Applying Intrinsic Safety

Today's world of increasing process control in potentially explosive atmospheres has forced designers and engineers to specify more efficient and effective ways of protecting personnel from harm and property from damage. Since its initial introduction nearly 50 years ago, intrinsic safety has evolved into a complete system solution including remote I/O (inputs and outputs).

What Is Intrinsic Safety?

Intrinsically safe equipment is defined as "equipment and wiring which is incapable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignited concentration.[1]" This is achieved by limiting the power available to (and used or generated by) the electrical equipment in the hazardous area to a level below that which will ignite the hazardous atmosphere.

The following industries are known to have hazardous locations: chemical, munitions, petrochemical, auto (paint spray booths), grain, waste water, printing, distilling, pharmaceutical, brewing, cosmetics, mining, plastics and utilities.

What authority allows the user to utilize intrinsic safety?

Normally, the user's insurance carrier and/or government authority having jurisdiction require that the system be approved by a recognized approval authority. In North America, the following organizations develop and publish documents and standards dealing with intrinsic safety: the National Fire Protection Agency (NFPA), the Canadian Standards Association (CSA), Underwriters Laboratories (UL), Factory Mutual (FM), National Electric Code (NEC), and the Instrument Society of Measurement and Control (ISA). Typically, I.S. products are tested and Approved or Listed by Factory Mutual Research Corporation or Underwriters Laboratories, Inc. The Canadian Standards Association is the predominant approval authority of Canada.

Many international standards for intrinsic safety exist throughout the world. The most influential of these is the European Committee for Electrotechnical Standardization (CENELEC). The CENELEC standards are a single set of documents agreed upon by all of the member nations, mainly the European Community nations of Western Europe. There are several test laboratories authorized to issue approvals of intrinsic safety equipment to CENELEC standards. A CENELEC certification is valid in all CENELEC member nations.

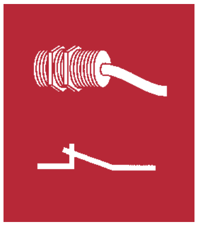
When installing electrical equipment in a hazardous area, extensive regulations must be observed. In North America, these regulations must be verified in each province, state or city since individual locations can differ in their installation and/or application of intrinsic safety. The same is true in Europe where regulations are subdivided into European (EU) and national requirements. The European standards define the general specifications and the detailed guidelines for methods of protection against explosion. The national requirements primarily contain installation requirements.

In the past, the U.S. and Canada have relied on classification of hazardous areas by Classes, Divisions and Groups. Although this system is still in use, North America is gradually beginning to adopt a classification system based on Zones as standardized in many countries of the world (those accepting International Electrotechnical Commission (IEC) or CENELEC standards). The chart on the next page compares common specifications of Explosion Protection for the European Union and North America.

Note 1: Excerpt from ISA-RP12.6

	Classification by Classes, Divisions and Groups	Classification by Zones
Type of Hazard	Explosive mixtures of air with: **Class I:** gases or vapors **Class II:** dusts **Class III:** fibers or flyings	Explosive mixtures of air with flammable gases or vapors. **Group I:** Mines where methane may be present **Group II:** Places with potentially explosive atmosphere other than mines susceptible to methane
Degree of Hazard	**Division 1:** An explosive concentration of the hazardous material may be continuously, intermittently or periodically present under normal operating conditions.	**Zone 0:** An explosive air/gas mixture is continuously present or present for long periods. **Zone 1:** An explosive air/gas mixture is likely to exist under normal operating conditions for short periods.
	Division 2: An explosive concentration of the hazardous material is present only under fault conditions and if such a condition occurs, it will exist only for a short period.	**Zone 2:** An explosive air/gas mixture is not likely to occur under normal operating conditions and if such a condition occurs, it will exist only for a short period.
Ignition by Spark	Explosive atmospheres are grouped according to their ignition capabilities. Representative atmospheres are: **Group A:** acetylene **Group B:** hydrogen **Group C:** ethylene **Group D:** propane **Group E:** metal dust **Group F:** carbon dust **Group G:** flour, starch, grain	Explosive gases are grouped according to their ignition capabilities. Representative gases are: **Group I:** methane **Group IIC:** hydrogen, acetylene **Group IIB:** ethylene **Group IIA:** propane
Ignition by Hot Surface	Hazardous area apparatus is classified according to the maximum surface temperature produced under fault conditions at an ambient temperature of 40°C (or as otherwise specified). **T1:** 450°C **T2:** 300°C **T2A*:** 280°C **T2B*:** 260°C **T2C*:** 230°C **T2D*:** 215°C **T3:** 200°C **T3A*:** 180°C **T3B*:** 165°C **T3C*:** 160°C **T4:** 135°C **T4A*:** 120°C **T5:** 100°C **T6:** 85°C *North America only	
Gas Characteristics	Information regarding **gas grouping** by ignition energy and **gas ignition temperatures** are contained in: -NFPA 497M, *Manual for Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous (Classified) Locations* -CSA No. C22-1 -NEC Article 500 -British Standard Code of Practice for Electrical Apparatus and Associated Equipment for use in Explosive Atmospheres (other than Mining Application), BS5345: Part 1—Basic requirements for all parts of the code	

