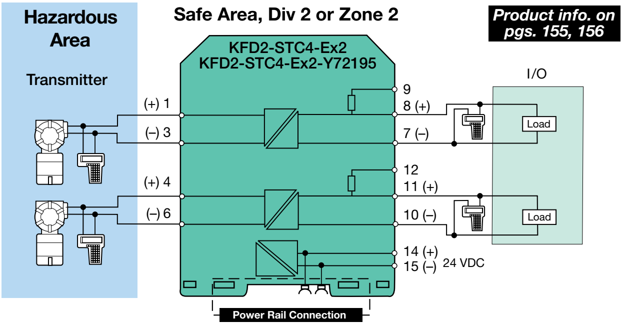

Figure 9.31

Note: *The KFD2-STC4-Ex2-Y72195 has sink mode outputs*

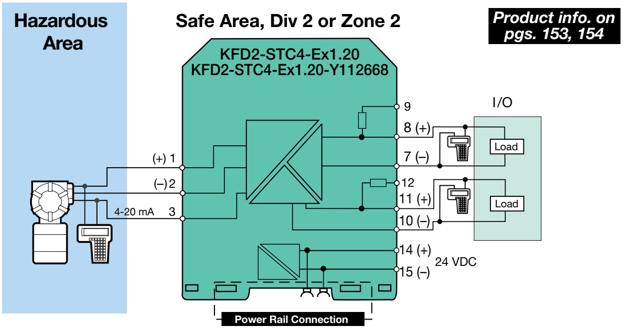

Figure 9.32

Note: *The KFD2-STC4-Ex1.20-Y112668 has sink mode outputs.*

I/P Converters

Zener Diode Barriers

A single channel Z728.* is the most efficient method of connecting an I/P converter if the power supply in the controller is either isolated from other I/O channels or has its negative return connected to the earth ground.

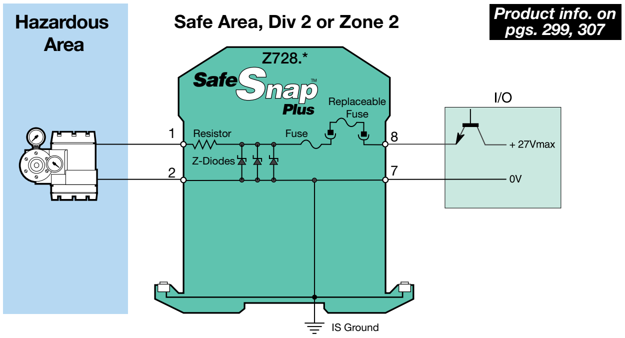

Figure 9.33

Note: *In order to conserve DIN rail space, the dual channel Z779.* could provide operation and protection for two I/P converters if the Z728.* is acceptable.*

A dual channel Z787.* can be used in situations where the return line of the I/P cannot be connected to the earth ground. The additional diode-return channel of the Z787.* provides isolation for the 4-20 mA current.

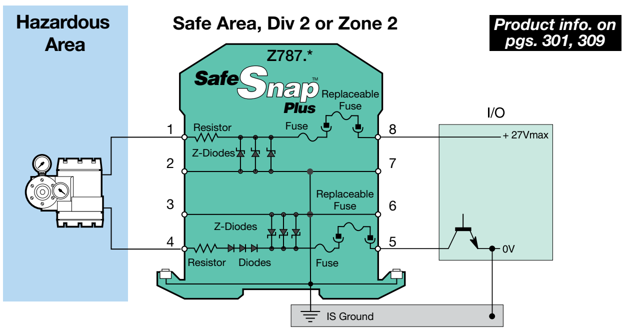

Figure 9.34

Note: *SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.*

Isolated Barriers

Isolated Current/Voltage Driver

The KFD2-CD-Ex1.32 driver barrier features high accuracy and temperature stability. By special order both the input and output of this galvanically isolated barrier can be altered to suit the application. They can be independently configured for either voltage or current. This module provides 3-way isolation between power, input and output for superior signal integrity. This barrier is suitable for SIL 2 applications according to IEC 61508.

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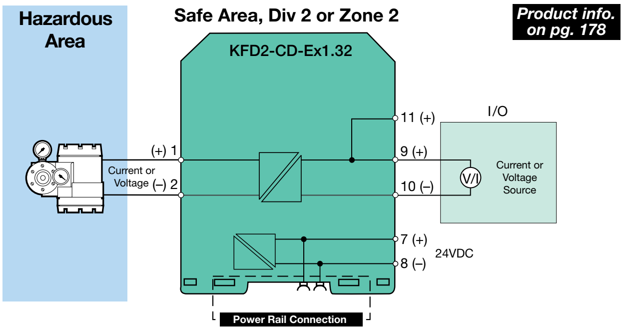

Figure 9.35

Isolated Current Driver

The loop powered KFD0-CS-Ex1.51P barrier is galvanically isolated making its application very simple. Although primarily designed for fire detector applications where accuracy is much less important, it is usually accurate enough for I/Ps. The accuracy of the KFD0-CS-Ex1.51P is ≤200 µA. This barrier is suitable for SIL 2 applications according to IEC 61508.

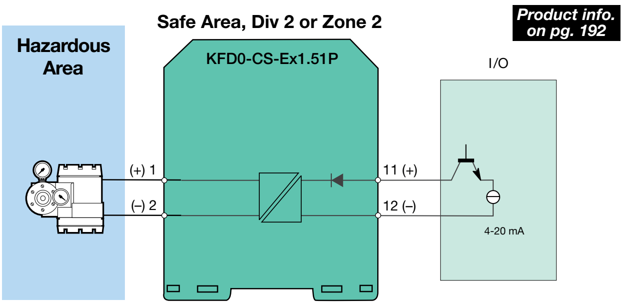

Figure 9.36

Note: A dual channel KFD0-CS-Ex2.51P can provide both cost and space savings.

Isolated Current Driver

The KFD2-SCD2-Ex1.LK current driver barrier features 3-way isolation between power, input and output. The isolator is designed to control I/P converters in a hazardous location. It also provides lead breakage and short circuit monitoring. This barrier is suitable for SIL 2 applications according to IEC 61508.

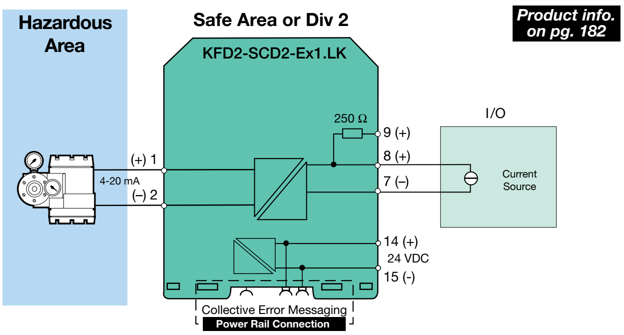

Figure 9.37

Dual Channel Isolated Current Driver

The KFD2-SCD2-Ex-2.LK is a dual channel current driver barrier, and provides 3-way isolation between power, input and output. The isolator is desiged to control I/P converters electrical values and positioners in a hazardous area. It also provides lead breakage and short circuit monitoring. This barrier is suitable for SIL 2 applications according to IEC 61508.

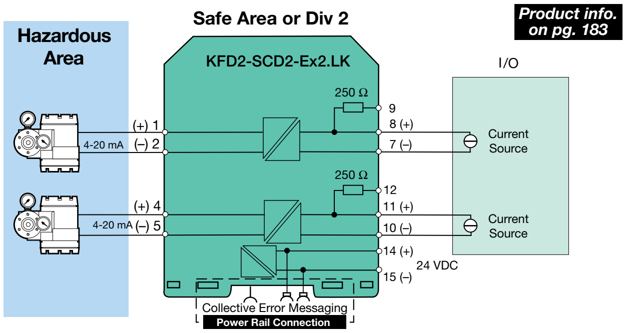

Figure 9.38

SMART I/P Converters

Zener Diode Barriers

A single channel Z728.* is the most efficient method of connecting a 2-wire SMART I/P if the power supply in the controller is either isolated from other I/O channels or has its negative return connected to the earth ground.

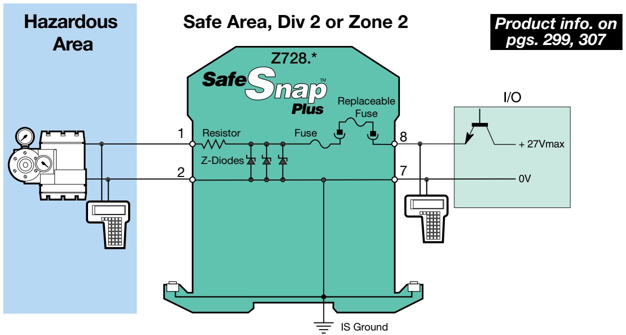

Figure 9.40

A dual channel Z787.* can be used in situations where the return line of the SMART I/P cannot be connected to the earth ground. The additional diode-return channel of the Z787.* provides isolation for the 4-20 mA current and digital signal.

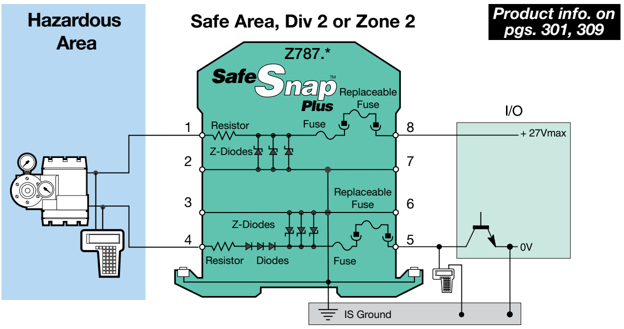

Figure 9.41

Note: *When using zener barriers with SMART I/P field devices, the over-all resistance for the loop must be considered to ensure correct operation. SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.*

Isolated Barriers

Isolated SMART Current Driver

The KFD2-SCD2-Ex1.LK SMART current driver barrier provides 3-way isolation between power, input and output for optimal signal integrity. This intrinsic safety barrier is designed to control SMART I/P converters in a hazardous location. The digital information generated by the processing system, field device or hand-held terminal is bidirectionally transferred by the barrier. This barrier is suitable for SIL 2 applications according to IEC 61508.

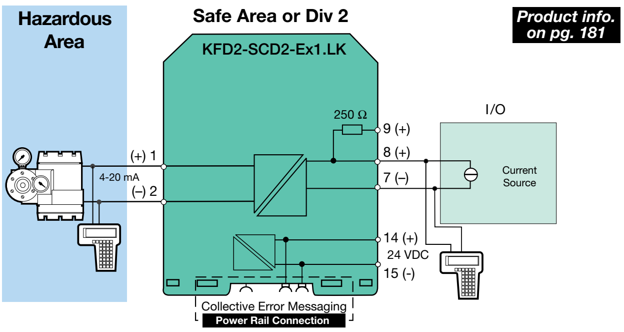

Figure 9.42

Dual Channel Isolated SMART Current Driver

The KFD2-SCD2-Ex2.LK is a dual channel SMART current driver barrier, and which provides 3 way isolation between power, input and output. The isolator is designed to control SMART I/P converters,electrical valves and positioners in a hazardous area. It also provides lead breakage and short circuit monitoring. This barrier is suitable for SIL 2 applications according to IEC 61508.

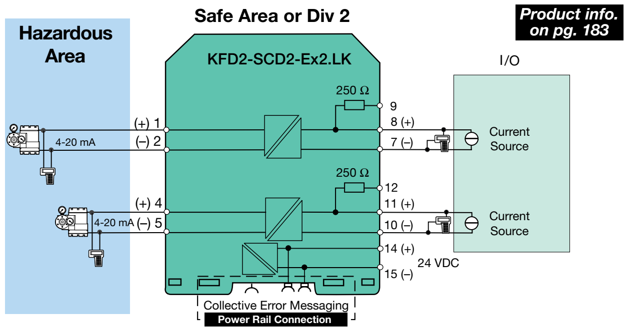

Figure 9.43

Thermocouples

Zener Diode Barriers

This is most common method of connecting a thermocouple to a zener diode barrier. The dual channel configuration provides a balanced circuit with a maximum of 64 Ω in each channel, allowing operation for any thermocouple type.

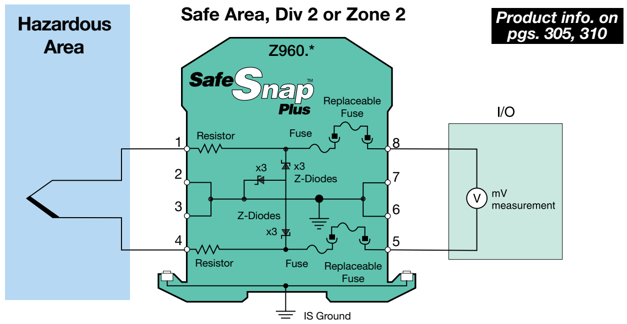

Figure 9.44

Note: *SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.*

Isolated Barriers

Isolated Loop Powered Thermocouple Transmitter

The loop powered KFD0-TT-Ex1 barrier is galvanically isolated and provides a 4-20 mA output for multiple thermocouple inputs. This barrier can be configured manually for the thermocouple type and upscale or downscale burnout and is also provided with zero and span point potentiometers.

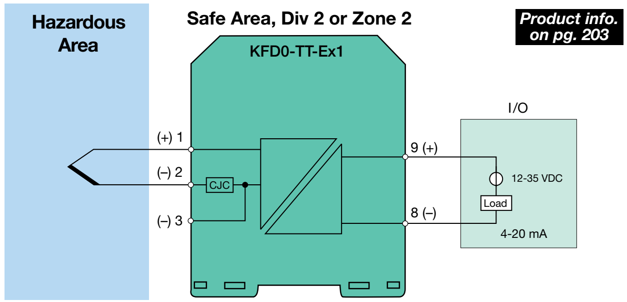

Figure 9.45

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Isolated Milivolt Repeater

When an increased interference rejection or increased isolation between the thermocouple and measuring instrument is required, this galvanically isolated mV repeater can provide the necessary results. This barrier will repeat the mV signal generated by the thermocouple while the KFD2-VR-Ex1.50m.R and KFD2-VR-Ex1.50m.L will additionally output a +80 mV or –80 mV signal during a burnout condition.

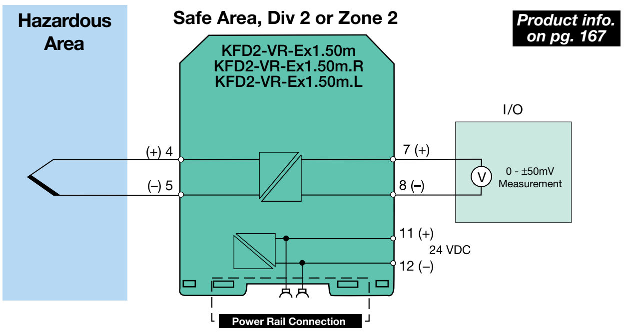

Figure 9.46

Isolated Thermocouple Transmitter – mA

This figure illustrates a galvanically isolated thermocouple transmitter barrier. This barrier provides accuracy and temperature stability over the entire input range selected. The thermocouple type, burnout condition, span, zero, tag information and user specific data are configurable through a standard PC port and a P+F software package.

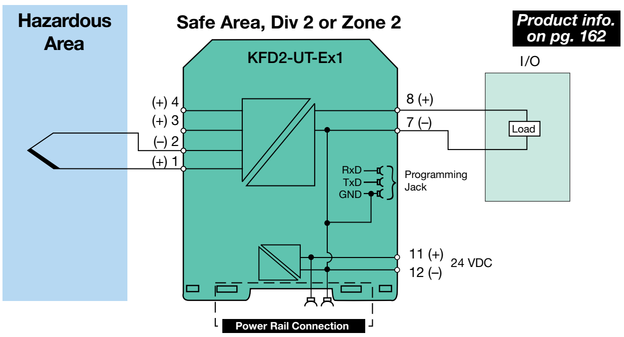

Figure 9.47

Note: *Contact Pepperl+Fuchs regarding the availablity of the new single-channel KFD2-UT2-Ex1 and dual-channel KFD2-UT2-Ex2.*

RTDs

Zener Diode Barriers

This circuit shows a 3-wire RTD connected to a Z954 zener barrier. Due to its 3-channel configuration, the negative power supply lead is not connected directly to ground, providing a "quasi-floating system." All three channels have matched end-to-end resistance which in conjunction with the bridge measuring instrument keep errors to a minimum.

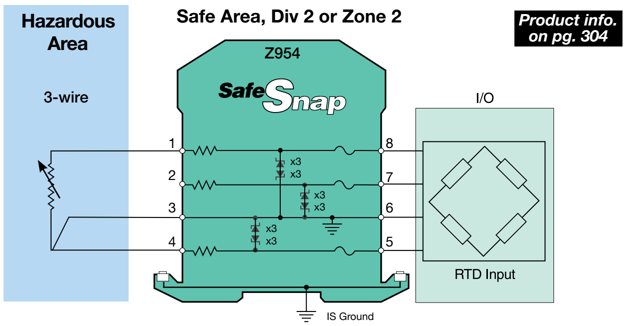

Figure 9.48

A 4-wire RTD connection with zener barriers offers the most accuracy. In this configuration, the measurement circuit is not sensitive to the end-to-end resistance of the barrier.

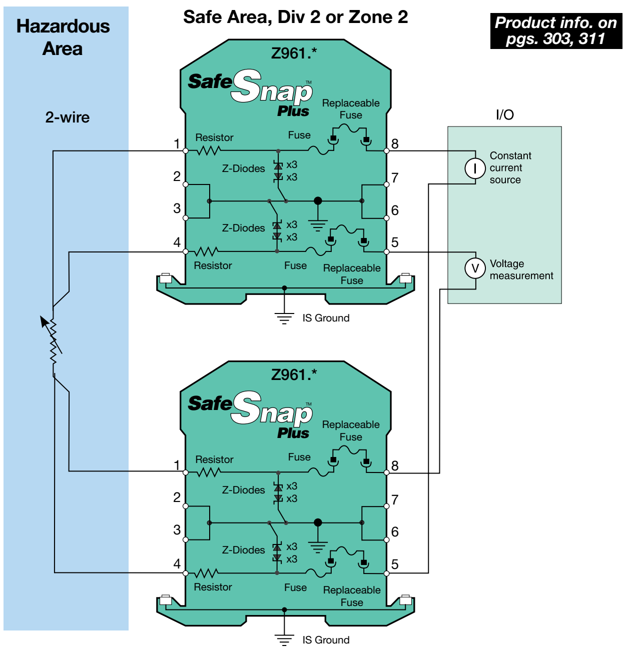

Figure 9.49

Note: *SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.*

Isolated Barriers

Isolated Loop Powered RTD Transmitter

The loop powered KFD0-TR-Ex1 barrier is galvanically isolated and provides a 4-20 mA output for 2- or 3-wire RTDs. The zero and span for the RTD are adjusted manually with calibration potentiometers located on the barrier.

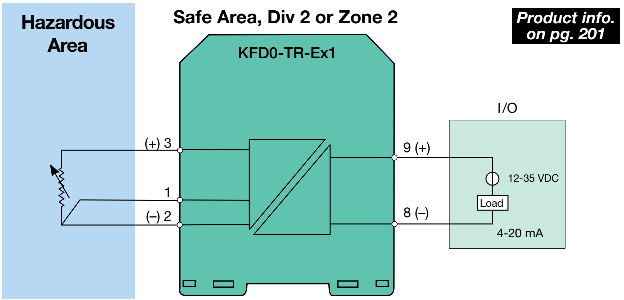

Figure 9.50

Isolated RTD Transmitter

When increased interference rejection or increased isolated between the RTD and measuring instrument is required, this galvanically isolated RTD repeater can provide the necessary results. Depending on the required accuracy, this barrier can be used in a 2-, 3- or 4-wire configuration. The barrier repeats the resistance measurement of the RTD into the safe area.

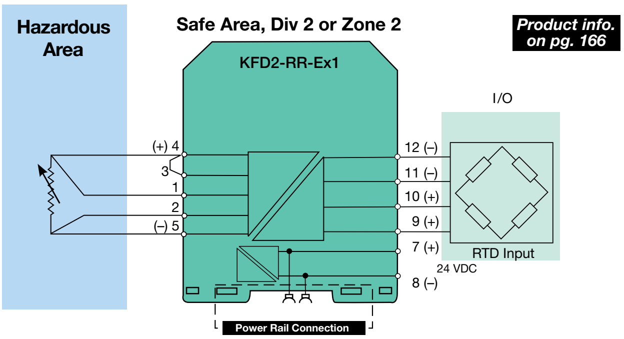

Figure 9.51

Isolated RTD Transmitter – mA

This figure illustrates a galvanically isolated RTD transmitter barrier. This barrier provides accuracy and temperature stability over the entire input range selected. The RTD type, lead breakage condition, span, zero, tag information and user specific data are configurable through a standard PC port and a P+F software package.