■ *Instruments Commonly Found in Hazardous Areas:*

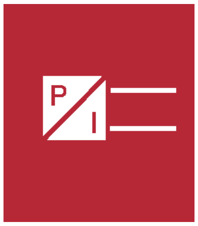


Switches

Includes push buttons, selector switches, float switches, flow switches, proximity switches, limit switches, etc.)

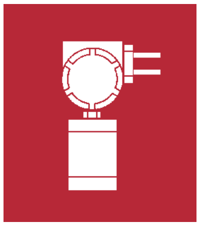
Thermocouples

A thermocouple is a device used to sense temperature. It is inexpensive and with the various types available, covers a wide range of measured temperatures. Thermocouples are constructed of two dissimilar metals which generate a millivolt signal varying with temperature.



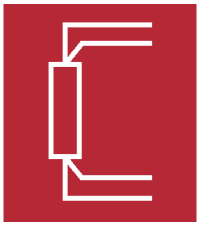
I/P Converters

This device is commonly known as an electro-pneumatic transducer or current/pressure converter. It converts a DC milliamp signal to a proportional pneumatic output signal. This pneumatic signal is commonly used to position a control valve.



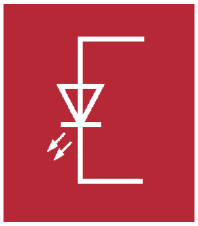
Transmitters

A 2- or 3-wire transmitter is a device used in a control system which converts a process variable (i.e., temperature, level, pressure, flow, etc.) to a proportional electrical signal. The electrical output is a 0/4-20mA, 0/1-5V or 0/2-10V signal.



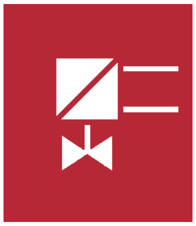
RTDs

An RTD (resistance temperature detector) converts temperature into resistance. An example of a resistance change is .385 ohms/°C for a 100 Ohm platinum RTD.



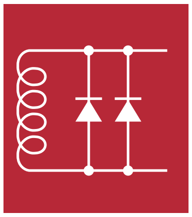
Light Emitting Diodes (LEDs)

Standard incandescent bulbs may not be used in explosive areas because of radiant heat, current requirements and the susceptibility of the bulb to breakage. LEDs are an alternative that can be made intrinsically safe through the use of barriers.



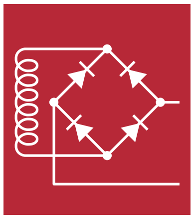
Solenoids

A solenoid is an electrically actuated valve that allows full flow or no flow of gases or liquids. Standard 24 VDC solenoids may not be used in the hazardous area due to the coil's energy storing capacity.