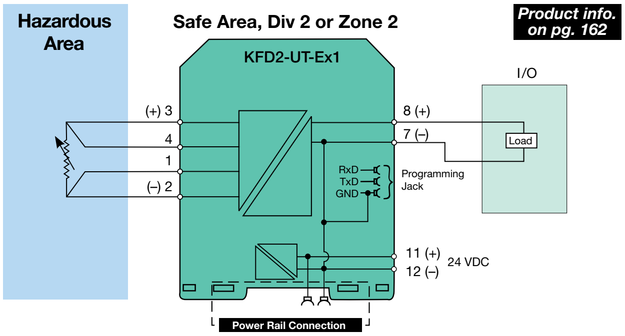

Figure 9.52

Note: Contact Pepperl+Fuchs regarding the availablity of the new single-channel KFD2-UT2-Ex1 and dual-channel KFD2-UT2-Ex2.

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Strain Gauges

Zener Diode Barriers

The Z966.* zener barrier supplies a 350 Ω strain gauge bridge with the necessary excitation voltage while the optional Z964.* supplies the power supply with a voltage sense input for increased accuracy. The millivolt signal is transferred to the safe area through the Z961.* These barriers are connected in a "quasi-floating" configuration for the best possible signal integrity when using zener barriers.

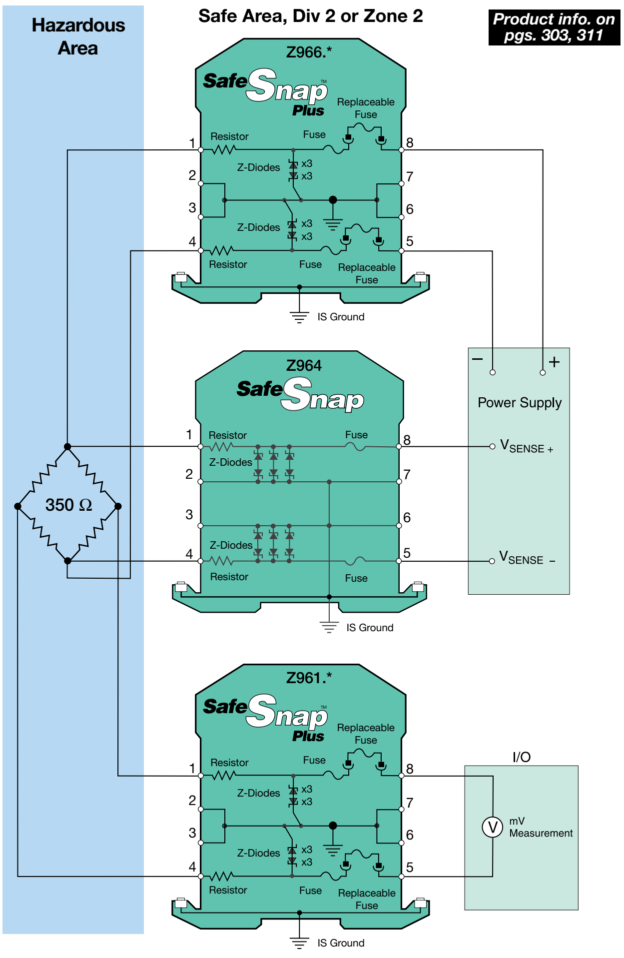

Figure 9.53

Note: SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.

Isolated Barriers

Isolated Strain Gauge Current Transmitter

This figure illustrates a galvanically isolated strain gauge transmitter barrier. With its 3-way isolation between power supply, input and output, this barrier provides a highly accurate means of supporting strain gauge applications within a hazardous location. The strain gauge can be connected in either a 4- or 6-wire configuration depending on the required accuracy. The strain gauge excitation voltage, mV signal range, tare value and current output range are all field selectable on the barrier.

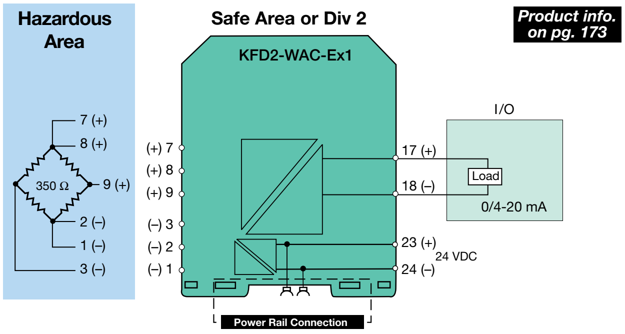

Figure 9.54

Note: Contact Pepperl+Fuchs regarding the availablity of the new KFD2-WAC2-Ex1 strain gauge converter.

Vibration Monitoring

Zener Diode Barriers

This figure illustrates an example of a zener diode barrier and a vibration monitor in the hazardous area. The vibration monitor outputs a voltage signal, which is referenced to the positive supply, proportional to the vibration waveform at frequencies up to 4 kHz. Therefore, a negative polarity barrier is required and the positive side of the power supply must be grounded.

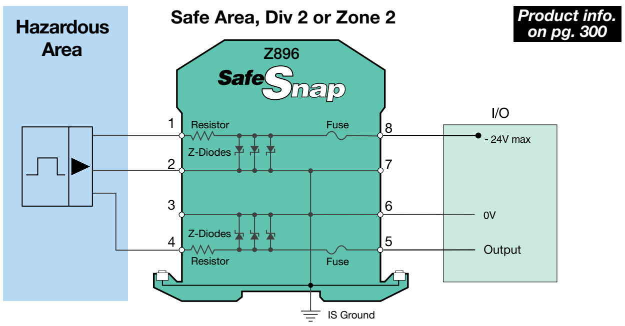

Figure 9.55

Isolated Barriers

Isolated Voltage Repeater

The galvanically isolated model KFD2-VR4-Ex1.26 is designed specifically for use with vibration monitoring instruments. The unit is designed with three port isolation between power, input and output while it provides a stable supply for the vibration transducer. A high-input impedance amplifier modifies the transducer signal and repeats the signal on safe side by a second amplifier to give low-output impedance.

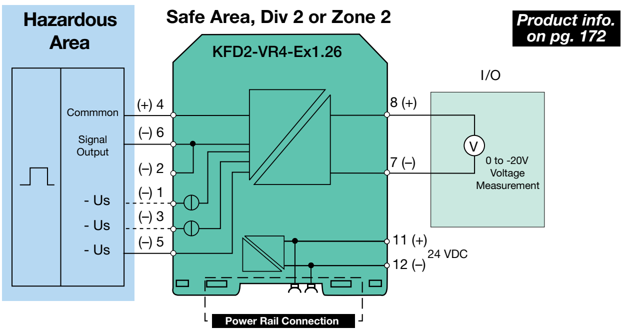

Figure 9.56

Isolated Voltage Repeater

For applications where the frequency requirements are over 5 kHz, the KFD2-VR-Ex1.19-Y109129 will accept an active voltage pulse up to +/-10V. The voltage pulse can be transmitted up to frequencies of 50 kHz.

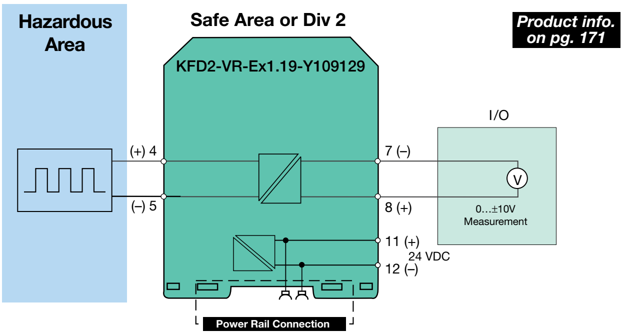

Figure 9.57

Potentiometers

Zener Diode Barriers

If the accuracy of the potentiometer signal is not critical, the Z960.* offers a 3-wire configuration that connects the return line to the I.S. ground. This connection can influence the measurement since the resistance in the negative line must be taken into account.

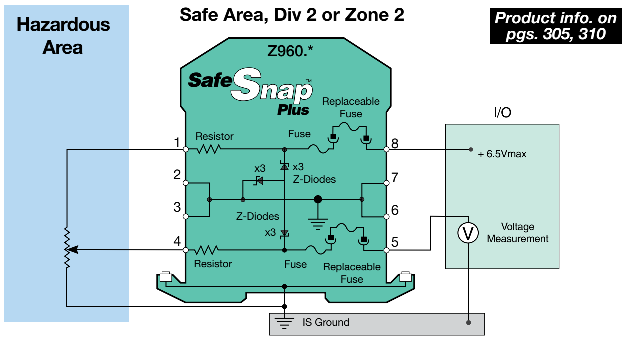

Figure 9.58

When a higher degree of accuracy is required on the potentiometer voltage signal, a four-wire connection is recommended. In this case, neither the source nor the signal is connected to the I.S. ground. This results in a high level of accuracy.

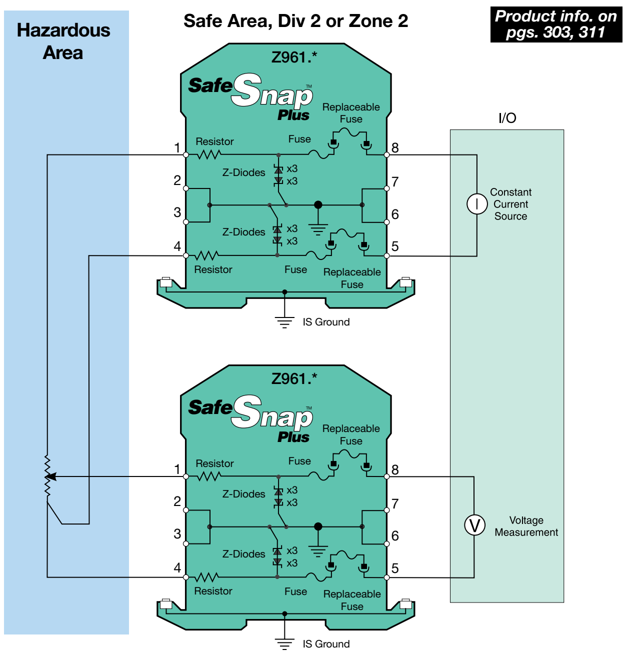

Figure 9.59

Note: *SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.*

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Isolated Barriers

Isolated Potentiometer Transmitter – mA

These potentiometer transmitter barriers feature 3-way galvanic isolation between power supply, input and output for the best signal conversion accuracy and noise immunity. This barrier can be configured for either 3-, 4- or 5-wire potentiometers depending on the required accuracy of the application. The KFD2-PT2-Ex1-4 and KFD2-PT2-Ex1-5 are designed to provide a safe area signal of 0-20 mA and 4-20 mA respectively.

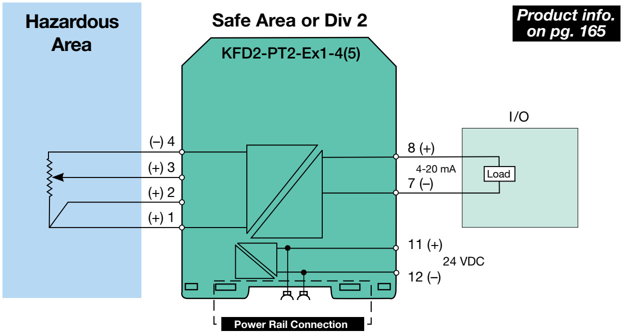

Figure 9.60

Isolated Potentiometer Transmitter – Voltage

The KFD2-PT2-Ex1, KFD2-PT2-Ex1-1, KFD2-PT2-Ex1-2 and KFD2-PT2-Ex1-3 are similar to the unit shown in Figure 9.60, except the safe area output is a voltage signal of 0-10 V, 0-5 V, 2-10 V and 1-5 V respectively.

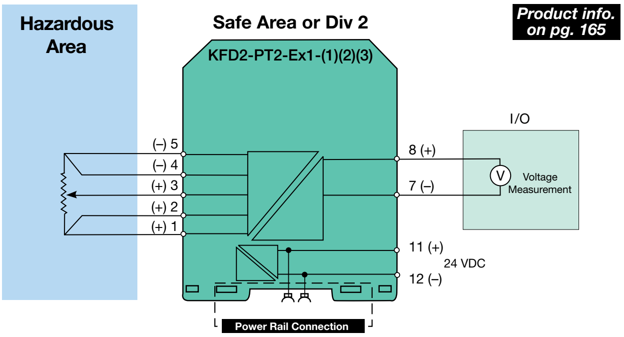

Figure 9.61

LED Clusters, Solenoids and Alarms

Zener Diode Barriers

Figure 9.62 illustrates the standard method of driving solenoids, LED clusters and audible/visual alarms in a hazardous location. For this configuration, the control switch must be located in the source line for proper operation. If additional voltage is required for the field instrument, a Z728.H.* may provide the necessary increase.

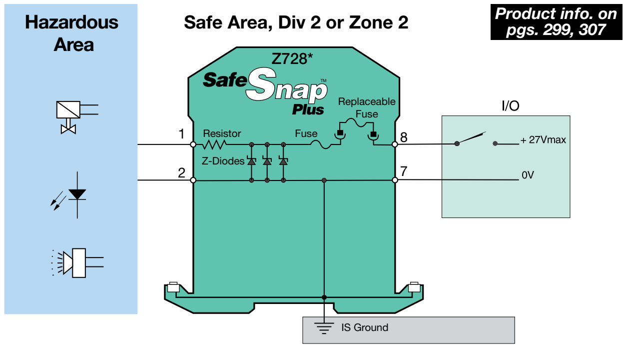

Figure 9.62

This figure shows an alternate method of driving solenoids, LED clusters and audible/visual alarms in a hazardous location when the control switch is located in the return line.

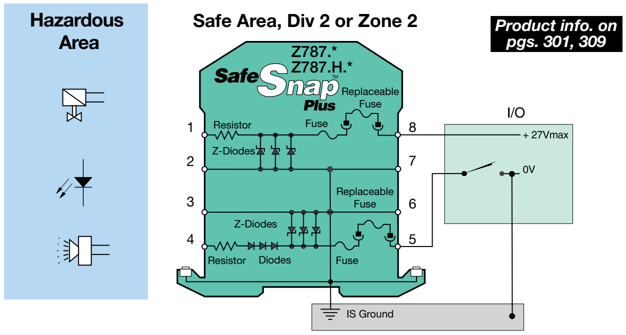

Figure 9.63

Note: SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.

Isolated Barriers

Isolated Loop Powered Discrete Output Driver

The loop powered KFD0-CS-Ex1.51P barrier is a galvanically isolated discrete output barrier. It can be used to energize certain types of solenoids, LEDs and alarms. With a 24 V source, this barrier will supply approximately 27 mA at 12 V to the hazardous area field instrument. This barrier is suitable for SIL 2 applications according to IEC 61508.

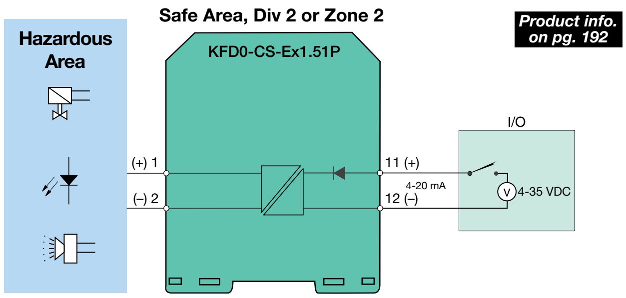

Figure 9.64

Note: A dual channel KFD0-CS-Ex2.51P provides both cost and DIN rail space savings.

Isolated Loop Powered Solenoid Driver

The following solenoid driver barriers provide the necessary power to energize discrete output instruments such as solenoids, LEDs and alarms. The KFD2-SD-Ex1.48, KFD2-SD-Ex1.48.90A and KFD2-SD-Ex1.36 are internally current-limited to 35mA, 45mA and 80mA respectively. These barriers are suitable for SIL 2 applications according to IEC 61508.

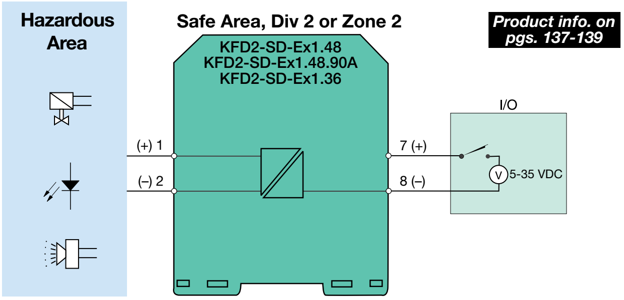

Figure 9.65

Isolated Logic Input Solenoid Driver

The KFD2-SL2-Ex1 Single channel solenoid driver provides power to a load in a hazardous area and can be switched on or off by a signal from a logic circuit. It also provides lead breakage, short circuit monitoring and collective error messaging. These barriers are suitable for SIL 2 applications according to IEC 61508.

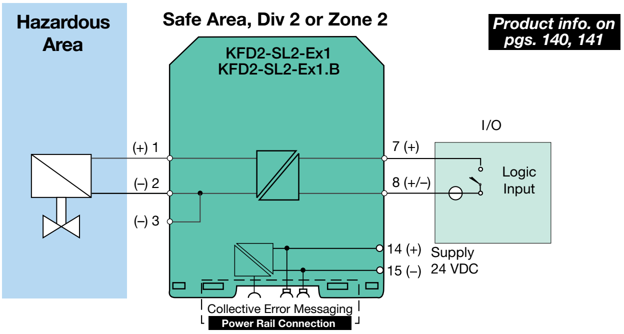

Figure 9.66

Note: KFD2-SL2-Ex1.B is the basic unit and does not include such features as LB/SC monitoring or collective error massaging.

Dual Channel Isolated Logic Input Solenoid Driver

The KFD2-SL2-Ex2 dual channel solenoid driver provides power to a load in a hazardous area and can be switched on or off by a signal from a logic circuit. It also provides lead breakage, short circuit monitoring and collective error messaging. These barriers are suitable for SIL 2 applications according to IEC 61508.

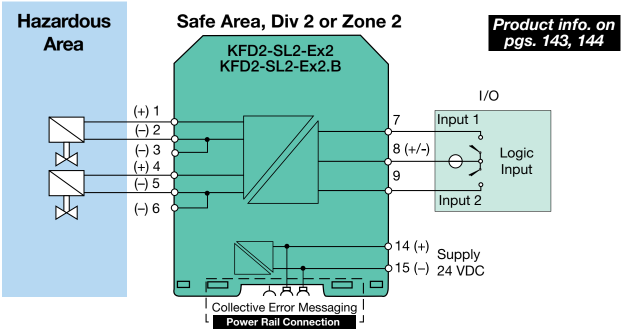

Figure 9.67

Note: KFD2-SL2-Ex2.B is the basic unit and does not include such features as LB/SC monitoring or collective error massaging.

Isolated Logic Input Solenoid Driver

The KFD2-SL2-Ex1.LK solenoid driver provides power to a load in a hazardous area and can be switched on or off by a signal from a logic circuit. It also provides lead breakage, short circuit monitoring and collective error messaging and a relay contact fault output that can be wired in series for a fail-safe configuration. This barrier is suitable for SIL 2 applications according to IEC 61508.

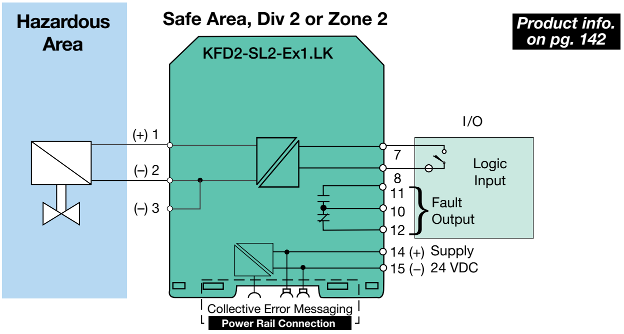

Figure 9.68

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Pulse Input/Serial Communication

Zener Diode Barriers

The figure below illustrates an example of a zener diode barrier and an active pulse generator located in the hazardous area. The voltage pulse can be as high as 20 V since the signal is isolated from ground due to the dual channel configuration of the zener diode barrier.

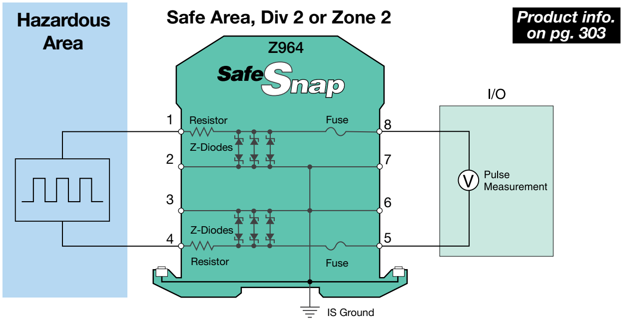

Figure 9.69

This configuration can be used when the passive pulse signal generator requires a voltage source to operate. The pulses are received in the safe area through the diode return channel of the barrier. These diodes may attenuate the pulse height, therefore the sensitivity of the receiving instrument must be considered.

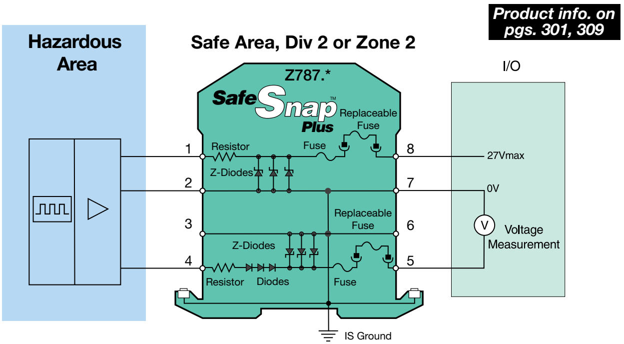

Figure 9.70

Note: *SafeSnapPlus zener barriers are designed with replaceable fuses which is denoted by an "F" at the end of the model number. SafeSnap zener barriers have internal fuses.*

Isolated Barriers

Isolated Millivolt Repeater

This galvanically isolated millivolt repeater provides 3-way isolation between the power, input and output for the best pulse repetition. When the active pulse signal has a magnitude of ± 500 mV, the KFD2-VR-Ex1.500m will accurately repeat the signal up to 1.3 kHz.

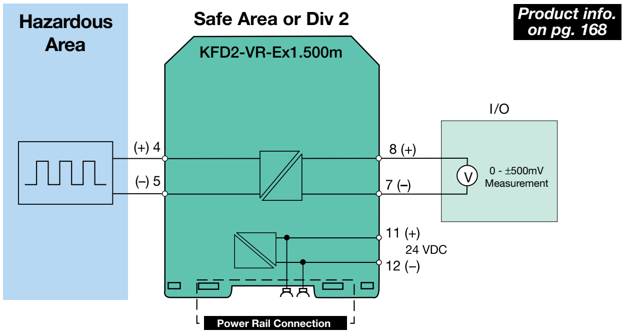

Figure 9.71

Isolated Voltage Repeater

This figure shows a galvanically isolated voltage repeater similar to Figure 3, except the active pulse signal can have a magnitude of ± 10 V. Additionally, the KFD2-VR-Ex1.19 will transmit the voltage pulse at frequencies up to 4 kHz.

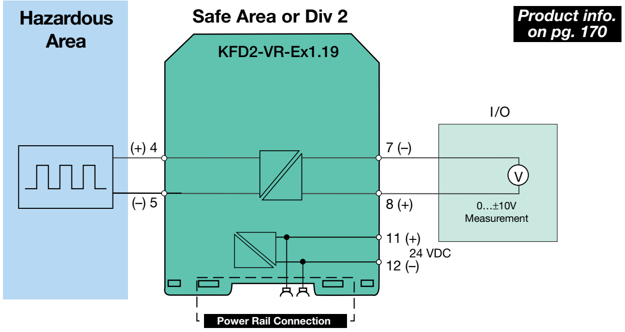

Figure 9.72

Isolated RS-232 Repeater

This figure illustrates a galvanically isolated RS-232 repeater used for data transfer through a hazardous area. The figure below shows the signal being passed through the hazardous location at a maximum data transfer of 20 k bits/sec. Since the barrier is galvanically isolated, an intrinsic safety ground is not necessary.

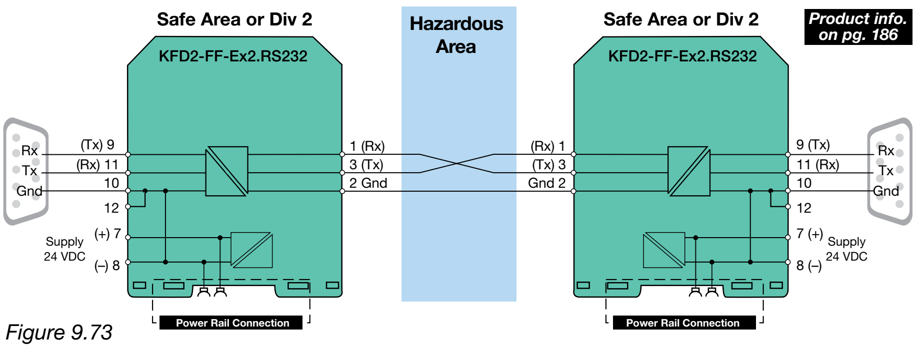

Figure 9.73

Logic Controls/Limit Alarms

Isolated Barriers

Isolated Speed Monitoring

Often it is necessary to know if a process is operating under or over a desired speed. The KFD2-DWB-Ex1.D provides relay outputs that energize at field-programmed setpoints. This barrier is suitable for SIL 2 applications according to IEC 61508.

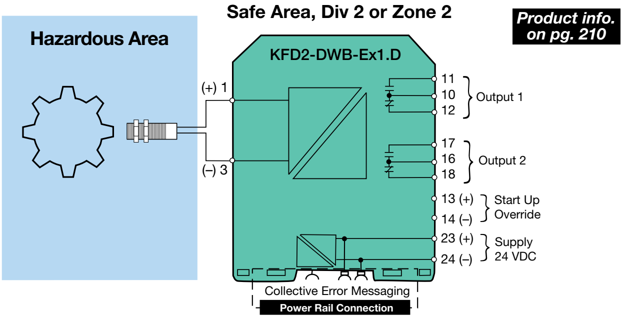

Figure 9.74

Note: *For AC Powered units ask for KFA5-DWB-Ex1.D (120 VAC) or KFA6-DWB-Ex1.D (240 VAC). Collective error messaging and Power Rail connection are not available on the AC units.*

Isolated TimeDelay Relay

The galvanically isolated KFD2-DU-Ex1.D comes with a display for easy on site programming and is commonly used in applications requiring on delay, off-delay, one-shot or pulsating signal conditioning.

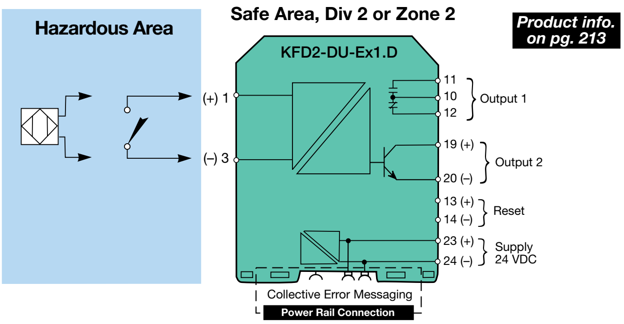

Figure 9.75

Note: *For AC versions of this unit order the KFA5-DU-Ex1.D (120 VAC) or the KFA6-DU-Ex1.D (240 VAC). The AC units are not equipped with collective error messaging or Power Rail connection.*

Isolated Univeral Frequency Converter

The galvanically isolated KFD2-UFC-Ex1.D comes with a display for easy on site programming and converts the signals from a NAMUR proximity sensor or dry contact into a 0/4-20 mA output. For non-display version use the KFD2-UFC-Ex1. These barriers are suitable for SIL 2 applications according to IEC 61508.

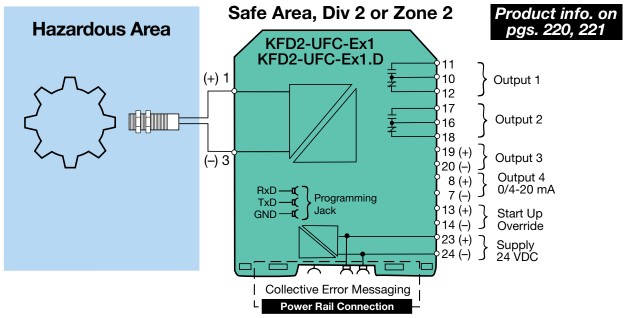

Figure 9.76

Note: *For AC powered units ask for our universal power supply version, the KFU8-UFC-Ex1.D or KFU8-UFC-Ex1. Collective error messaging & Power Rail connections are not available on the universally powered units.*

Isolated Rotation Direction Indicator and Synchronization Monitor

The galvanically isolated KFD2-UFT-Ex2.D comes with a display for easy on site programming and is used when a rotation direction indicator or synchronization monitor is needed. A non-display unit is available with the KFD2-UFT-Ex2.

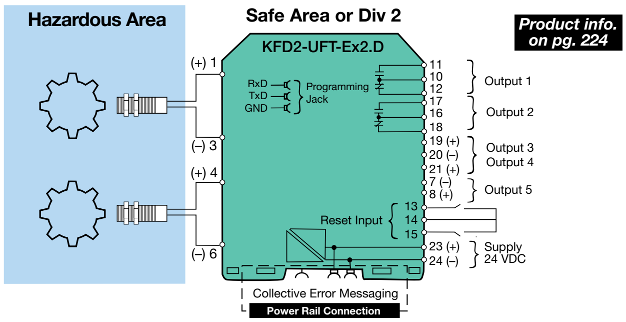

Figure 9.77

Note: *For AC versions of this unit ask for our universal power supply version the KFU8-UFT-Ex2.D or the KFU8-UFT-Ex2. Collective error messaging & Power Rail connection are not available on the universally powered units.*

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Isolated Limit Alarm

The following galvanically isolated limit alarm provides two independent set points for RTDs, thermocouples or voltage/current signals. This intrinsic safety barrier is PC configurable for trip point, hysteresis and high/low alarm. This module not only provides the necessary isolation for intrinsic safety, but also offers a simple logic function for alarm set points.

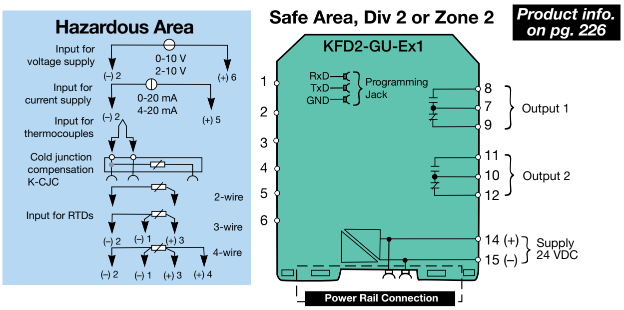


Figure 9.78

Isolated Limit Alarm

The following galvanically isolated limit alarm provides two independent set points for RTDs, thermocouples, voltage or potentiometer signals. This intrinsic safety barrier is PC or push-button programmable.

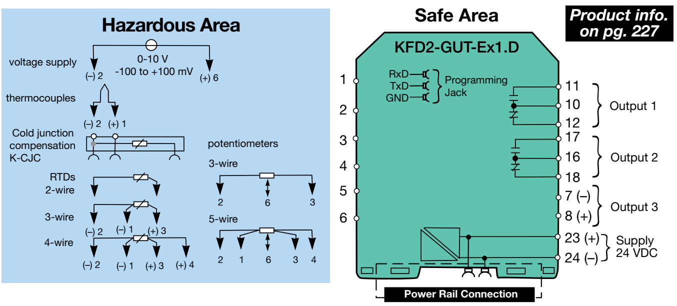


Figure 9.79

Isolated Limit Alarm

The KFD2-CRG-Ex1.D is a galvanically isolated transmitter power supply for a 2- or 3-wire transmitter or current source. It not only repeats the 0/4-20 mA signal but has two programmable relay outputs. Lead breakage and short-circuit monitoring are provide along with collective error messaging. This barrier is suitable for SIL 2 applications according to IEC 61508.

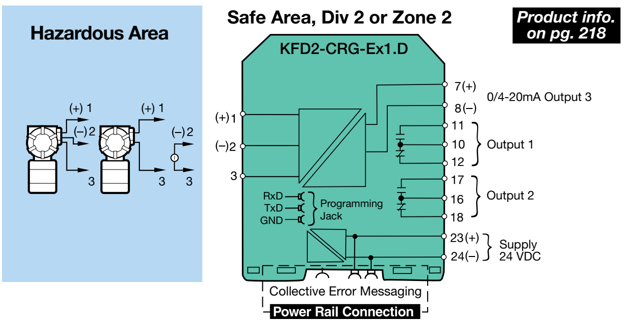


Figure 9.80

Isolated Latching Relay

The galvanically isolated KFA5-SR2-Ex2.W.IR provides latching functions for use as a two step controller. To maintain the levels of a process between two points, this level control unit can be programmed for pump-up or pump-down applications.

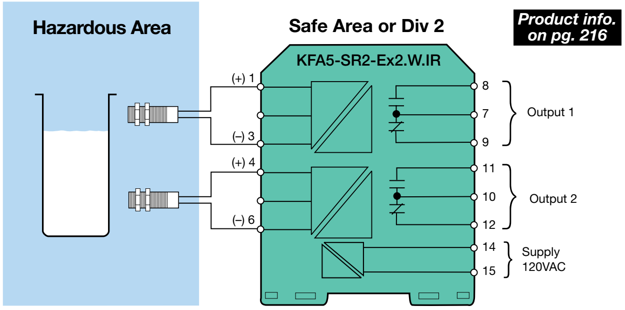


Figure 9.81

Power Supplies

Conventional Wiring Method

The conventional method of wiring barriers is daisy-chaining from barrier to barrier.

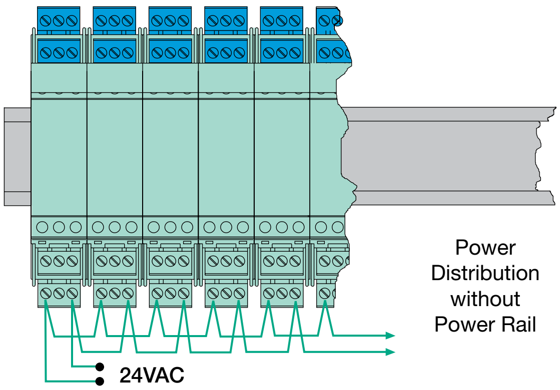


Figure 9.82

Power Rail Method

Eliminate the labor intensive daisy chain method by using Power Rail. Combined with the KFD2-EB2 power feed module and the PR-03 or UPR-03 Power Rail, this configuration quickly and easily distributes power to all the barriers via 2 gold plated conductors.

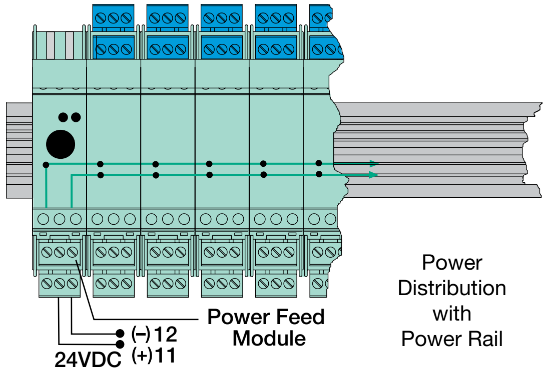


Figure 9.83

Note: *PR-03 is a 500 mm insert for standard 35mm DIN Rail. UPR-03 is sold in 2 meter lengths and comes with its own 35 mm DIN Rail.*

Collective Error Messaging

The collective error messaging enables lead breakage and short circuit monitoring for Pepperl+Fuchs isolators. The KFD2-EB2 power feed module combined with PR-03 or UPR-03 Power Rail allows a fault signal to be transferred along the Power Rail's 3rd conductor to the KFD2-EB2 and provides a relay contact output for the entire isolator group.

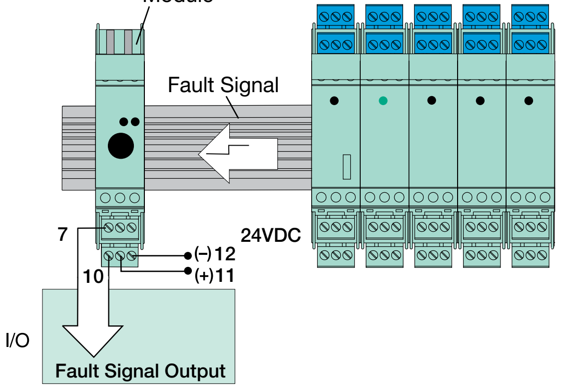


Figure 9.84

Redundant Power Feed Modules

When a process needs a higher degree of safety and reliability, use two KFD2-EB-R4A.B modules. If either power supply fails, the Power Rail and isolators continue to be energized via the second power feed module.

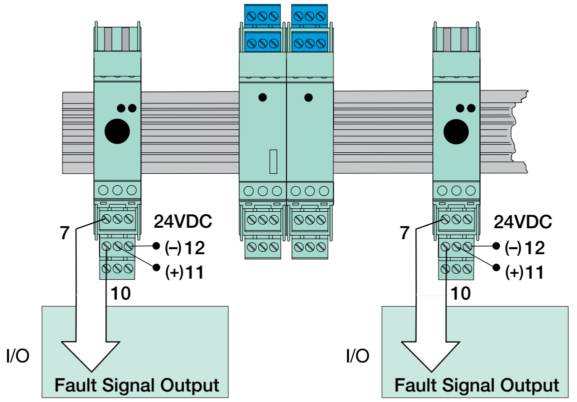


Figure 9.85

Power Supply

Provide a complete solution for an isolator installation by using a 120/240 VAC to 24 VDC/4A power supply. The KFA6-STR-1.24.4. It snaps quickly on to Power Rail to easily distribute power to the isolators.

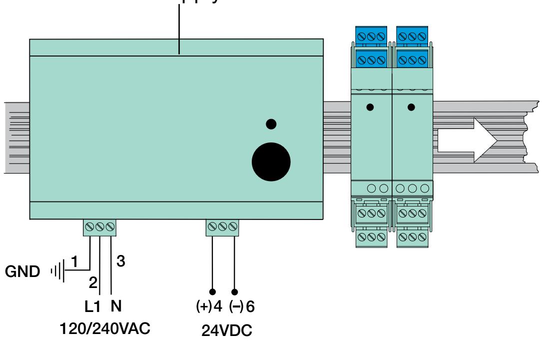


Figure 9.86

Note: *The number of isolators per power supply depends upon the power consumption of each module.*

Power Supply

The KFA6-STR-1.24.500 provides 24 VDC 500 mA for those small projects that do not require a large number of isolators. It snaps quickly on to Power Rail to easily distribute power to the isolators.

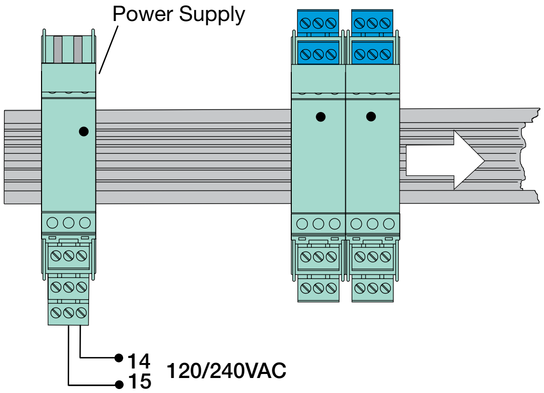
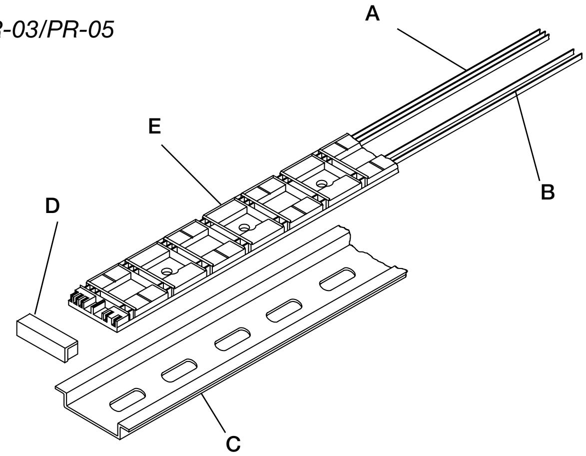


Figure 9.87

Note: The number of isolators per power supply depends upon the power consumption of each module.

Power Rail

PR-03/PR-05



A - One conductor for collective error (PR-03)
Three conductors for bus connection (PR-05)

B - Two conductors for power supply

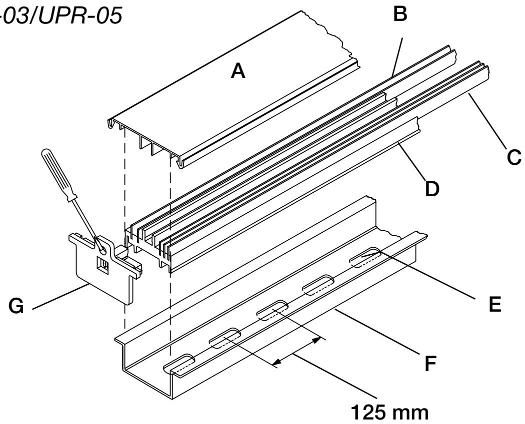
C - DIN Rail

D - End Cap

E - Power Rail

Note: PR-03 and PR-05 is a 500 mm insert for standard 35 mm DIN rail. Individual sections can be connected with a VE-PR link.

UPR-03/UPR-05



A - Cover

B - Two leads for power

C - One conductor for collective error (UPR-03)
Three conductors for bus connection (UPR-05)

D - Universal Power Rail

E - Mounting Holes

F - DIN Rail

G - End Cap UPR-E

Note: The UPR-03 nd UPR-05 is two meters in length and comes with its own 35 mm DIN rail.