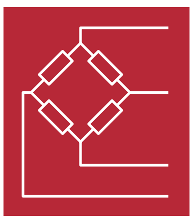


I.S. Solenoids

In order to design a solenoid for hazardous areas and to obtain I.S. certification, one common procedure is to embed (2) diodes connected in parallel to the coil. These diodes are used to eliminate the potential arcing if a wire were to break in the hazardous area during operation. These diodes will suppress the arc and provide the solenoid with a low inductance rating.

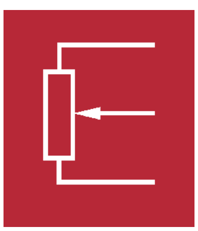


Some I.S. solenoid manufacturers go a step further when installing diodes in their valves. They are installed as full wave bridge rectifiers which give the additional advantage of non-polarity sensitive valves. The diodes in series cause an additional voltage drop of approximately 1.4V (.7Vx2). This is very important when applying intrinsic safety barriers.



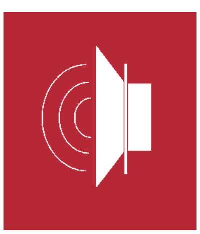
Strain Gauges

Strain gauges are used to measure stress or are used in load cells, scales and transducers to measure force, weight and pressure. The operation of a strain gauge is based on the premise that the electrical resistance of metal wire is changed when it is stretched or compressed.



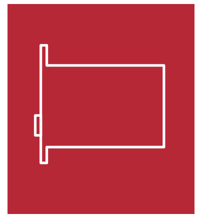
Potentiometers

Potentiometers are adjustable resistors. The resistance value (ohms) changes with mechanical movement of the wiper.



Audible Alarms

Audible alarms (horns or buzzers) are devices sometimes used in hazardous areas to signal that an event has taken place. Typically, the choice of which barrier to use would be the same for audible alarms as it is for solenoids.



Serial Communications

Serial communication is the transfer of data in a sequence of bits, generally in the form of a low voltage signal (0-15V). The most common serial communications protocol is RS-232.

Fire Detectors

A fire detector is used to detect flames in a hazardous environment. In the normal state, a low current (4-6mA) passes through the detector circuit. When an alarm condition occurs, higher current (15-20mA) flows through the circuit. An end-of-line resistor distinguishes between detector normal state and a broken wire between detector and barrier (a broken wire means zero current flow).

What is a simple apparatus?

The approval agencies recognize devices known as “simple apparatus.” A simple apparatus does not generate or store more than the following:

- 1.2V
- 100mA
- 20µJ
- 25mW

This type of device does not need certification from a third party. Even though a device is considered a “simple apparatus,” it must be connected to an intrinsic safety barrier. Examples of simple apparatus are:

Discrete Inputs
- Limit, Pressure, Float, Flow and Temperature switches
- Push buttons

Analog Inputs
- Thermocouples
- RTDs

Discrete Outputs
- LEDs

What Are Zener Diode Barriers?

Zener diode barriers limit the energy to the hazardous area to a level below that which could ignite a specific air/gas mixture. This is accomplished by protecting against the following faults:

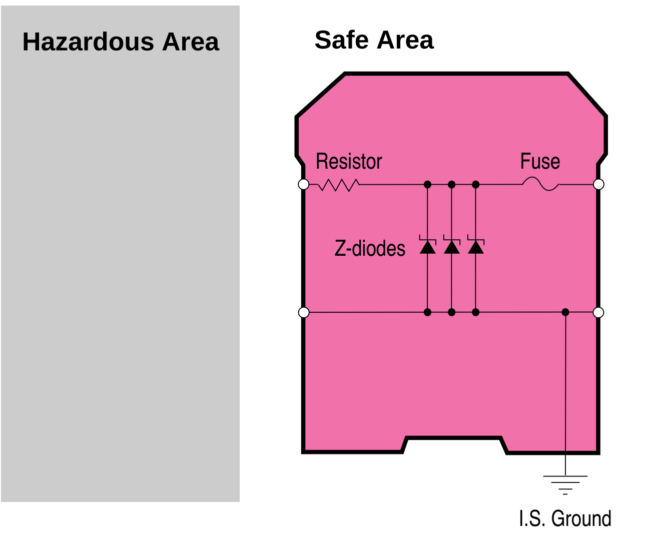
1. Shorting of wires connected to the hazardous area side of the barrier.
2. Grounding of wires connected to the hazardous area side of the barrier.
3. Misconnection or failure of the power supply allowing an unsafe voltage to be applied to the safe area side of the barrier.