Section 10
Intrinsic Safety: Future Trends

Intrinsic safety (I.S.) is not new. In fact I.S. has been used as a method of preventing explosions in hazardous locations for decades, and has changed only incrementally since its introduction as a method of protection. But there are three trends warranting discussion that will impact the future application of intrinsic safety.

Evolving Technology

Revolutionary is not a word commonly associated with intrinsic safety technology, and that is not likely to change. However, in an effort for manufacturer's to remain competitive, instrumentation technology is evolving and has led to the need for higher-level integration of I/O systems and with I.S. products.

Many of today's I.S. systems are developed such to maximize a standard line of products, while incorporating an adaptive interface strategy. This allows standard I.S. products to be integrated into a system by way of standard adapter modules that are unique to a given manufacturer.

One example is the I/O processors of a DCS manufacturer. These are most often connected to a termination panel that facilitates connection to the field instruments.

Historically speaking, these DCS termination panels would then be hard-wired to marshaling terminals in a separate cabinet, which in turn were connected to I.S. termination panels. The latest approach is to provide I.S. termination panels that are compatible with the DCS termination panel, and allow direct connection using the standard I/O interconnecting cable. Many I.S. manufacturers are now providing a means of marshaling (cross-wiring) on the I.S. termination board, resulting in even lower installation costs.

Newer, more accurate microprocessor-based instrumentation is requiring higher-speed communication protocols. As a result, the industry is moving toward a universally accepted communication protocol that can be used in a multi-drop fashion, and that can communicate data bidirectionally between the instrument and the I/O controller.

4-20 mA signaling systems are still commonly used today, but such signals provide limited performance due to A/D converter resolution in the range of 12-16 bits, and can only transmit a single variable in one direction. The HART protocol, introduced more than 15 years ago and now a defacto standard for intelligent instrumentation, facilitates the bi-directional communication of numerous process variables.

Because HART communication signals can coexist with 4-20 mA systems, it was not a burden for I.S. manufacturers to provide HART compatible products. Hand-held terminals used to configure and communicate with smart instruments were designed to be intrinsically safe, and barriers were designed to pass bipolar voltages between the instrument and the controller. The use of multidrop configurations was also added to the equation.

Strategies in Communication Protocol

Fieldbus, HART and Profibus are the main driving technologies for the next generation of Asset Optimization applications within process automation. Traditional 4-20 mA or analog devices relay little or no maintenance information that can help maximize asset effectiveness. Fieldbus devices, on the other hand, provide timely reporting of diagnostic data, with the ability to implement more sophisticated maintenance applications now and in the future.

Intelligent field devices such as transmitters and positioners are able to provide critical status information to the control system via fieldbus networks. Other conditional events are used to provide maintenance triggers via logical comparison of data within the device, or from other sources (e.g. historical conditions). In the case of maintenance triggers, fieldbus has been a prime motivator for the shift from reactive maintenance to predictive maintenance, maximizing plant availability. The degree of assistance within the maintenance procedure could include work order generation – status tracking – component inventory checking and ordering.

Fieldbus is clearly the underlying driver for Asset Optimization opportunities because of the access to device diagnostics and stored data. As technology advances further, the opportunity to distribute Asset Optimization functions and more advanced maintenance triggers into the field device becomes possible. All of this is possible using intrinsic safety techniques; therefore, the promise of new developments involving these exciting new technologies and intrinsic safety is guaranteed.

International Standards

A plethora of economic and political changes are taking place across the globe, which have indeed created a need for some level of international standards. Manufacturers of all sizes are now marketing products around the world, and many end-users are standardizing on the products they use throughout their business – whether the plant is in North America, China or anywhere in between. The result is a very strong trend toward harmonizing standards, terminology and specifications that are used to certify intrinsically safe and associated apparatus.

Europe's policy is to allow the sharing of certifications between countries. For instance, CENELEC, as a unifying body, allows products certified by BASEEFA in the United Kingdom to be used in France, Germany, Italy, etc. CENELEC standards are typically ratified by the IEC in much the same way as ISA or NFPA standards are accepted by ANSI.

In North America, the terminology and requirements of intrinsic safety are viewed in the same manner by both CSA and nationally recognized testing laboratories (NRTLs), such as FM and UL. However, subtle differences do exist, and therefore products certified by FM are not automatically accepted by CSA, and vice versa.

Initiatives by the various agencies have led to a harmonizing of specifications that are used to certify products, as well as to share certifications on a global basis. Most test laboratories have a mutual testing program, whereby a client may go to one agency and obtain certification for both countries. This reduces time to market for the manufacturer, and allows users to specify one product for use throughout North America.

In addition to the NEC activity, ISA has approved a set of the certification standards used by UL, FM, CSA and CENELEC. The goal is to produce a universally accepted standard for the testing of intrinsically safe and associated apparatus, including such test methods as transformer tests, zener diode tests and others. The SP12.2 standard set was developed by the ISA12.2 Committee and includes members from UL, FM, CSA, MSHA, the NEC technical committees, barrier manufacturers, instrument manufacturers and end-users.

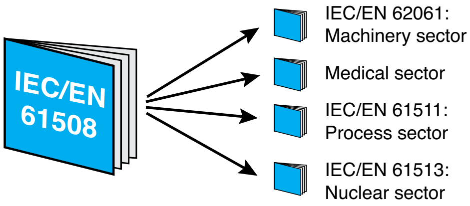
Section 11
Safety Integrity Level (SIL) Overview

Functional Safety for Signal Generation, Signal Transmission and Signal Evaluation

The internationally established standard IEC/EN 61508 has been in force since the middle of 2004. This standard focuses on the functional safety of Electrical, Electronic and Programmable Electronic Systems (E/E/PES).

The previous national standards, DIN V VDE 0801, DIN V 19250 and DIN V 19251, have lost their justification for existence and were withdrawn on July 31, 2004.

Thus far, four sector standards have been derived from IEC/EN 61508:



What Does This Mean for You as the Customer and Equipment User?

For process technology

As the sector standard, IEC/EN 61511 reflects the current state of technology.

For machinery and plant construction

The current state of the art for this sector is reflected by the standard IEC/EN 62061. For machinery and plant, which are considered in the light of the provisions of EN 954, the reference standard has changed from the old DIN V VDE 0801 (Fundamentals for computers in systems with safety tasks) to the now current IEC/EN 61508 and its sector standard IEC/ EN 62061.

Due to the process of internationalization, the value of EN 954 has also changed. Subsequently, it has received the status of an international standard and will be known as ISO 13489-1 in the future.

Burner controls

In the area of burner controls, previously covered by VDE 0116, DIN EN 50156-1 now reflects the current technology and is based in part on IEC/EN 61508.

Requirements for proximity switches

The previous standard VDE 0660 T209, for proximity sensors, is supplemented by VDE 0660 T 214/A1 and corresponds to IEC/EN DIN 60947-5-3/A3 "Requirements for proximity switches with specified behavior under fault conditions" which also creates a reference to IEC/EN 61508.

Today, in process technology and in the other sector-specific standards, E/E/PES components can be used, as soon as they satisfy the specifications of IEC/EN 61508. Other standards will follow in the future, which will likewise be aligned with the specifications of IEC/EN 61508.

What Must You Comply With?

Example: Process technology

A process plant involves risks. These risks are determined by the type of process, the substances involved and the plant environment.

In order to avoid risks, the procedures and processes selected should be as safe as possible. Secondly, mechanical protection devices should be the preferred choice. These are constructional precautions (minimum distances, protective screens, separating walls, adequate container wall thickness, selection of materials, etc.).

The reduction of risk by means of process control devices is recommended only when either alternative methods with inherently greater safety or reliable mechanical protection devices are not available. Process control devices are a suitable means of reducing process risks. When this path is chosen, the functional safety and reliability of the field instrumentation, and the control & monitoring systems must be assured. It requires adequate precautions to avoid faults while fault detection and fault rectification must also be guaranteed.

The First Step - Analysis

The risk potential of a process plant is determined in accordance with IEC/EN 61511. Depending on the established risk, a risk reduction plan is implemented. If this risk reduction involves process control means, the components used within the structurew must satisfy the requirements of IEC/ EN 61508. Both of the standards mentioned sub-divide plants and risk-reducing measures into four safety gradings: SIL1 for a minimal risk up to SIL4 for a very high risk.

The risk graph in the following figure, based on IEC/EN 61508 shows the relationship between the risk parameters and the Safety Integrity Level (SIL) for the safety function.

Risk parameter

Consequence (severity)

C_1	minor injury or damage
C_2	serious injury or one death, temporary serious damage
C_3	several deaths, long-term damage
C_4	many dead, catastrophic effects

Frequency/exposure time

F_1	rare to quite often
F_2	frequent to continuous

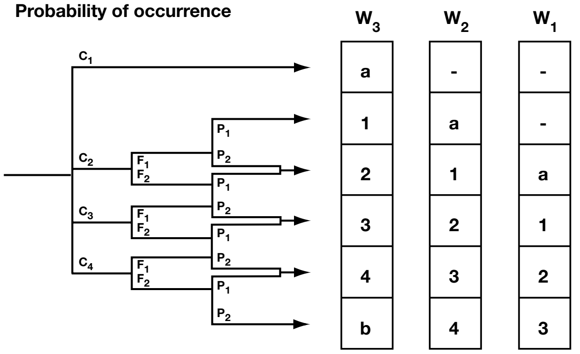
Possibility of avoidance

P_1	avoidance possible
P_2	unavoidable, scarcely possible

Probability of occurrence

W_1	very low, rarely
W_2	low
W_3	high, frequent

Probability of occurrence



1, 2, 3, 4 = Safety integrity level
- = Tolerable risk, no safety requirements
a = No special safety requirements
b = A single E/E/PE is not sufficient

Reduction of Risk

The risk analysis provides the value SIL1 to SIL4. The greater the risk, more precautions must be taken to reduce the risk and more reliable components must be used.

Quantitative components

PFD The probability of failure on demand (with PFD_{avg} as the mean value)

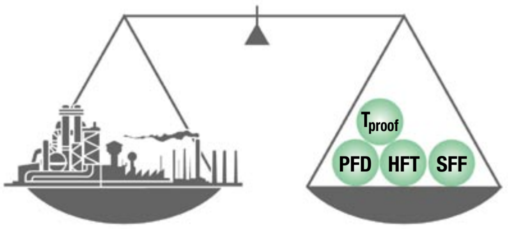
SFF Safe failure fraction - The proportion of safe failures or faults

Qualitative components

HFT Hardware fault tolerance (evaluation architecture)

T_{proof} The proof interval for the complete safety device

The counter-weight to the potential danger are all the organizational and technical measures taken to reduce the risk.



In all risk-reducing measures, it is the overall result that is critical. Thus, it is not possible to consider an individual device in the signal circuit without reference to the remaining components. Furthermore, the evaluation structure and the organizational measures, such as the interval between repeated function tests must also be considered.

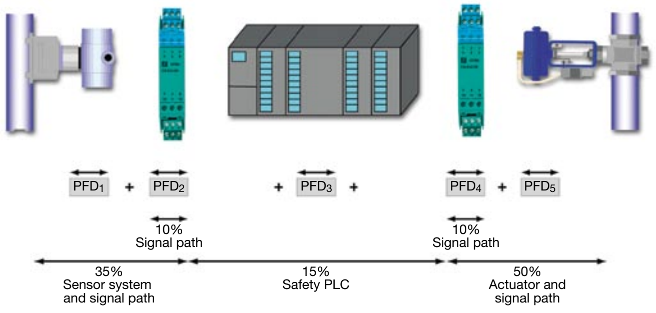
To better aid in the understanding of safety systems, we have illustrated the influence of the individual characteristics and influence factors in an example:

Organizational Measures

In process automation, the intervention of a safety device in the operating mode normally takes place with a low demand rate (low demand mode). On average, this corresponds to one such intervention during a period of one year.

T_{proof} The most important organizational precaution is the regular function testing of the complete safety device. The function test is intended to check the functional capability of the complete system, including its mechanical components. The smaller the time interval between tests, the greater the probability that the safety device will function correctly.

PFD The value of the PFD (probability of failure on demand) is the probability of a piece of equipment, within the safety network, not being available when it is needed.



Important Recommended Values in Practical Application

The PFD value for the complete safety device is the sum of the values for the individual components. The failure summation of the individual components provides the overall failure level of the instrumentation circuit (PFD1 to PFD5). The maximum permissible PFD value of the instrumentation circuit is predetermined by the desired SIL and can be obtained from the standards.

Notes on Equipment Selection

The standards contain no recommended values for the failure distribution within the instrumentation circuit. The distribution is determined by the user through selection of the respective components. The user merely has to keep within the 100 % limit. Since the sensors and actuators are installed in the field, they are subject to chemical and physical loading (Process medium, pressure, temperature, vibration, etc.); therefore, the failure risk of these components is correspondingly high. We recommend the overall PFD be divided between the individual components as follows: 25% for the sensor, 40% for the actuator, 15% for the fail-safe control and 10% for each interface module. Note, the distribution of the PFD can be applied within the 100% limit as appropriate to match the component characteristics.

Use components that alone contribute only a small percentage of the permissible total failure probability of the instrumentation circuit so a good measure of planning flexibility is built-in. This also gives you the advantage of being able to extend the safety test cycle. Low PFD values permit long test cycles and reduce the costs of plant operation.

In the documentation for our devices, the PFD values are given for use over a period of 1 year. The PFD values are based on a time factor; therefore, they increase linearly with time.

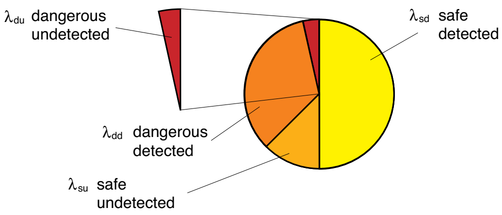
Depending on the target SIL and the corresponding PFD values, the test cycle could be a very short period of time or could be relatively long. The PFD of a device assumes the value of zero on commissioning and also on the completion of each test cycle.

If the operator of the safety device extends the test cycle from 1 to 2 years, the PFD values double as well as the probability that a device forming a component of the complete safety mechanism will fail when it is needed. If the operator reduces the test cycle for the safety device from 1 year to six months, the PFD values are reduced by half.

The PFD value of a device is a quantitative statement of the reliability of the unit within a safety-aligned application; therefore, the only part of the failure value that counts is that which is detrimental to the safety function.

Failures that do not endanger the safety function and the number of "dangerous" failures that are detected by the system and taken into consideration do not contribute to the overall PFD value.

SFF The SFF (safe failure fraction) is the proportion of "safe" failures that does not endanger the safety function (Comprising "λsd" and "λsu"). This value includes the "dangerous" failures that are detected by the system and are therefore accounted for ("λdd"). It is merely those dangerous failures ("λdu") that are undetected by the system, which are detrimental to the safety function.



A SIL Evaluation by Pepperl+Fuchs–All the Facts About Functional Safety at a Glance

By considering SFF and Tproof the following values are obtained for PFD (see table).

Example for the report (full version) on the KFD2-STC4-... transmitter power supply

Failure categories	T_{proof} = 1 year	T_{proof} = 2 years	T_{proof} = 5 years	SFF
Fail low (L)= safe Fail high (H) = safe	$PFD_{avg} = 1.6 \times 10^{-4}$	$PFD_{avg} = 3.2 \times 10^{-4}$	$PFD_{avg} = 8.0 \times 10^{-4}$	> 91 %
Fail low (L)= safe Fail high (H) = dangerous	$PFD_{avg} = 2.2 \times 10^{-4}$	$PFD_{avg} = 4.5 \times 10^{-4}$	$PFD_{avg} = 1.1 \times 10^{-3}$	> 87 %
Fail low (L)= dangerous Fail high (H) = safe	$PFD_{avg} = 7.9 \times 10^{-4}$	$PFD_{avg} = 1.6 \times 10^{-3}$	$PFD_{avg} = 3.9 \times 10^{-3}$	> 56 %
Fail low (L)= dangerous Fail high (H) = dangerous	$PFD_{avg} = 8.6 \times 10^{-4}$	$PFD_{avg} = 1.7 \times 10^{-3}$	$PFD_{avg} = 4.3 \times 10^{-3}$	> 52 %

Transmitter power supplies of the type KFD2-STC4-... are used as interfaces between the (intrinsically safe) transmitters and the process control system inputs. The signal level is 4 mA ... 20 mA. If the transfer is in accordance with NE 43, then a difference occurs between the case when the current is less than the measuring range (4.0 mA ... 3.8 mA) and a lead breakage (less than 3.6 mA). Likewise, a distinction can be made between a value above the measuring range (20 mA ... 20.5 mA) and a lead short-circuit (21 mA or higher). The conclusions to be drawn from the diagnostic features are of great significance for safety assessment. The key factor is the diagnostic capability of the safety control.

If the safety control system is unable to detect either a lead breakage or a lead short-circuit, then only 52% of the theoretically possible failures will be detected. In other words, every second failure could lead to the failure of the safety function because it goes unnoticed.

If both lead fault types - lead breakage (Fail low) and lead short-circuit (Fail high) – are detected and processed by the safety control, then over 90% of the theoretically possible failures result in a safe condition of the control. This means that only 10% of the possible failures of the safety function would be detrimental.

In order to achieve SIL2, IEC/EN 61511 requires a SFF (proportion of failures that lead to a safe condition) of at least 60%. If this value is not achieved, then a SIL classification higher than SIL1 is not permitted.

Depending on the safe failure fraction (SFF), IEC/EN 61508 requires a minimum level of hardware fault tolerance (HFT). The following table illustrates this requirement.

The SFF of Pepperl+Fuchs devices lies in the range between 60% and 100%. A device with SFF of 100% can achieve SIL3 in the 1oo1 (1 out of 1) evaluation structure (i.e., without redundancy).

The table shows the maximum permissible SIL as a function of the fault tolerance and the "safe" failure fraction in accordance with IEC/EN 61508-2 for sub-systems type A (noncomplex sub-systems).

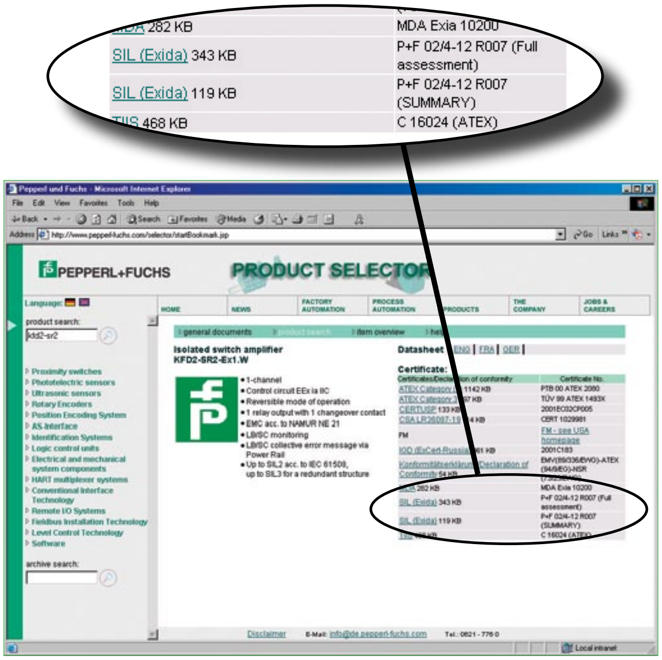
Fraction of safe failures (SFF)	Hardware fault tolerance (HFT)		
	0	1	2
< 60 %	SIL1	SIL2	SIL3
60 % ... 90 %	SIL2	SIL3	SIL4
90 % ... 99 %	SIL3	SIL4	SIL4
>99 %	SIL3	SIL4	SIL4

The hardware fault tolerance is the number of hardware faults that can occur without failure of the safety function. A hardware fault tolerance of zero signifies that a single fault can cause a dangerous failure. By contrast, a functional unit with a sufficiently high hardware fault tolerance has the capacity to continue to execute its demanded functions in the presence of faults or deviations.

Where Can You Find the Necessary SIL Value?

Our SIL ratings can be downloaded from the Internet free-of-charge, either as the full version (15 to 20 pages), or as a management summary (2 pages) at www.am.pepperl-fuchs.com under the appropriate data sheet page.

All Pepperl+Fuchs devices with a SIL rating are from our standard product offering.



What Are the Advantages of Using the Pepperl+Fuchs Standard Devices?

- no surcharge for the user
- no changes to the approval values
- consistent demonstration of intrinsic safety
- consistent device documentation
- simple stores and spares program
- high worldwide delivery capability
- simple planning and commissioning
- devices that are well-proven in operation

The Optional Safety Classifications SIL1 to SIL4: What Should be Noted?

As a rule, all Pepperl+Fuchs devices with a SIL rating can be used directly as standard types in SIL2 applications.

To this end, a simple evaluation structure (e. g. 1oo1) is adequate to achieve the customary industrial cycles for function checks (i.e. annual intervals).