The barrier will prevent unsafe levels of voltage current from passing into the hazardous area as a result of these conditions. A schematic diagram of a zener diode barrier is shown below with a resistor for current limitation, a fuse which opens in the case of excessive current and redundant zener diodes which limit the voltage to a safe level.

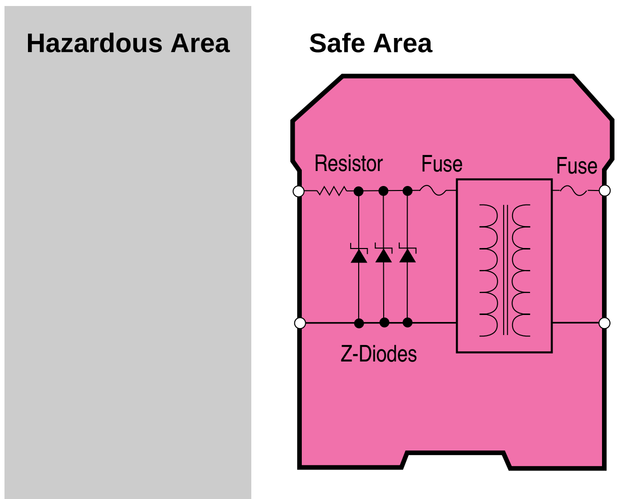
The Alternative to Zener Diode Barriers — Transformer Isolation

While zener diode barriers provide suitable protection, operate properly and are cost effective, inherent characteristics require close attention to the installation.

1. A high integrity intrinsic safety ground is required to be connected to the ground electrode. There must be no more than one ohm of resistance in this line.
2. A regulated power supply should be utilized. This will prevent the possibility of the voltage rising too high, causing the zener diodes to conduct and the fuse to open, or falling too low preventing the minimum operating voltage from reaching the field device.
3. Process control loops cannot totally float above ground. Therefore, it is possible to obtain electrical noise on the control signal.
4. If the protective fuse should open, it cannot be replaced and the barrier must be discarded.



Transformer Isolated Barrier



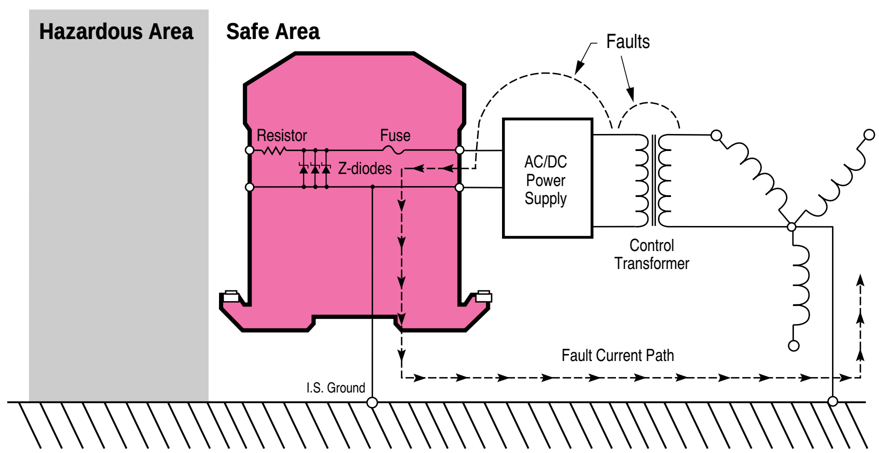
Because of these considerations, we have designed a different type of barrier known as a Transformer Isolated Barrier (TIB). It is designed to address each of the disadvantages of zener barriers.

A simplified diagram is shown on the previous page. A TIB contains a zener barrier for the voltage and current limitation. However, it does not utilize an I.S. ground. The transformer in a TIB provides a high degree of isolation between the primary and secondary windings, therefore, the ground connection is unnecessary.