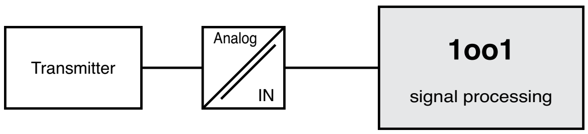
Attention

The functional reliability of the complete risk-reducing measure is always expressed with the SIL grading; therefore, all the components that contribute to this measure must be given consideration.

Devices for Applications in the Safety Grading SIL1

Simple evaluation structure

The signal circuit with a simple 1oo1 evaluation structure has no hardware fault tolerance (HFT = 0). The failure of a device can result in the loss of the safety function.



Hardware fault tolerance: as a rule, 1oo1 is always adequate

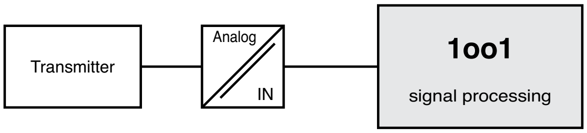
Proof interval: up to 5 years is possible

USA Headquarters web: www.am.pepperl-fuchs.com
phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com
Worldwide Headquarters web: www.pepperl-fuchs.com
phone: +49 621 776-0 • email: pa-info@de.pepperl-fuchs.com
Asia Pacific Headquarters web: www.pepperl-fuchs.com
phone: +65 67799091 • email: sales@sg.pepperl-fuchs.com

Devices for Applications in the Safety Grading SIL2

Simple evaluation structure

The signal circuit with a simple 1oo1 evaluation structure has no hardware fault tolerance (HFT = 0). The failure of a device can result in the loss of the safety function.



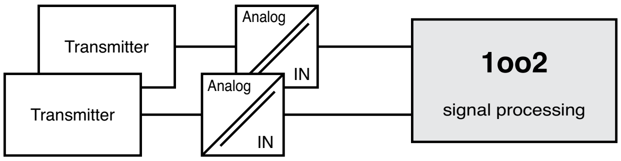
Hardware fault tolerance: as a rule, 1oo1 is always adequate

Proof interval: approx. 1 year

Devices for Applications in the Safety Grading SIL3

Redundant evaluation structure (SIL2 and SIL3 with the same devices)

The signal circuit with a redundant 1oo2 evaluation structure has a hardware fault tolerance of 1 (HFT = 1). The failure of a device does not lead to the loss of the safety function.



Hardware fault tolerance: as a rule1oo2 is necessary

Proof interval: approx. 1 year

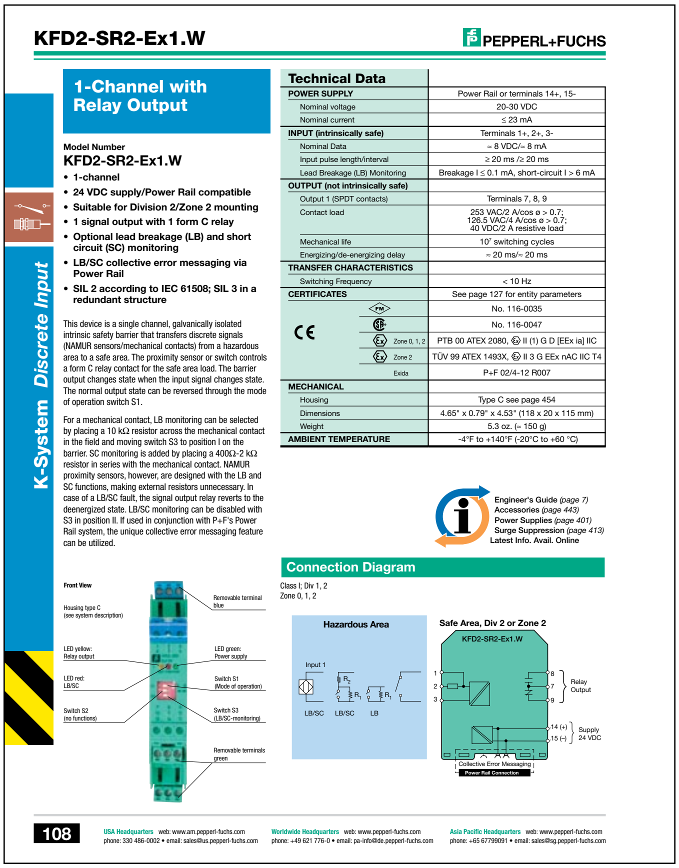
Devices for Applications in the Safety Grading SIL4

Attention

The SIL 4 risk is too high to be covered by the normal process technology means. In such cases, the operator is advised to seek alternative process means with an inherently higher level of safety.

Which Devices Can Be Used for Functional Safety?

All devices with a SIL grading are accompanied by direct advice on this topic in the respective data sheet.



KFD2-SR2-Ex1.W PEPPERL+FUCHS

K-System Discrete Input

1-Channel with Relay Output

Model Number
KFD2-SR2-Ex1.W

- **1-channel**
- **24 VDC supply/Power Rail compatible**
- **Suitable for Division 2/Zone 2 mounting**
- **1 signal output with 1 form C relay**
- **Optional lead breakage (LB) and short circuit (SC) monitoring**
- **LB/SC collective error messaging via Power Rail**
- **SIL 2 according to IEC 61508; SIL 3 in a redundant structure**

This device is a single channel, galvanically isolated intrinsic safety barrier that transfers discrete signals (NAMUR sensors/mechanical contacts) from a hazardous area to a safe area. The proximity sensor or switch controls a form C relay contact for the safe area load. The barrier output changes state when the input signal changes state. The normal output state can be reversed through the mode of operation switch S1.

For a mechanical contact, LB monitoring can be selected by placing a 10 kΩ resistor across the mechanical contact in the field and moving switch S3 to position I on the barrier. SC monitoring is added by placing a 400Ω-2 kΩ resistor in series with the mechanical contact. NAMUR proximity sensors, however, are designed with the LB and SC functions, making external resistors unnecessary. In case of a LB/SC fault, the signal output relay reverts to the deenergized state. LB/SC monitoring can be disabled with S3 in position II. If used in conjunction with P+F's Power Rail system, the unique collective error messaging feature can be utilized.

Technical Data	
POWER SUPPLY	Power Rail or terminals 14+, 15-
Nominal voltage	20-30 VDC
Nominal current	≤ 23 mA
INPUT (intrinsically safe)	Terminals 1+, 2+, 3-
Nominal Data	≈ 8 VDC/≈ 8 mA
Input pulse length/interval	≥ 20 ms /≥ 20 ms
Lead Breakage (LB) Monitoring	Breakage I ≤ 0.1 mA, short-circuit I > 6 mA
OUTPUT (not intrinsically safe)	
Output 1 (SPDT contacts)	Terminals 7, 8, 9
Contact load	253 VAC/2 A/cos ø > 0.7; 126.5 VAC/4 A/cos ø > 0.7; 40 VDC/2 A resistive load
Mechanical life	10^7 switching cycles
Energizing/de-energizing delay	≈ 20 ms/≈ 20 ms
TRANSFER CHARACTERISTICS	
Switching Frequency	< 10 Hz
CERTIFICATES	See page 127 for entity parameters
CE FM	No. 116-0035
CSA	No. 116-0047
Ex Zone 0, 1, 2	PTB 00 ATEX 2080, Ex II (1) G D [EEx ia] IIC
Ex Zone 2	TÜV 99 ATEX 1493X, Ex II 3 G EEx nAC IIC T4
Exida	P+F 02/4-12 R007
MECHANICAL	
Housing	Type C see page 454
Dimensions	4.65" x 0.79" x 4.53" (118 x 20 x 115 mm)
Weight	5.3 oz. (≈ 150 g)
AMBIENT TEMPERATURE	-4°F to +140°F (-20°C to +60 °C)

Engineer's Guide *(page 7)*
Accessories *(page 443)*
Power Supplies *(page 401)*
Surge Suppression *(page 413)*
Latest Info. Avail. Online

Front View
Housing type C (see system description)
Removable terminal blue
LED yellow: Relay output
LED green: Power supply
LED red: LB/SC
Switch S1 (Mode of operation)
Switch S2 (no functions)
Switch S3 (LB/SC-monitoring)
Removable terminals green

Connection Diagram

Class I; Div 1, 2
Zone 0, 1, 2

Hazardous Area
Input 1
LB/SC LB/SC LB
Safe Area, Div 2 or Zone 2
KFD2-SR2-Ex1.W
Relay Output
14 (+) 15 (–) Supply 24 VDC
Collective Error Messaging
Power Rail Connection

108

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Special Item - Isolating Switch Amplifier with Dynamic Evaluation

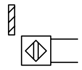
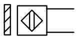
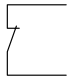
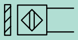
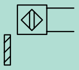
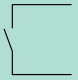
The isolated switch amplifiers equipped with dynamic evaluation, KFD2-SH-Ex1, KHA6-SH-Ex1 and KFD2-SH-Ex1.T.OP can be used in conjunction with our safety-aligned proximity switches in the series *SN and *S1N, with a simple evaluation structure (e. g. 1oo1) to achieve SIL3.

The system operates in accordance with the principle: safe condition = de-energized condition.

In contrast to the other isolating switch amplifiers, these devices are designed with dynamic safety in mind. There is no option to switch the mode of operation. By removing the option of selecting the mode of operation, an intentional or unintentional changeover of the direction of operation, leading to the loss of the safety function, is eliminated.

With the proper selection of a proximity sensor the direction of operation can be adapted to the required mechanical function. The table clarifies this mode of operation:

Mode of operation:

Input SN-Sensor	Input S1N-Sensor	Mech. Contact	Output I + II	Status display LED yellow	Output III Fault signal	Status display LED red
			Logic 1 energized	ON	cut-off de-energized	OFF
			Logic 0 de-energized	OFF	cut-off de-energized	OFF
Lead breakage I < 2.1 mA Lead short circuit I > 5.9 mA Contact fusing output I at K**-SH-Ex1			Logic 0 de-energized	OFF	through switched energized	ON

The input signals must be generated by safety-aligned proximity sensors (Fail Safe technology) from Pepperl+Fuchs or appropriately approved mechanical contacts. The prerequisite for correct functioning with mechanical switches, is that a series resistance of 1.5 kΩ and a parallel resistance of 10 kΩ be applied directly at the contact.

The dynamic signal processing safeguards the continual control of all the incorporated electronic components of the sensor circuit and of the isolating switch amplifier.

Installation conditions:

- The prescribed ambient conditions must be observed.
- The installation conditions of the proximity sensor must also be followed.
- The proximity sensor and its related actuating element are to be secured against becoming loose from their fixing.

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phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com
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phone: +65 67799091 • email: sales@sg.pepperl-fuchs.com

Section 12
Additional Information

Bibliography

Bass, H.G., Intrinsic Safety, Quartermainte House, Ltd., Sunbury, Middlesex, U.K., 1984.

Calder, W., Magison, E.C., Electrical Safety in Hazardous Locations, Instrument Society of America, North Carolina, U.S.A., 1983.

Garside, R., Intrinsically Safe Instrumentation: a guide, Safety Technology, Ltd., Feltham, Middlesex, U.K., 1997.

Magison, E.C., Electrical Instruments in Hazardous Locations, 4th Ed., Instrument Society of America, North Carolina, U.S.A., 1998.

Magison, E.C., Intrinsic Safety, Instrument Society of America, North Carolina, U.S.A., 1984.

Magison, E.C., Electrical Instruments in Hazardous Locations, 3rd ed., Instrument Society of America, North Carolina, U.S.A., 1990.

Minard, A., Systems et Installations de Securite Intrinseque, Laboratoire Central des Industries Electriques, Fontenay aux Roses, France, 1986.

Redding, R.J., Intrinsic Safety, McGraw-Hill, Ltd., Berkshire, U.K., 1971.

Reference Standards

United States

ANSI/NFPA 70	National Electrical Code, Articles 500-505, Hazardous (Classified) Locations
ANSI/NFPA 496	Purged and Pressurized Enclosures for Electrical Equipment in Hazardous (Classified) Locations
ANSI/NFPA 497	Classification of Flamable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

NFPA Standards Available From:

National Fire Protection Association
Batterymarch Park
Quincy, Massachusetts 02269

FM 3610	Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1 Hazardous Locations
FM 3615	Explosion-proof Electrical Equipment

FM Standards Available From:

Factory Mutual Research Corporation
1151 Boston-Providence Turnpike
Norwood, Massachusetts 02062

ANSI/UL 698	Standard for Industrial Control Equipment for Use in Hazardous Locations, Class I, Groups A, B, C and D and Class II, Groups E, F and G
ANSI/UL 913	Standard for Intrinsically Safe Electrical Circuits and Equipment for Use in Hazardous Locations

UL Standards Available From:

Underwriters Laboratories, Inc.
333 Pfingsten Road
Northbrook Illinois 60062

ANSI/ISA-12.00.01-2002 (IEC 60079-0 Mod)	Electrical Apparatus for Use in Class I, Zones 0, 1, & 2 Hazardous Locations: General Information
ANSI/ISA-12.00.01-1999	Definitions and Information Pertaining to Electrical Instruments in Hazardous (Classified) Locations
ANSI/ISA-12.00.01-2002 (IEC 60079-11 Mod)	Electrical Apparatus for Use in Class I, Zones 0, 1, & 2 Hazardous Locations - Intrisic Safety "i"
ISA-RP12.2.02-1969	Recommendations for the Preparation, Content, and Organization of Intrinsic Safety Control Drawings
ISA-RP12.4-1996	Pressurized Enclosures
ISA-12.04.01-2003 (IEC 60079-2 Mod)	Electrical Apparatus for Exlposive Gas Atmospheres - Part 2 Pressurized Enclosures
ANSI/ISA-12.06.01-2003	Recommended Practice for Wiring Methods for Hazardous (Classified) Locations Instrumentation Part 1: Intrinsic Safety
ANSI/ISA-12.12.01-2000	Nonincendive Electrical Equipment for Use in Class I and II, Division 2 and Class III, Divisions 1 and 2 Hazardous (Classified) Locations
ANSI/ISA-12.12.02-2003	Electrical Apparatus for Use in Class I, Zone 2 Hazardous (Classified) Locations - Type of Protection "n"

ISA Standards Available From:

The Instrumentation, Systems and Automation Society
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, North Carolina 27709

Canada

C22.1	Canadian Electrical Code
C22.2-30	Explosion-Proof Enclosures for Use in Class I Hazardous Locations
C22.2-157	Intrinsically Safe and Non Incendive Equipment for Use in Hazardous Locations
C22.2-213	Non Incendive Electrical Equipment for Use in Class I, Division 2 Hazardous Locations

CSA Standards Available From:

Canadian Standards Association
178 Rexdale Boulevard
Rexdale (Toronto), Ontario, Canada M9W IR3

International

IEC 60079-0	General Requirements
IEC 60079-1	Electrical Apparatus - Type of Protection "d"
IEC 60079-2	Electrical Apparatus - Type of Protection "p"
IEC 60079-4	Method of Test for Ignition Temperature
IEC 60079-5	Electrical Apparatus - Type of Protection "q"
IEC 60079-6	Electrical Apparatus - Type of Protection "o"
IEC 60079-7	Electrical Apparatus - Type of Protection "e"
IEC 60079-10	Classification of Hazardous Areas
IEC 60079-11	Electrical Apparatus - Type of Protection "i"
IEC 60079-15	Electrical Apparatus - Type of Protection "n"
IEC 60079-18	Electrical Apparatus - Type of Protection "m"
IEC 60079-25	Intrinsically Safe Systems

IEC Standards Available From:

IEC Central Office
3, Rue de Varembé
CH-1211 Geneva 20
Switzerland

Europe

EN60079-0 (EN50014)	General Requirements.
EN50015	Oil Immersion "o".
EN60079-2 (EN50016)	Pressurized Apparatus "p".
EN50017	Powder Filling "q".
EN60079-1 (EN50018)	Flameproof Enclosure "d".
EN60079-7 (EN50019)	Increased Safety Protection Method "e".
EN50020	Intrinsic Safety Protection Method "i".
EN60079-25 (EN50039)	Intrinsically Safe Systems "i".

CENELEC Standards Available From:

CENELEC
35, Rue de Stassartstraat
B-1050 Brussels, Belgium

Internet Resources

Instrumentation, Systems and Auomation Association (ISA): www.isa.org

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

International Electrotechnical Commission (IEC): www.iec.ch

Environmental Protection Agency (EPA): www.epa.gov

Occupational Safety and Health Association (OSHA): www.osha.gov

TÜV: www.tuvps.com

Factory Mutual (FM): www.factorymutual.com

Underwriters Laboratory (UL): www.ul.com

Canadian Standards Association (CSA): www.csa.ca

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

European Commitee for Electromechanical Standardization (CENELEC): www.cenelec.org

National Fire Ptrotection Association (NFPA): www.nfpa.org

North American Enclosure Protection Ratings

Organizations such as NEMA, CSA, UL, IEC and TÜV have developed rating systems for the identification of an enclosure's ability to withstand and repel the outside environment. NEMA, CSA and UL are the systems most often used in North America.

The European rating system, developed by IEC and TÜV Rhineland, is very similar to the North American system for non hazardous location enclosures. But because, historically, the European system has been more deeply rooted in the concept of intrinsic safety, IEC 60529 has no equivalents to the NEMA hazardous location enclosure Types 7, 8, 9 and 10. The North American system also includes a 4X rating that indicates resistance to corrosion.

The following tables show the enclosure types for non hazardous and hazardous locations according to NEMA standards, and an approximate cross-reference for the North American and European rating systems.

Enclosure Types for Non Hazardous Locations

Type Designation	NEMA National Electrical Manufacturers Association (NEMA Standard 250)
1	Intended for use primarily to provide a degree of protection against limited amounts of falling dirt.
2	Similar to Type 1 but with addition of drip shields used where condensation may be severe.
3	Intended for outdoor use primarily to provide a degree of protection against rain, sleet, windblown dust, and damage from external ice formation.
3R	Intended for outdoor use primarily to provide a degree of protection against rain, sleet, and damage from external ice formation.
3S	Intended for outdoor use primarily to provide a degree of protection against rain, sleet, windblown dust, and to provide for operation of external mechanisms when ice laden.
4	Intended for indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, hose-directed water, and damage from external ice formation.
4X	Intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water, hose-directed water, and damage from external ice formation.
6	Intended for indoor or outdoor use primarily to provide a degree of protection against hose-directed water, the entry of water during occasional temporary submersion at a limited depth, and damage from external ice formation.
6P	Intended for indoor or outdoor use primarily to provide a degree of protection against hose-directed water, the entry of water during prolonged submersion at a limited depth, and damage from external ice formation.
12	Intended for indoor use primarily to provide a degree of protection against circulating dust, falling dirt, and dripping non-corrosive liquids.
12K	Type 12 with knockouts.
13	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil, and non corrosive coolant.

Enclosure Types for Hazardous Locations

Type Designation	NEMA National Electrical Manufacturers Association (NEMA Standard 250)
7	Intended for indoor use in locations classified as Class I, Groups A, B, C, or D, as defined in the National Electrical Code.
8	Intended for indoor or outdoor use in locations classified as Class I, Groups A, B, C, or D, as defined in the National Electrical Code.
9	Intended for indoor use in locations classified as Class II, Groups E, F, or G, as defined in the National Electrical Code.
10	Constructed to meet the applicable requirements of the Mine Safey and Health Administration.

North American Enclosure Protection Ratings

NEMA to IEC Enclosure Types Cross-reference (Approximate)

Cannot be used to convert IEC Classifications to NEMA Type Numbers

Enclosure Type [1]	IP10	IP11	IP14	IP52	IP54	IP56	IP67
1	✓						
2		✓					
3					✓		
3R			✓				
3S					✓		
4						✓	
4X						✓	
6/6P							✓
12/12K				✓			
13					✓		

[1] IEC 60529 has no equivalents to NEMA enclosure Types 7, 8, 9 or 10.

USA Headquarters web: www.am.pepperl-fuchs.com
phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com

Worldwide Headquarters web: www.pepperl-fuchs.com
phone: +49 621 776-0 • email: pa-info@de.pepperl-fuchs.com

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Enclosure Protection Degrees (European Rating System)

IEC Definitions

The IEC 60529 standard defines Ingress Protection as a two digit code. The first digit describes the degree of protection against access to hazardous parts and ingress of solid objects. The second digit designates the Ingress Protection against water. Please refer to the appropriate sections of IEC 60529 for complete information regarding applications, features, and design tests.