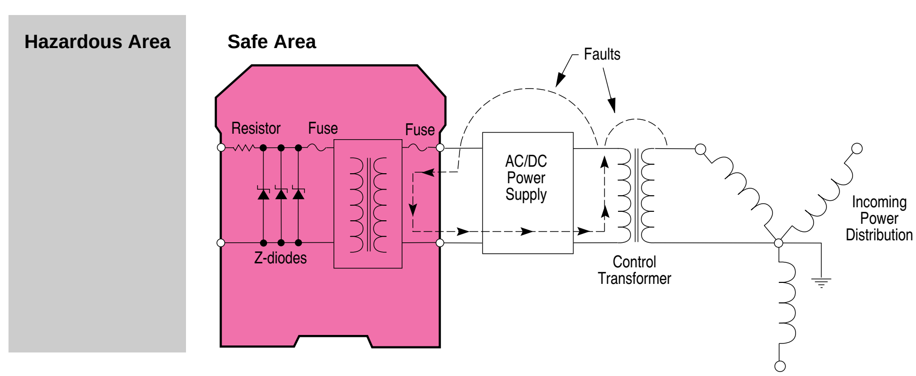
Advantages of Transformer Isolated Barriers vs. Zener Diode Barriers

1. Transformer isolated barriers do not require a high integrity I.S. ground since the transformer isolates the hazardous area connections from the non-hazardous area connections.
2. Regulated power supplies are no longer necessary. A voltage regulator circuit is used to allow a wide supply voltage range without interruption of the process or damage to the barrier.
3. Any process control loops (milliamp or millivolt signals) connected to a TIB will remain floating, unlike zener barriers that ground one side of the signal or at best provide a quasi-floating system.
4. TIBs can be repaired, unlike zener barriers that are encapsulated in epoxy.
5. TIBs contain current limiting circuitry that will not allow the protective barrier fuse to open in the case of a short circuit condition.
6. TIBs are designed for specific applications (transmitter, solenoid, switching input, thermocouple, etc.), allowing easy system design.

The major objection to using zener diode barriers is that they must be connected to an I.S. ground. This is absolutely necessary to keep a fault in the safe area from reaching the hazardous area.



In a TIB, the fault current will flow through the primary of the transformer. Once the current has reached a sufficient level, the fuse will open, preventing the fault condition from reaching the hazardous area.



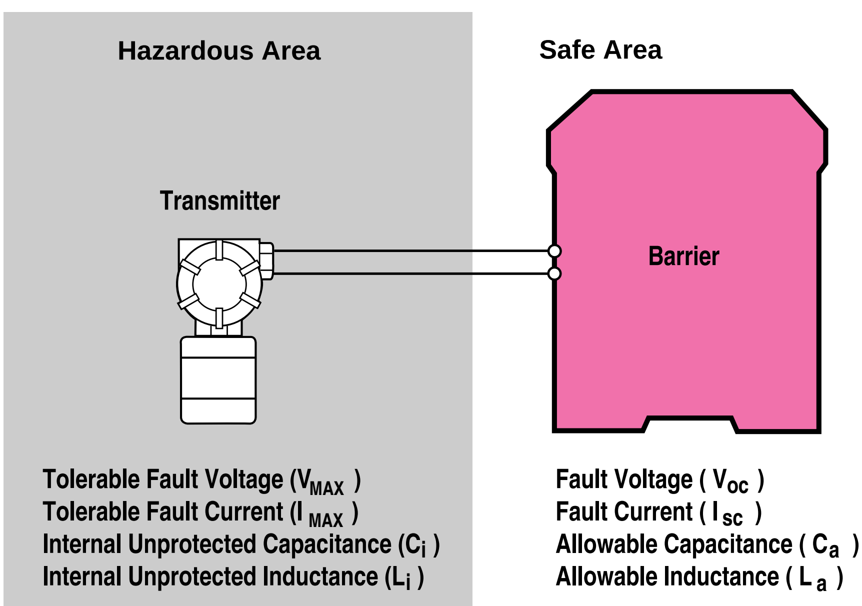
When to Use Transformer Isolated Barriers