Protection Against Access to Hazardous Parts (First Digit)	
Number	**Description**
0	Non-protected
1	Protected against access with back of hand (50 mm)
2	Protected against access with jointed finger (12 x 80 mm)
3	Protected against access with a tool (2.5 mm)
4, 5, 6	Protected against access with a wire (1.0 mm)

Protection Against Ingress of Solid Foreign Objects (First Digit)	
Number	**Description**
0	Non-protected
1	Protected against ingress of objects equal to or greater than 50 mm
2	Protected against ingress of objects equal to or greater than 12.5 mm
3	Protected against ingress of objects equal to or greater than 2.5 mm
4	Protected against ingress of objects equal to or greater than 1 mm
5	Dust protected
6	Dust tight

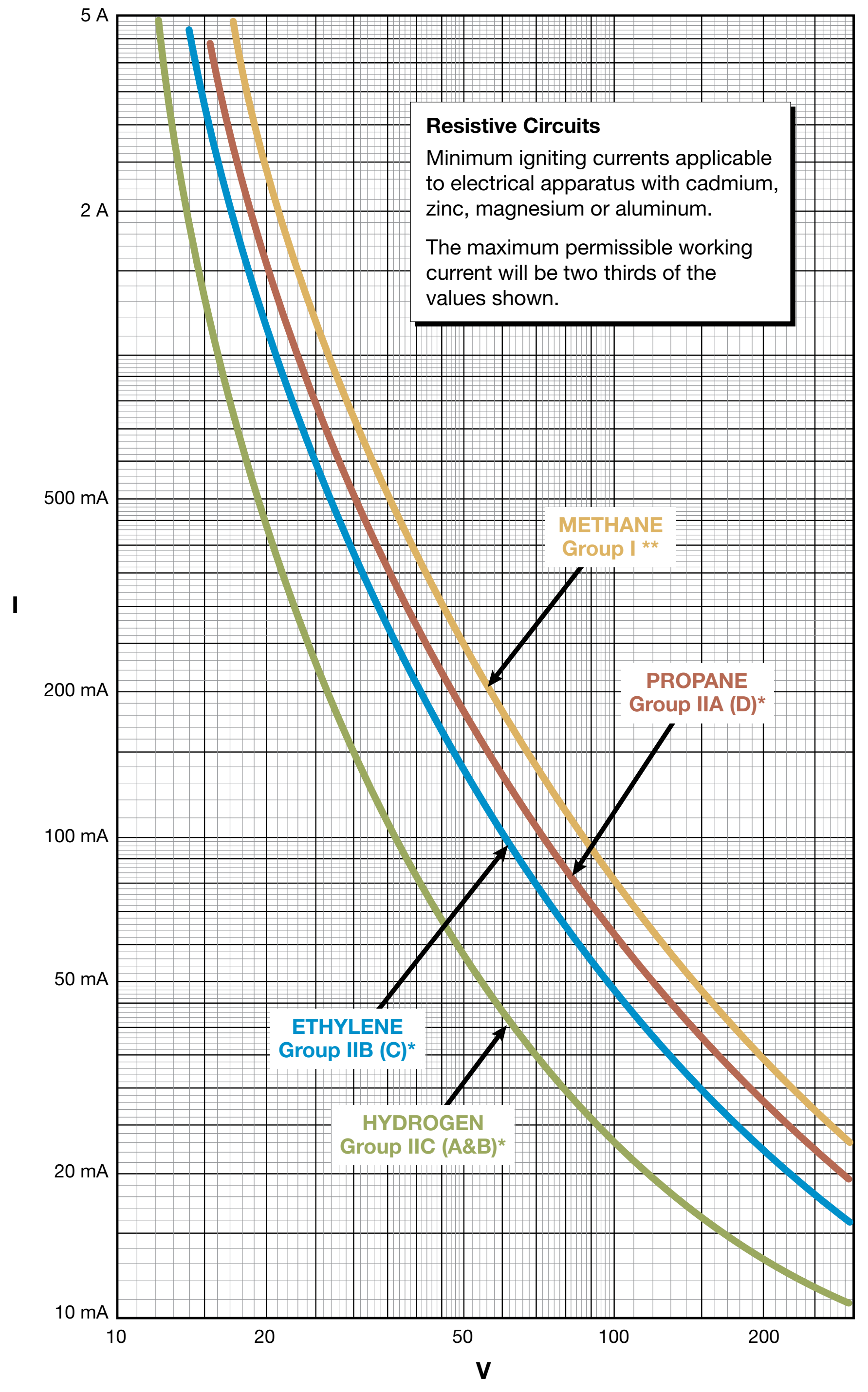
Protection Against Ingress of Liquids (Second Digit)	
Number	**Description**
0	Non-protected
1	Protected against ingress of water dripping vertically
2	Protected against ingress of water dripping, enclosure tilted up to 15°
3	Protected against ingress of spraying water, up to 60° from vertical
4	Protected against ingress of spraying water, any direction
5	Protected against ingress of jetting water, any direction
6	Protected against ingress of powerful jetting water, any direction
7	Protected against ingress of water during temporary immersion
8	Protected against ingress of water during continuous immersion

Minimum Ignition Curves

The following graphs answer the question: What is a dangerous amount of electrical energy? These graphs are for circuits containing aluminum, cadmium, magnesium or zinc—substances that produce a high temperature incendiary spark. It is important to keep in mind that these curves reflect the worst case scenario. When designing intrinsically safe electronic equipment today, most manufacturers start by specifying the equipment for the worst possible case.

The graphs chosen are those that are used most often by designers and manufacturers of electrical apparatus.

Minimum Ignition Curves for Resistive Circuits



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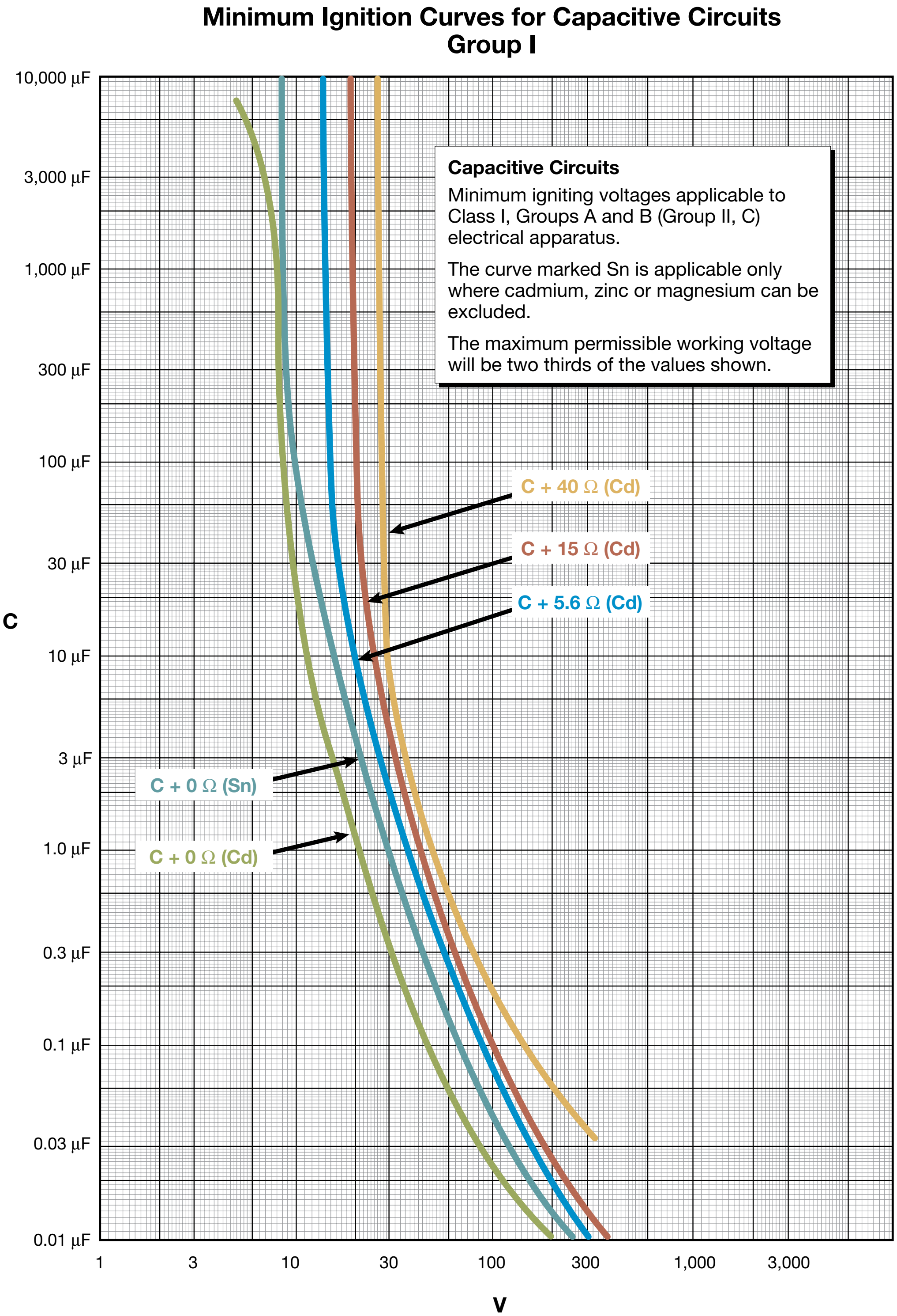

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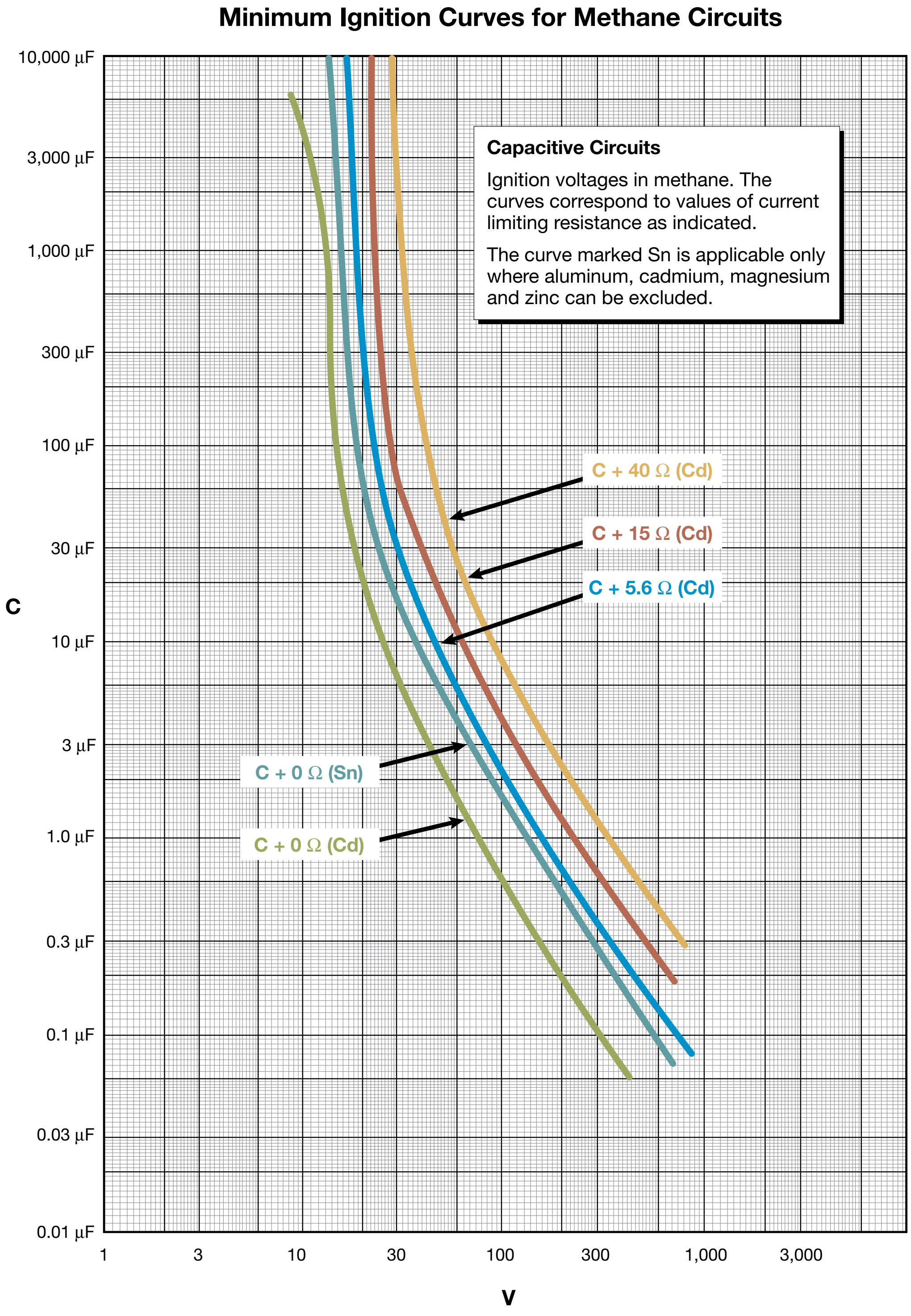

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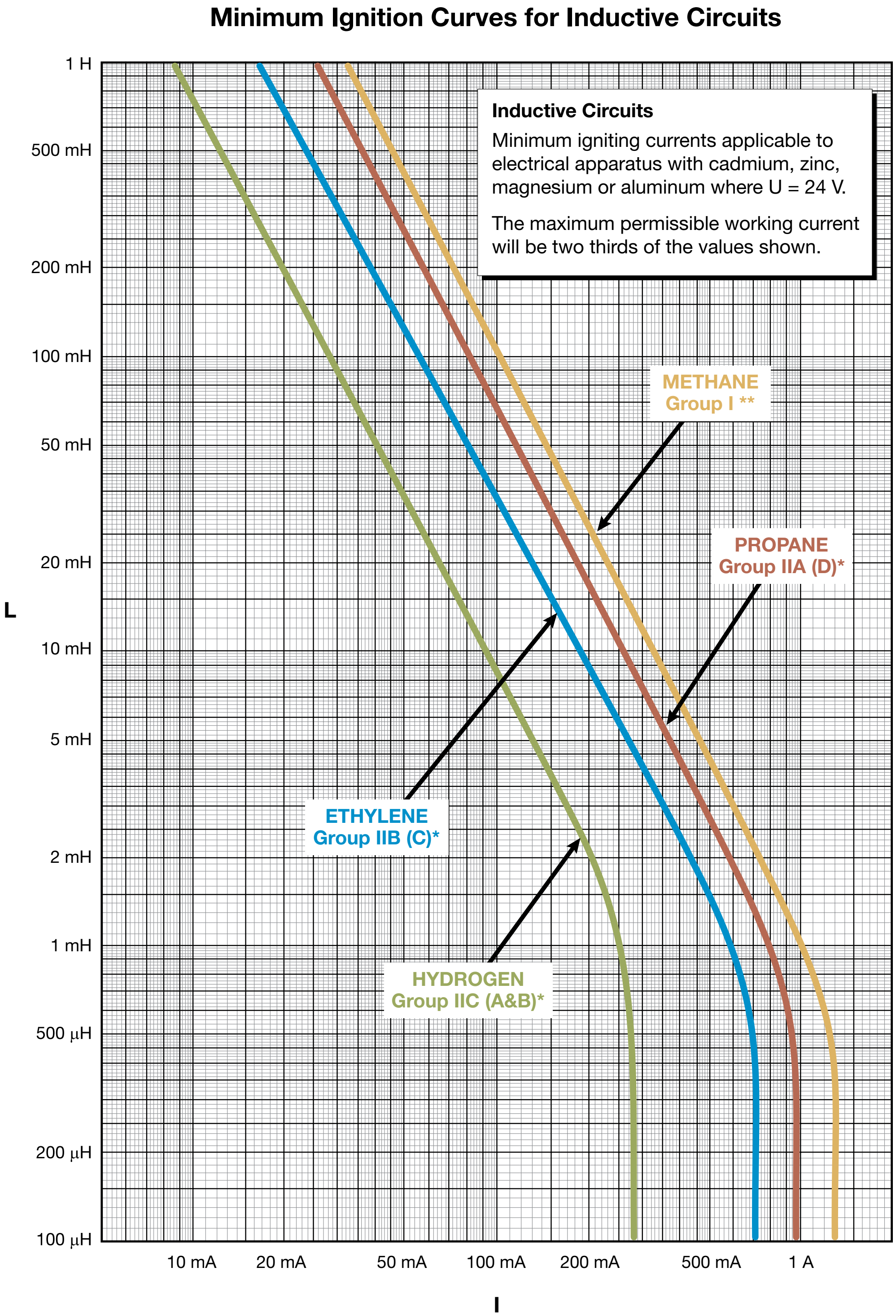

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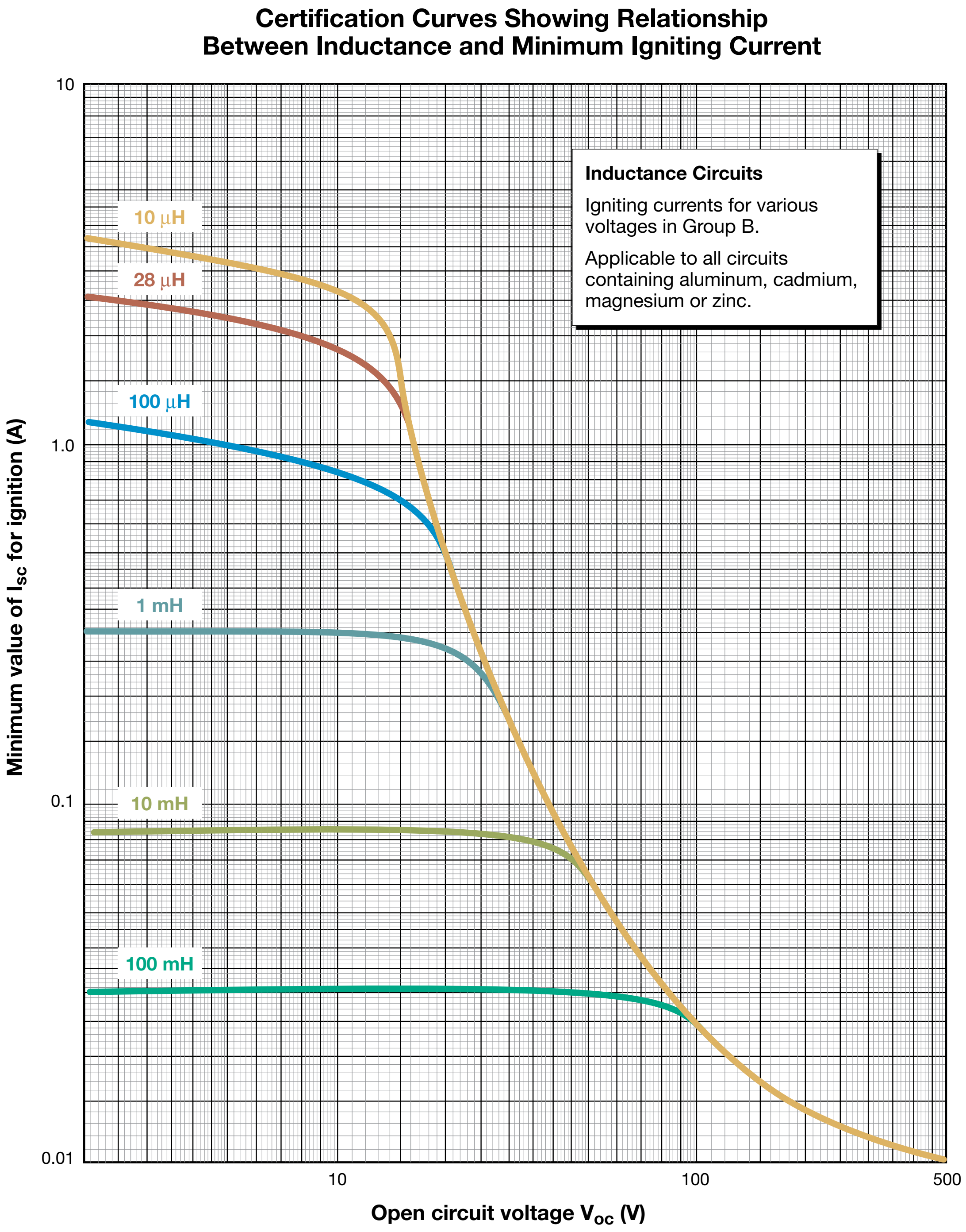

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US Recognized Testing Laboratories

The Occupational Safety & Health Administration (OSHA) has accredited the following laboratories as Nationally Recognized Testing Laboratories (NRTL). A NRTL determines that specific equipment and materials ("products") meet consensus-based standards of safety to provide the assurance, required by OSHA, that these products are safe for use in the U.S. workplace.