There are several good reasons to consider TIBs:

- When installation of a high integrity I.S. ground is impractical, costly or even impossible.
- When regulated power supplies are too expensive.
- When the potential of signal noise due to ground loop problems is undesirable.
- When the cost of replacing zener barriers due to installation problems (misconceptions and shorted wires) exceeds the initial cost of TIBs.
- When the total loop resistance (including barrier, interconnecting cable and safe area load) exceeds the specifications of the transmitter (transmitter applications) or controller card (I/P applications).
- When uncertainty arises during the design of the system due to unfamiliarity with applying barriers.

TIBs are not without a downside. Generally, TIBs cost more than zener barriers and in some cases, need a separate power supply. However, they may be connected in parallel so that one power supply may feed many TIBs.

Entity Parameter Matching



$$V_{MAX} \geqslant V_{oc}$$
$$I_{MAX} \geqslant I_{sc}$$
$$C_i \leqslant C_a$$
$$L_i \leqslant L_a$$

Equipment Approval Methods

There are two methods used by approval authorities to ensure an intrinsically safe system. Although they may be called by different names by each authority, the two methods can be described as system approvals or parametric approvals.

1. System Approvals

The system approval method is one in which specific field devices are examined in combination with specific barriers. No other field device or barrier may be substituted unless specifically examined by the approval authority.

2. Parametric (Entity) Approvals

The parametric approval method is one in which each piece of equipment is evaluated separately and assigned a set of safety parameters. The field device may then be connected to a barrier with compatible safety parameters, sometimes known as “entity” parameters.

The hazardous area instrument is given the following entity parameters:

U_i; V_{max} – Maximum allowable voltage under fault conditions

I_i; I_{max} – Maximum allowable current under fault conditions

C_i – Internal unprotected capacitance

L_i – Internal unprotected inductance

The safety barrier is given the following entity parameters:

U_0; V_{oc} – Open circuit voltage - maximum voltage that can be transferred to the hazardous area under fault conditions.

I_0; I_{sc} – Short circuit current - maximum current transferred to the hazardous area under fault conditions.

C_0; C_a – Maximum allowable capacitance that can be connected to the barrier including interconnecting wiring (C_{cable}).

L_0; L_a – Maximum allowable inductance that can be connected to the barrier including interconnecting wiring (L_{cable}).

Wiring Practices*

Intrinsically safe wiring must be separated from non-intrinsically safe wiring in order to prevent the transfer of unsafe levels of energy to the hazardous area. The following are a few recommended practices.

Hazardous Area

In the hazardous area, all intrinsically safe and non-intrinsically safe wiring must be separated by the same methods suggested for the safe area. However, the following requirements must also be followed:

1. In enclosures containing multiple intrinsically safe circuits, the terminals for connection must have a spacing of at least 6mm or a grounded or insulated partition between the circuits.
2. Devices like limit switches or pressure switches must not contain a non-intrinsically safe circuit in addition to an intrinsically safe circuit unless:
   A. It is enclosed in a separate compartment, or
   B. It is separated by 50mm spacing or contains a grounded metal or insulated partition.
3. When conduit or raceway is utilized to enclose intrinsically safe wiring, it must be sealed or vented in order to prevent the transfer of hazardous atmosphere to a safe area.

Safe Area

In the non-hazardous area, intrinsically safe and non-intrinsically safe wiring must be separated by one of the following methods:

1. Raceway or conduit
2. Grounded metal or insulated partition between the intrinsically safe and non-intrinsically safe wiring
3. Airspace of at least 50mm (2 inches) between intrinsically safe and non-intrinsically safe wiring and the wires must be tied down to prevent loosening and shorting together.

The same methods are used for intrinsically safe and non-intrinsically safe terminals.

General Requirements

Intrinsically safe wiring must be identified, preferably by color coding of light blue, if no other wiring is light blue. If light blue is used on non-intrinsically safe wiring, the intrinsically safe wiring can be marked by other means, such as tagging. This alternate means, however, must be visible after installation.