Applied Research Laboratories, Inc.
5371 NW 161st Street
Miami, Florida 33014
+1 305 624 4800

CSA International, Etobicoke (Toronto)
178 Rexdale Boulevard
Etobicoke, Ontario M9W 1R3
Canada
+1 416 7474000

CSA International, Pointe-Claire (Montreal)
865 Ellingham Street
Pointe-Claire, Quebec H9R 5E8
Canada
+1 514 694 8110

CSA International, Richmond (Vancouver)
13799 Commerce Parkway
Richmond, British Columbia V6V 2N9
Canada
+1 604 273 4581

CSA International, Edmonton
1707-94th Street
Edmonton, Alberta T6N 1E6
Canada
+1 780 450 2111

CSA International, Cleveland
8501 East Pleasant Valley Road
Cleveland, Ohio 44131
+1 216 524 4990

CSA International, Irvine
2805 Barranca Parkway
Irvine, California 92606
+1 949 733 4300

Communication Certification Laboratory, Inc.
1940 West Alexander Street
Salt Lake City, Utah 84119
+1 801 972 6146

Curtis-Straus LLC
527 Great Road
Littleton, Massachusetts 01460
+1 978 486 8880

Entela, Inc.
3033 Madison, S.E.
Grand Rapids, Michigan 49548
+1 800 888 3787

FM Approvals
1151 Boston-Providence Turnpike
P.O. Box 9102
Norwood, Massachusetts 02062
+1 781 762 4300

FM Approvals
743 Reynolds Road
West Glocester, Rhode Island 02814

Intertek Testing Services NA, Inc.
3933 U.S. Route 11
Cortland, New York 13045
+1 800 345 3851

Intertek Testing Services NA, Inc.
1950 Evergreen Boulevard
Duluth, Georgia 30096
+1 678 775 2400

Intertek Testing Services NA, Inc.
1365 Adams Court
Menlo Park, California 94025
+1 650 463 2900

Intertek Testing Services NA, Inc.
70 Codman Hill Road
Boxborough, Massachusetts 01719
+1 978 263 2662

Intertek Testing Services NA Ltd.
1500 Brigantine Drive
Coquitlam, British Columbia V3K 7C1
Canada
+1 604 520 3321

Intertek Testing Services Hong Kong Ltd.
2/F., Garment Centre, 576 Castle Peak Road
Kowloon, Hong Kong
+852 2173 8888

Intertek Testing Services Taiwan Ltd.
5F, No. 423, Ruiguang Rd., Neihu District
Taipei City 114, Taiwan R.O.C.
+886 2 6602 2888

Intertek Testing Services NA, Inc.
27611 LaPaz Road, Suite C
Laguna Niguel, California 92677
+1 949 448 4100

Intertek Testing Services NA, Inc.
8431 Murphy Drive
Middleton, Wisconsin 53562
+1 608 836 4400

Intertek Testing Services NA, Inc.
7250 Hudson Blvd., Suite 100
Oakdale, Minnesota 55128
+1 651 730 1188

Intertek Testing Services NA, Inc.
40 Commerce Way, Unit B
Totowa, New Jersey 07512
+1 973 785 9211

Intertek Testing Services NA Sweden AB
Box 1103, S-164 #22
Kista, Stockholm
Sweden
+46 8 750 00 00

Intertek Testing Services NA Lexington
731 Enterprise Drive
Lexington, Kentucky 40510
+1 859 226 1000

MET Laboratories, Inc.
914 West Patapsco Avenue
Baltimore, Maryland 21230
+1 800 638 6057

NSF International
789 Dixboro Road
Ann Arbor, Michigan 48105
+1 800 673 6275

National Technical Systems
1146 Massachusetts Avenue
Boxborough, Massachusetts 01719
+1 978 263 1933

Southwest Research Institute
6220 Culebra Road
Post Office Drawer 28510
San Antonio, Texas 78228
+1 210 684 5111

TUV Product Services (TUVAM)
5 Cherry Hill Drive
Danvers, Massachusetts 01923
+1 978 739 7000

TUV Product Services (TUVAM)
10040 Mesa Rim Road
San Diego, California 92121
+1 858 678 1400

TUV Product Services (TUVAM)
1775 Old Highway 8 NW, Suite 104
New Brighton (Minneapolis), Minnesota 55112
+1 651 631 2487

TUV Product Services GmbH
Ridlerstrasse 65
D-80339 Munich
Germany
+49 89 5008 4335

TUV Rheinland of North America, Inc.
12 Commerce Road
Newtown, Connecticut 06470
+1 203 426 0888

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, Illinois 60062
+1 847 272 8800

Underwriters Laboratories Inc.
1285 Walt Whitman Road, Melville
Long Island, New York 11747
+1 631 271 6200

Underwriters Laboratories Inc.
1655 Scott Boulevard
Santa Clara, California 95050
+1 408 985 2400

Underwriters Laboratories Inc.
12 Laboratory Drive, P.O. Box 13995
Research Triangle Park, North Carolina 27709
+1 919 549 1400

Underwriters Laboratories Inc.
2600 N. W. Lake Road
Camas, Washington 98607
+1 360 817 5500

UL International Limited
18th Floor, Delta House
3 On Yiu Street
Shatin, Hong Kong
+852 2276 9000

UL International Services, Ltd.
Taiwan Branch
4th Floor, 260 Da-Yeh Road
Pei Tou District
Taipei City, Taiwan
+886 2 2896 7790

UL International Demko A/S
Lyskaer 8
P.O. Box 514
DK-2730
Herlev, Denmark
+45 44 85 65 65

UL (UK) Ltd.
Wonersh House
The Guildway
Old Portsmouth Road
Guildford, Surrey GU3 1LR
United Kingdom
+44 (0) 1483 302 130

Underwriters Laboratory International Italia S.r.l.
Centro Direzionale Colleoni
Plazzo Andromeda/3
1-20041 Agrate Brianza (MI)
Milan, Italy
+39 039 6410 101

Underwriters Laboratories of Canada
7 Crouse Road
Scarborough, Ontario MIR 3A9
Canada
+1 416 757 3611

UL Apex Co., Ltd.
4383-326 Asama-cho
Ise-shi, Mie 516-0021
Japan
+81 596 24 6717

UL Korea, Ltd.
33rd Fl. Star Tower
737 Yeoksam-dong Kangnam-gu
Seoul 135-984
Korea
+82 2 2009 9000

UL International Germany GmbH
Frankfurter Strass 229
D-63263 Neu Isenburg
Germany
+49 (0) 6102 369 0

UL International (Netherlands) B.V.
Landjuweel 52
NL-3905 PH Veenedaal
Netherlands
+31 (0) 318 581 310

Wyle Laboratories
7800 Highway 20 West
P.O. Box 077777
Huntsville, Alabama 35807
+1 256 837 4411

Recognized Certifying Authorities

The following is a list of key certifying authorities that can issue Certificates of Conformity in their respective country or region. This list is not all-inclusive but contains many of the major agencies used for the certification of equipment to relevant standards of safety.

Australia

Safety in Mines Testing and Research Station (SIMTARS)
2 Smith Street, Redbank Q 4301
PO Box 467, Goodna Q 4300
+61 7 3810 6333

Belgium

Institut Scientifique de Service Public (ISSEP)
Rue du Chéra 200
4000 Liege
+32 4 252 71 50

Brazil

Centro de Pesquisas de Energia Electrica (CEPEL)
P. O. Box 2754
CEP 20001 Rio de Janeiro, Brazil
+55 21 598 2442

Canada

Canadian Standards Association (CSA)
178 Rexdale Boulevard
Toronto, Ontario M9W IR3
+1 416 747 4000

China

National Supervision and Inspection Center for Explosion Protection and Safety of Instrumentation(NEPSI)/ Shanghai Institute of Process Automation (SIPAI)
103 Cao Bao Road
Shanghai
+21 643 86180

Czech Republic

Fyzikálnì Technický Zkušební ústav (FTZU)
Pikartska 7
Ostrava-Radvanice 716 07
+420 59 6232715

Denmark

DEMKO (UL International)
Lyskaer 8
P.O. Box 514
2730 Herlev
+45 44 85 65 65

France

Laboratoires Central des Industries Electriques (LCIE)
33 Avenue du General Leclerc
F 92260 Fontenay-aux-Roses
+33 1 409 55519

Institut National de l'Environnement Industriel et des Risques (INERIS)
B Piquette
Parc Technologique ALATA - B.P.2
F-60550 Verneuil-EN-Halatte
+33 44 55 66 77

Germany

Physikalisch-Technische Bundesanstalt (PTB)
Bundesallee 100
38116 Braunschweig
+49 (0)531 592 0

EXAM BBG Pruf-und Zertifier GmbH (formerly BVS/DMT)
Beylingstr. 65
D-44329 DORTMUND
+49 231 2491 0

ZELM
38124 Braunschweig,
Siekgraben 56,
+49 531 61404 0

Great Britain

Baseefa 2001 Ltd
Rockhead Business Park
Staden Lane
Buxton SK17 9RZ
+44 1298 766600

SIRA Certification Service (SCS)
South Hill
Chiselhurst Kent BR7 5EH
+44 20 8467 2636

Hungary

Hungarian Testing Authority for Explosion
Proof Electrical Apparatus (BKI)
H 1037 BUDAPEST
MIKOVINY S.u. 2-4
+36 1 250 1720

Italy

Centro Elettrotecnico Sperimentale Italiano (CESI)
Via Rubattino 54
20134 Milano
+39 2 2125 1

Japan

Technical Institute of Industrial Safety (TIIS)
1-4-6 Umezono Kiyose
Tokyo 204
+81 424 91 4514

Netherlands

KEMA Registered Quality Nederland BV
Postbus 9035
6800 ET Arnhem
+31 26 3569111

Norway

Norges Elektriske Materiel Kontroll (NEMKO)
PO Box 73 Blindern
N - 0314 Oslo
+47 22 96 03 30

Russia

State Committee of the Russian Federation
for Standardization (GOSSTANDART)
Leninsky Prospekt 9
Moscow 119991
+7 095 236 03 00

The Russian Scientific and Research Institute
for Russian Certification (VNIIEF)
Elektricheski Prospekt 3
Moscow 123557
+7 095 253 70 06

Spain

Laboratorio Official Jose Maria de Madariaga (LOM)
Calle Alenzaa 2
E 28003 Madrid
+349 1 442 13 66

Sweden

Swedish National Testing and Research Institute (SP)
Box 857
SE-50115 Borås
+46 33 16 55 92

Switzerland

Schweizerischer Elektrotechnischer Verein (SEV)
Luppmenstrasse 1
CH-8320 Fehraltorf
+41 01 956 13 18

USA

Underwriters Laboratories (UL)
333 Pfingsten Road
Northbrook, Illinois 60062
+1 847 272 8800

FM Approvals (FM)
1151 Boston-Providence Turnpike
Norwood, MA 02062
+1 781 762 4300

Active Transistor Output
A transistor that has either the emitter or the collector connected to an internal power source.

Active Zener Barrier
A zener barrier with additional active components (i.e., transistors, integrated circuits, etc.) that provides special functions or features.

AIT
Abbreviation for autogenous ignition temperature.

Amplifier
A device that enables an input signal to control power from a source independent of the signal and thus be capable of delivering an output that bears some relationship to, and is generally greater than, the input signal.

Analog Device
An automatic computing device that operates in terms of continuous variation of some physical quantities, such as electrical voltages and currents, mechanical shaft rotations or displacements, and which is used primarily to solve differential equations.

Analog Input
Analog type signal from a hazardous area instrument (i.e., transmitter) to the safe area controller.

Analog Output
Analog type signal from the safe area controller to the hazardous area instrument (i.e., I/P positioner).

ANSI
Acronym for American National Standards Institute.

API
Acronym for American Petroleum Institute.

Approved
Acceptable to the authority having jurisdiction.

Arcing Device
A device, such as make/ break component, that under normal conditions produces an arc with energy sufficient to cause ignition of an ignitable mixture. See also "nonincendive circuit."

Associated Apparatus
Apparatus in which the circuits are not necessarily intrinsically safe themselves, but which affect the energy in the intrinsically safe circuits and are relied upon to maintain intrinsic safety. Associated electrical apparatus may be either

(1) electrical apparatus that have an alternative type of protection, for use in the appropriate hazardous (classified) location; or (2) electrical apparatus that are not protected and therefore cannot be used within a hazardous (classified) location.

Associated Nonincendive Field Wiring Apparatus
Apparatus in which the circuits are not necessarily nonincendive themselves but that affect the energy in nonincendive field wiring circuits and are relied upon to maintain nonincendive energy levels.

Associated Safe-Location Equipment
Equipment designed to form part of an intrinsically safe system, in which not all the circuits are of an intrinsically safe system, in which not all the circuits are intrinsically safe, but which affects the safety of the intrinsically safe system of which it forms a part. Such equipment may not be installed in a hazardous location unless provided with appropriate protection, such as the installation of an explosion-proof enclosure in a Class I hazardous location. Examples of associated safe-location equipment are

(1) a line-connected power unit supplying power to intrinsically safe equipment in a hazardous location and (2) a recorder in a safe location actuated by a transducer situated in a hazardous location.

Authority Having Jurisdiction
The organization, office, or individual that has the responsibility and authority for approving equipment, installations, or procedures.

Autogenous Ignition Temperature
The temperature at which a mixture of a specified gas or vapor in air will spontaneously ignite under specified test conditions, without any source of ignition.

Automation System
The system that provides overall control and monitoring functions of a specific process or application. Generally consists of a network of computers, controllers, and I/O modules.

Barrier Specification
The typical way of describing a barrier, for example 28V 300Ω 93mA. This is a reference to the maximum voltage of the terminating zener diode during the period of time it takes for the fuse to break, the minimum value of the terminating resistor and the resulting maximum short circuit current. The description does not refer to the working voltage or the end-to-end resistance, but is purely an indication of the potential fault energy that could be generated in the hazardous area.

BASEEFA
Acronym for British Approvals Service for Electrical Equipment in Flammable Atmospheres. A governmental body in the United Kingdom that has the authority to accept or reject the design of an electrical apparatus based on recognized safety standards.

BSI
Acronym for British Standards Institute.

Capacitance
The property of a system of conductors and dielectrics that permits the storage of electrically separated charges when potential differences exist between the conductors. The greater the capacitance, the greater the charge that can be stored. The practical difference between capacitance and inductance in an intrinsically safe circuit is minimal. Both store energy but a capacitor will release energy when a circuit is made and an inductor will release energy when the circuit is broken.

Glossary

CENELEC
Acronym for European Electrotechnical Committee for Standardization. The standard for the European Economic Community (EEC) nations and the European Free Trade Association. Legally, certification to the CENELEC standard is sufficient to permit sale in any European country. If IEC standards are available, CENELEC tries to utilize them because these standards are already adopted by the European community.

Certified Equipment
Equipment that has been evaluated by a recognized testing agency and confirmed to be in compliance with the applicable standard(s).

CESI
Acronym for Centro Elettronico Sperimentale Italiano. A governmental body in Italy that has the authority to accept or reject the design of an electrical apparatus based on recognized safety standards.

Class I Location
A location in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

Class I, Division 1 Location
A location (1) in which ignitable concentrations of flammable gases or vapors can exist under normal operating conditions; (2) in which ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors and might also cause simultaneous failure of electrical equipment that could act as a source of ignition.

Class I, Division 2 Location
A location (1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; (2) in which ignitable concentrations of gases or vapors are normally prevented by positive mechanical ventilation and might become hazardous through failure or abnormal operation of the ventilating equipment; or (3) that is adjacent to a Class I, Division 1 location and to which ignitable concentrations of 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. Electrical conduits and their associated enclosures separated from process fluids by a single seal or barrier are classified as a Class I, Division 2 location if the outside of the conduit and enclosures is a nonhazardous (unclassified) location.

Class II Location
A location that is hazardous because of the presence of combustible dust.

Class II, Division 1 Location
A location (1) in which combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitable mixtures; (2) in which mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitable mixtures to be produced and might also provide a source of ignition through simultaneous (the word "simultaneous" is not included in the Canadian definition) failure of electric equipment, operation of protection devices, or from other causes; or (3) in which combustible dusts of an electrically conductive nature may be present in hazardous quantities.

Class II, Division 2 Location
A location in which combustible dust is not normally in the air in quantities sufficient to produce explosive or ignitable mixtures and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus, but combustible dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment and where combustible dust accumulations on, in, or in the vicinity of the electrical or may be ignitable by abnormal operation or failure of electrical equipment.

Class III Location
A location that is 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.

Class III, Division 1 Location
A location in which easily ignitable fibers or materials producing flyings are handled, manufactured or used.

Class III, Division 2 Location
A location in which easily ignitable fibers are stored or handled (except in the process of manufacture).

Clearance Distance
The shortest distance measured in air between conductive parts.

Distance Through Casting Compound
The shortest distance between two conductive parts separated by a casting compound.

Distance Through Solid Insulation
The shortest distance between two conductive parts separated by solid insulation.

Code of Practice
An international term referring to a document that describes basic safety features and methods of protection and recommends the selection, installation, and maintenance procedures that should be followed to ensure the safe use of electrical apparatus.

Converter
A type of isolated barrier that receives a signal from the hazardous area instrument (i.e. transmitter, thermocouples, etc.) and converts it into an equivalent signal (i.e. 4-20mA, 1-5V, etc.)

Control Drawing
A drawing or other document provided by the manufacturer of the intrinsically safe or associated apparatus that details the allowed interconnections between the intrinsically safe and associated apparatus.

CSA
Acronym for Canadian Standards Association. A third party certification agency headquartered in Canada and recognized by OSHA as a Nationally Recognized Test Laboratory in the United States. The presence of CSA, UL or FM certification marks on equipment is normally sufficient to the local inspector that the product is designed to recognized safety standards.

Discrete Input
Signal from a hazardous area instrument that is an on/off type electrical input to the safe area (i.e., contact closure, proximity sensor).

Discrete Output
On/Off type signal from the safe area to the hazardous area (i.e., signal to a solenoid or LED cluster).

Driver
A type of active or transformer isolated barrier that receives a signal from a safe area source (i.e., DCS, process controller, etc.) and drives that signal to the hazardous area instrument (i.e., I/P positioner).

Dust, Combustible
Dust that (when mixed with air in certain proportions) can be ignited and will propagate a flame. The combustible properties of dust are dependent upon test conditions and dust particle size, chemical structure, and other particle characteristics.

Dust-Ignitionproof
A term used in the United States to describe an enclosure that will exclude ignitable amounts of dusts that might affect performance or rating and that, when installed and protected in accordance with the original design intent, will not permit arcs, sparks, or heat otherwise generated or liberated inside the enclosure to cause ignition of exterior accumulations or atmospheric suspensions of a specified dust.

Dust-Protected Enclosure
An international term describing an enclosure in which the ingress of dust is not totally prevented, but dust does not enter in sufficient quantity to interfere with the safe operation of the equipment or accumulate in a position within the enclosure where it is possible to cause an ignition hazard.

Dust-Tight
An enclosure so constructed that dust will not enter the enclosing case under specified test conditions.

Encapsulation
An international term describing a type of protection in which the parts that could ignite an explosive atmosphere by either sparking or heating are enclosed in an encapsulant in such a way that this explosive atmosphere cannot be ignited. This type of protection is referred to by CENELEC as "Ex m" in Standard EN 60079-18.

End-to-End Resistance
The resistance between both ends of a barrier channel. It is the sum of the resistor itself and the resistance of the fuse at an ambient temperature of 20°C.

Entity Concept
The entity concept provides more flexibility in selecting equipment to form an intrinsically safe system. The entity concept allows the user to identify acceptable combinations of intrinsically safe apparatus and associated apparatus that have not been examined as a system.

Entity Parameters
The four categories that are set by the certification agency in order to properly match the intrinsic safety barrier to the hazardous area instrument. These four parameters are voltage, current, capacitance and inductance.

Ex "d"
Designation for the flame-proof (explosion containment) method of protection.

Ex "e"
Designation for the increased safety (prevention) method of protection.

Ex "i"
Designation for the intrinsic safety (prevention) method of protection. This method consists of two categories—"ia" and "ib."

Ex "ia"
This intrinsic safety category is limited to low power circuits and is suitable for process instrumentation. Up to two faults are allowed and can be used in Zones 0, 1 and 2.

Ex "ib"
This intrinsic safety category is similar to the Ex "ia" method, except that category "ib" allows only one fault and can only be used in Zones 1 and 2.

Ex "m"
Designation for the encapsulation (segregation) method of protection.

Ex "n"
Designation for the simplified (prevention) method of protection.

Ex "o"
Designation for the oil-immersion (segregation) method of protection.

Ex "p"
Designation for the pressurization (segregation) method of protection.

Ex "q"
Designation for the powder-filling (segregation) method of protection.

Ex "s"
Designation for the special (special protection) method of protection. This method is standardized only in Great Britain and Germany.

Explosion-Proof Enclosure
An enclosure that is capable of withstanding an explosion of a gas or vapor within it and of preventing the ignition of an explosive gas or vapor that may surround it and that operates at such an external temperature that a surrounding explosive gas or vapor will not be ignited. This type of enclosure is similar to a flame-proof enclosure.

Explosion-Proof Equipment (apparatus)
Equipment or apparatus enclosed in an explosion-proof enclosure.

Glossary

Fault
A defect or electrical breakdown of any component, spacing or insulation that alone or in combination with other faults may adversely affect the electrical or thermal characteristics of the intrinsically safe circuit. If a defect or breakdown leads to defects or breakdowns in other components, the primary and subsequent defects and breakdowns are considered to be a single fault.

Countable Fault
A fault that is applied to a part of the electrical apparatus that meets the constructional requirements of this standard.

Uncountable Fault
A fault that is applied to areas of the electrical apparatus that do not meet the constructional requirements of this standard. If application of a countable fault leads to subsequent defects and breakdowns, they are considered to be uncountable faults.