Wiring Examples

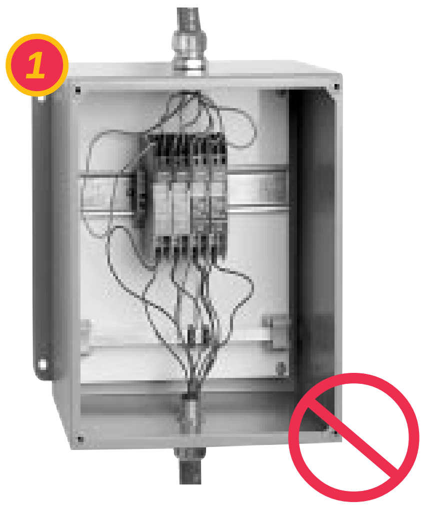
The pictures shown on the following page show barriers mounted in enclosures and wired in unsafe and safe examples.

*These sections are to be used as guidelines or recommendations only. For rules and more detailed practices, refer to National Electrical Code, NFPA 70 Article 500, ISA-RP12.6-1995 or EN 50 020.

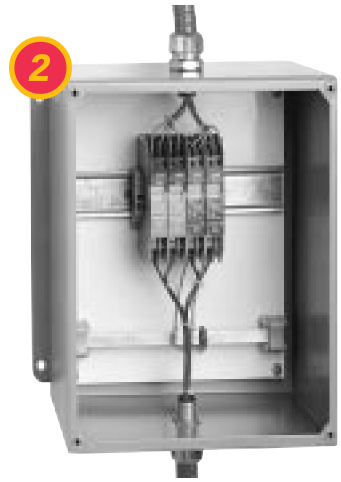
Unsafe Wiring
In Picture #1, the hazardous and safe area wiring are too close together (<50mm). Therefore, it is unsafe.

Wired Correctly
As shown in Picture #2, both sets of wiring are properly tied down and the distance between the safe and hazardous area wiring is >50mm. Therefore, the installation is considered safe.

Unsafe Wiring

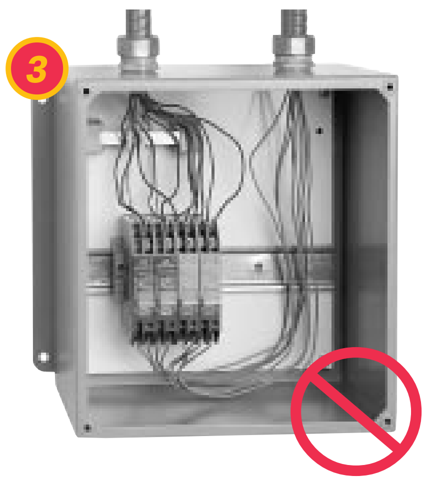


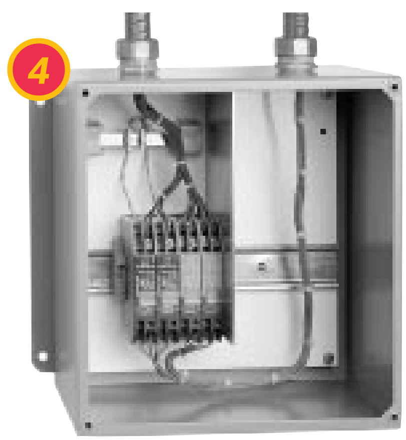
Wired Correctly



Unsafe Wiring
In Picture #3, both conduit entrances are on the same side of the enclosure. Once again, the wiring is too close together and is considered unsafe.

Wired Correctly
Picture #4 shows that either the tie-down method of the wiring or installing a partition (either grounded metal or insulated) is considered safe.





Unsafe Wiring
Picture #5 shows the barriers connected to a field wiring terminal strip. Because there is not proper distance between the safe and hazardous area wiring (<50mm) on the terminal strip, it is not considered safe.

Wired Correctly
In order to properly wire this enclosure safely, a partition must be installed between the safe area and hazardous area terminals as shown in Picture #6.