Fibers And Flyings, Easily Ignitable
Fibers and flyings that are easily ignitable including rayon, cotton (including cotton linters and cotton waste), sisal or henequen, jute, hemp, tow, cocoa fiber, oakum, baled waste kapok, Spanish moss, excelsior, and other materials of similar nature.

Flame-Proof Enclosure
An International term describing an enclosure that can withstand the pressure developed during an internal explosion of an explosive mixture and that prevents the transmission of the explosion to the explosive atmosphere surrounding the enclosure and that operates at such an external temperature that a surrounding explosive gas or vapor will not be ignited. This enclosure is similar to an explosion-proof enclosure. This type of protection is referred to by IEC as "Ex d."

FM
Acronym for Factory Mutual Approvals, a third party certification agency that is recognized by OSHA as a Nationally Recognized Testing Laboratory in the United States. It is a division of Factory Mutual Global, which specializes in property insurance. For marketing in the U.S., FM, CSA and UL provide testing, listing and labeling services for industrial and safety products. Generally, certifications by FM, CSA and UL are recognized in most jurisdictions; however, there are exceptions.

Fuse Rating
This is the maximum current that can flow continuously through the fuse (approx. 1000 hours at 35°C). The rated current may be exceeded for short periods at temperatures up to approximately 55°C.

Fuse-Protected Shunt Diode Barrier Assembly (Zener Barrier)
A network consisting of a fuse, voltage-limiting shunt diodes and a currentlimiting resistor or other current-limiting components designed to limit current and voltage. The fuse protects the diodes from open circuiting when high fault current flows.

Galvanic Isolation
A form of isolation that meets stringent standards for intrinsically safe circuits.

Grounding Device
An impedance device used to connect conductors of an electric system to ground for the purpose of controlling the ground current or voltages to ground, or a nonimpedance device used to temporarily ground conductors for the purpose of the safety of workmen. The grounding device may consist of a grounding transformer or a neutral grounding device, or a combination of these. Protective devices, such as surge arresters, may also be included as an integral part of the device.

Group
A classification of flammable materials of similar hazard. Consists of Groups A, B, C, D, E, F, and G to NEC and CEC standards and Groups I, IIA, IIB, and IIC to IEC standards.

Hazardous (Classified) Location
A location where fire or explosion hazards may exist due to the presence of flammable gases or vapors, flammable liquids, combustible dust, or easily ignitable fibers or flyings.

Hazardous Materials
Gases, vapors, combustible dusts, fibers, or flyings that are explosive under certain conditions.

Hermetically Sealed Device
A device that is sealed against the entrance of an external atmosphere and in which the seal is made by fusion. Continuous soldering, brazing, welding and the fusion of glass to metal are examples of recognized methods.

I.S Ground
A dedicated ground system to which Zener Barriers are connected. The resistance to ground path must be less than or equal to 1 Ohm from any Zener Barrier to designated ground electrode.

I.S.
Abbreviation for intrinsic safety.

I/O Module
A module that provides basic input and output functions between the automation system and the field devices. Disregarding specialty modules, there are four basic types available from various vendors - analog input, analog output, discrete input, and discrete output.

IEC
Acronym for International Electrotechnical Commission. An international commission of which most nations are members. IEC standards directly affect equipment for sale internationally. The benefit of participation in the IEC is that costly differences in plant or equipment design can be avoided by designing equipment consistent with IEC documents where feasible.

Ignitable Gas Mixture
A gas -air mixture that is capable of being ignited by an open flame, arc or spark or high temperature.

Ignition (Autoignition) Temperature
The minimum uniform temperature required to initiate or cause self-sustained combustion of a solid, liquid, or gaseous substance (independent of any other ignition source).

USA Headquarters web: www.am.pepperl-fuchs.com
phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com
Worldwide Headquarters web: www.pepperl-fuchs.com
phone: +49 621 776-0 • email: pa-info@de.pepperl-fuchs.com
Asia Pacific Headquarters web: www.pepperl-fuchs.com
phone: +65 67799091 • email: sales@sg.pepperl-fuchs.com

Increased Safety
An international term that describes a type of protection in which various measures are applied so as to reduce the probability of excessive temperatures and the occurrence of arcs or sparks in the interior and on the external parts of electrical apparatus that do not produce them in normal service. This type of protection is referred to by IEC as "Ex e".

Inductance
The property of an electric circuit by virtue of which a varying current induces an electromotive force in that circuit or in a neighboring circuit. The practical difference between capacitance and inductance in an intrinsically safe circuit is minimal. Both store energy, but an inductor will release energy when a circuit is broken, and a capacitor will release energy when the circuit is made.

Insulator
A material that conducts electrons slowly. The importance to intrinsic safety is that air (a spatial distance) is often an insulator.

Internal Wiring
Wiring and electrical connections that are made within the apparatus by the manufacturer. Within racks or panels, interconnections between separate pieces of apparatus made in accordance with detailed instructions from the apparatus manufacturer are considered to be internal wiring.

Intrinsic Safety Barrier
A component containing a network designed to limit the energy (voltage and current) available to the protected circuit in the hazardous (classified) location under specified fault conditions.

Intrinsic Safety Ground Bus
A grounding system that has a dedicated conductor separate from the power system so that ground currents will not normally flow and that is reliably connected to a ground electrode (e.g., in accordance with Article 250 of NEC, ANSI/NFPA 70, or Section 10 of CEC Part I, CSA C22.1).

Intrinsic Safety
A type of protection in which a portion of the electrical system contains only intrinsically safe equipment (apparatus, circuits, and wiring) that is incapable of causing ignition in the surrounding atmosphere. No single device or wiring is intrinsically safe by itself (except for battery-operated self-contained apparatus such as portable pagers, transceivers, gas detectors, etc., which are specifically designed as intrinsically safe self-contained devices) but is intrinsically safe only when employed in a properly designed intrinsically safe system. This type of protection is referred to by IEC as "Ex i."

Intrinsically Safe Apparatus
Apparatus in which all the circuits are intrinsically safe.

Intrinsically Safe Circuit
A circuit in which any spark or thermal effect, produced either normally or in specified fault conditions, is incapable, under the prescribed test conditions, of causing ignition of a mixture of flammable or combustible material in air in the mixture's most easily ignited concentration.

Intrinsically Safe Equipment
Equipment that may be installed in a hazardous location, in which all the circuits are intrinsically safe, or that is designed to form part of an intrinsically safe system.

Intrinsically Safe Ground
A clearly identified conductor of not less than 12 AWG/4 mm^2 cross-sectional area with a total impedance from barrier ground bus bar to main power system earth of not more than 1 Ω.

Intrinsically Safe System
An assembly of interconnected intrinsically safe apparatus, associated apparatus, and interconnecting cables in which those parts of the system that may be used in hazardous (classified) locations are intrinsically safe circuits.

ISA
Acronym for the Instrumentation, Systems and Automation Society. ISA Committee SP12, established in 1949, has been influential in establishing the recognition of intrinsic safety and nonincendive circuits in the NEC.

Isolated Barriers
A type of barrier with additional active components and galvanic isolation to separate the hazardous area instrument from the safe area controller providing advantages over the traditional zener barrier.

Knockout
A portion of the wall of an enclosure so fashioned that it may be removed readily by a hammer, screwdriver, and pliers at the time of installation in order to provide a hole for the attachment of an auxiliary device or raceway, cable, or fitting.

Labeled Equipment
Equipment or materials, to which has been attached a label, symbol, or other identifying mark of an organization concerned with product evaluation, that may maintain periodic inspection of the production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

LEL
Abbreviation for lower explosive limit (lower flammable limit).

Listed
Equipment or materials, included in a list published by an organization concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or materials meets appropriate standards or has been tested and found suitable for use in the specified manner.

Maintenance, Corrective
Any maintenance activity that is not normal in the operation of the equipment and requires access to the equipment's interior. Such activities are expected to be performed by qualified personnel who are aware of the hazards involved. Such activities typically include locating causes of faulty performance, replacement of defective components, adjustment of internal controls, and the like.

Maintenance, Operational
Any maintenance activity, excluding corrective maintenance, intended to be performed by the operator and required in order for the equipment to serve its intended purpose. Such activities typically include the correcting of "zero" on a panel instrument, changing charts, record keeping, adding ink, and the like.

Glossary

Make/Break Components
Components having contacts that can interrupt a circuit (even if the interruption is transient in nature). Examples of make/break components are relays, circuit breakers, servopotentiometers, adjustable resistors, switches, connectors and motor brushes.

Maximum External Capacitance (C_o; C_a)
Maximum capacitance in an intrinsically safe circuit that can be connected to the connection facilities of the apparatus without invalidating intrinsic safety.

Maximum External Inductance (L_o; L_a)
Maximum value of inductance in an intrinsically safe circuit that can be connected to the connection facilities of the apparatus without invalidating intrinsic safety.

Maximum External Inductance To Resistance Ratio (L_o/R_o)
Ratio of inductance (L_o) to resistance (R_o) of any external circuit that can be connected to the connection facilities of the electrical apparatus without invalidating intrinsic safety.

Maximum Inductance To Resistance Ratio (L/R)
As an alternative value to L_a the ratio of inductance (L) to resistance (R) of any external circuit that can be connected to the terminals of intrinsically safe apparatus without invalidating the intrinsic safety of the apparatus.

Maximum Input Current (I_i; I_{max})
Maximum current (peak AC or DC) that can be applied to the connection facilities for intrinsically safe circuits without invalidating intrinsic safety.

Maximum Input Power (P_i)
The maximum power that can be applied to the terminals of an intrinsically safe device without invalidating the intrinsic safety of the device.

Maximum Input Voltage (U_i; V_{max})
Maximum voltage (peak AC or DC) that can be applied to the connection facilities for intrinsically safe circuits without invalidating intrinsic safety.

Maximum Internal Capacitance (C_i)
The total unprotected internal capacitance of the intrinsically safe apparatus that must be considered as appearing across the terminals of the intrinsically safe apparatus.

Maximum Internal Inductance (L_i)
The total unprotected internal inductance of the intrinsically safe apparatus that must be considered as appearing across the terminals of the intrinsically safe apparatus.

Maximum Internal Inductance To Resistance Ratio (L_i/R_i)
Ratio of inductance (L_i) to resistance (R_i) which is considered as appearing at the external connection facilities of the electrical apparatus.

Maximum Output Current (I_o, I_{sc})
Maximum current (peak AC or DC) in an intrinsically safe circuit that can be taken from the connection facilities of the apparatus.

Maximum Output Power (P_o)
Maximum electrical power in an intrinsically safe circuit that can be taken from the apparatus.

Maximum Output Voltage (U_o, V_{oc})
Maximum output voltage (peak AC or DC) in an intrinsically safe circuit that can appear under open circuit conditions at the connection facilities of the apparatus at any applied voltage up to the maximum voltage, including U_m and U_i.

Maximum r.m.s. AC or DC Voltage (U_m)
Maximum voltage that can be applied to the non-intrinsically safe connection facilities of associated apparatus without invalidating intrinsic safety. The value of U_m may be different at different sets of connection facilities.

Maximum Surface Temperature
The highest temperature attained by a surface accessible to flammable gases, vapors, or combustible dusts under conditions of operation within the ratings of the apparatus (including recognized overloads and defined fault conditions.

MEIC
Abbreviation for most easily ignited concentration.

MESG
Abbreviation for maximum experimental safe gap.

MIC
Abbreviation for minimum ignition current.

MIE
Abbreviation for minimum ignition energy.

Minimum Igniting Voltage
Minimum voltage of capacitive circuits that causes the ignition of the explosive test mixture in the spark-test apparatus.

NEMA
Acronym for National Electrical Manufacturers Association. Provides a rating system to identify an enclosure's ability to repel the outside environment. Unlike organizations such as UL, FM and CSA, NEMA does not require independent testing and leaves compliance to its rating system completely up to the manufacturer.

NFPA
Acronym for National Fire Protection Association. The NFPA has acted as a sponsor and publisher of the National Electrical Code since 1911. Most of the NFPA standards tend to emphasize recommendations for the safe use of electrical apparatus, area classification, fire protection and hazards of materials.

Nonhazardous Location
A location utilizing drying, curing or fusion apparatus and provided with positive mechanical ventilation adequate to prevent accumulation of flammable concentrations of vapors, and provided with effective interlocks to deenergize all electric equipment (other than equipment approved for Class I locations) in case the ventilating equipment is inoperative, shall be permitted to be classified as non hazardous where the authority having jurisdiction so judges.

Nonincendive Circuit
A circuit in which any arc or thermal effect produced in normal operating conditions of the equipment is not capable, under prescribed conditions, of igniting the specified flammable gas, vapor-in-air mixture, combustible dusts, or ignitable fibers or flyings.

Nonincendive Component
A component having contacts for making or breaking a specified incendive circuit in which the contacting mechanism is constructed so that the component is not capable of ignition of the specified flammable gas or vapor-in-air mixture when tested as specified by appropriate test procedure. The housing of a nonincendive component is not intended to exclude the flammable atmosphere or contain an explosion.

Nonincendive Equipment
Equipment having electrical/electronic circuitry and components that are incapable under normal conditions, of causing ignition of a specified flammable gas or vapor-in-air mixture due to arcing or thermal effect.

Nonincendive Field Wiring
Wiring that enters or leaves an equipment enclosure and, under normal operating conditions of the equipment, is not capable, due to arcing or thermal effects, of igniting a specified flammable gas or vapor-in-air mixture or combustible dust-in-air mixture. Normal operation includes opening, shorting, or grounding the field wiring.

Nonincendive Field Wiring Apparatus
Apparatus intended to be connected to nonincendive field wiring.

Normal Operational Conditions
Conditions that conform electrically and mechanically with its design specifications and is used within the limits specified by the manufacturer.

NRTL
Acronym for Nationally Recognized Testing Laboratory. This recognition indicates that the Occupational Safety & Health Administration has accredited certain organizations to evaluate products according to consensus based safety standards.

Operational Maintenance
Any maintenance activity, other than corrective maintenance, intended to be performed by the operators and which is required in order for the equipment to serve its intended purpose. Such activities typically include the correcting of "zero" on a panel instrument, changing charts, making records, adding ink, etc.

OSHA
Acronym for Occupational Safety and Health Administration. The OSHA Act was passed by the U.S. Congress in 1971. Part 1910 of the OSHA regulations adopted the 1968 NEC and defined "approved" to mean "listed by UL or FM." "Approved" was redefined in 1972, providing exceptions to FM or UL listing; however, in practice the emphasis on listing remained unchanged. Listing requirements increased interest in developing standards for certain categories of apparatus, such as process control instrumentation. Third-party approval agencies (e.g., UL, FM, CSA) for electrical equipment must be accredited by OSHA.

Passive Transistor Output
A transistor in which the emitter and collector are not connected to an internal power source. Only the base is connected so that it may be switched on and off. The emitter and collector may be connected to the customer's power source.

Polarity
Zener barriers are available in polarized (DC) and non-polarized (AC) versions. Positive polarity types have the negative side of the circuit grounded, while negative polarity types have the positive side of the circuit grounded. Non-polarized barriers have zener diodes connected in inverse series pairs and can be used in both AC and DC circuits.

Protective (Infallible) Component or Assembly
A component or assembly which is so unlikely to become defective in a manner that will lower the intrinsic safety of the circuit it may be considered not subject to fault when analysis or tests for intrinsic safety are made. Examples of this type of component or assembly are:

PTB
Acronym for Physikalisch-Technische Bundesanstalt. An approval agency in Germany that has the authority to accept or reject the design of an electrical apparatus based on recognized safety standards.

Repeater
A type of active or transformer isolated barrier that receives a signal from the hazardous area instrument (i.e., transmitter, thermocouple, etc.) and repeats that signal into the safe area while providing Intrinsic Safety.

Resistance Temperature Detector (RTD)
A resistor made of some material for which the electrical resistivity is a known function of the temperature and that is intended for use with a resistance thermometer. It is usually in such a form that it can be placed in the region where the temperature is to be determined.

Resistance
That physical property of an element, device, branch, network or system that is the factor by which the mean-square conduction current must be multiplied to give the corresponding power lost by dissipation as heat or as other permanent radiation or loss of electromagnetic energy from the circuit.

RS-232
An EIA standard that specifies the electrical, mechanical, and functional characteristics for serial communications. Used in point-to-point applications.

RS-485
An EIA standard that specifies the electrical characteristics of a balanced-voltage digital interface. Used in multi-point applications.

Safe Area
A nonhazardous location.

Seal, Cable, Explosionproof
A cable terminator filled with compound and designed to contain an explosion in the enclosure to which it is attached or to minimize passage of flammable gases or vapors from one location to another. A conduit seal may also be used as a cable seal. This method differs from the international practice, which requires cable glands.

Seal, Conduit, Explosionproof
A sealed fitting, poured with a cement-like potting compound, designed to contain an explosion in the enclosure to which it is attached and to minimize passage of flammable gases or vapors from one location to another.

Glossary

Serial Interface
A method of digitally transmitting data between devices over a pair of conductors. See RS-232 and RS-485.

Short-Circuit Proof
The ability of an intrinsic safety barrier or isolator to withstand the shorting of its' intrinsically safe connections to ground. Determined by dividing the rated voltage by its' internal resistance. If the resulting value is less than the fuse rating, the barrier is said to be short-circuit proof.

Short-Circuit Protection
The ability of the solid-state output to withstand a direct short without damage to itself.

Shunt Diode Barrier Assembly
A fuse- or resistor- protected diode barrier.

Simple Apparatus
An electrical component or combination of components of simple construction with well-defined electrical parameters that is compatible with the intrinsic safety of the circuit in which it is used. A device that will neither generate nor store more than 1.5 V, 0.1 A and 25 mW. Examples are switches, thermocouples (TCs), light-emitting diodes (LEDs), and resistance temperature devices (RTDs).

SIT
Abbreviation for spontaneous ignition temperature.

Switch Isolator
Term used for the type of transformer isolated barrier that is used to repeat signals from discrete inputs (i.e., contact closures, proximity sensors.)

Temperature Code (Temperature Classification)
A system of classification by which one of 14 temperature identification numbers (internationally, six temperature classes) is allocated to an electrical apparatus. The temperature code represents the maximum surface temperature of any component that may come in contact with the flammable gas or vapor mixture.

Termination Panel
A mechanical assembly that resides in front of the I/O system and performs signal conditioning, electrical isolation, and other functions.

Thermistor
An electron device that makes use of the change of resistivity of a semiconductor with change in temperature.

Thermocouple (TC)
A pair of dissimilar conductors so joined at two points that an electromotive force is developed by the thermoelectric effects when the junctions are at different temperatures.

TIB
Acronym for Transformer Isolated Barrier. A term used to describe an isolated intrinsic safety barrier used for hazardous area applications. Although a typical TIB will employ multiple means of isolation, the term TIB is used to generically describe this type of barrier.

Transmitter (Tx)
A device for transmitting a coded signal when operated by any one of a group of actuating devices.

UEL
Abbreviation for upper explosive limit (upper flammable limit).

UL
Acronym for Underwriters Laboratories, Inc, a third party certification agency that is an independent, self-supporting, nonprofit testing laboratory and standards developer. It is recognized by OSHA as a Nationally Recognized Testing Laboratory in the United States. The presence of UL, CSA or FM certification labels on equipment is normally sufficient evidence to the local inspector that the product is designed to meet recognized safety standards.

Zener Barrier
A combination of components that limits energy to the hazardous area to a level below that which would ignite a specific gas/air mixture.

Zener Diode
A class of silicon diodes that exhibit in the avalanche breakdown region a large change in reverse current over a very narrow range of reverse voltage. This characteristic permits a highly stable reference voltage to be maintained across the diode despite a relatively wide range of current through the diode.

Zone
The international method of specifying the probability that a location is made hazardous by the presence, or potential presence, of flammable concentrations of gases and vapors. The term Division is used in the United States and Canada.

Zone 0
An area in which an explosive gas-air mixture is continuously present or present for long periods. Equal to a Class I, Division 1 hazardous location.

Zone 1
An area in which an explosive gas-air mixture is likely to occur in normal operation. Equal to a Class I, Division 1 hazardous location.

Zone 2
An area in which an explosive gas-air mixture is not likely to occur and if it does occur, will only exist for a short time. Equal to a Class I, Division 2 hazardous location.

Zone 20
An area in which a combustible dust cloud is part of the air permanently, over long periods of time or frequently. Equal to a Class II, Division 1 hazardous location.

Zone 21
An area in which a combustible dust cloud in air is likely to occur in normal operation. Equal to a Class II, Division 1 hazardous location.

Zone 22
An area in which a combustible dust cloud in air may occur briefly or during abnormal operation. Equal to a Class II, Division 2 hazardous location.

USA Headquarters web: www.am.pepperl-fuchs.com
phone: 330 486-0002 • email: sales@us.pepperl-fuchs.com
Worldwide Headquarters web: www.pepperl-fuchs.com
phone: +49 621 776-0 • email: pa-info@de.pepperl-fuchs.com
Asia Pacific Headquarters web: www.pepperl-fuchs.com
phone: +65 67799091 • email: sales@sg.pepperl-fuchs.com