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# Installing Automation in Hazardous Areas

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For most process plants, it's not possible for all automation system components to be installed in non-hazardous areas. As a result, some form of protection is required to prevent fires and explosions that could occur when a hazardous gas and energy source combine. Fortunately, there are standards and associated products that if properly designed, installed and maintained virtually eliminate the risk of an accidental explosion in hazardous areas.

Although existing standards are proven in use, these standards aren't harmonized worldwide. Most of the world uses the IEC Zone classification system, while much of North America relies on the NEMA Class and Division system. This paper will compare, contrast and explain the IEC and NEMA standards.

This paper will then explain how to protect automation system components using either standard via one of the three main methods of protection: Energy Limiting, Containment and Segregation.

### Area Classifications

Area classifications are a standardized method of defining the likelihood of an explosive substance being present at a certain location in a facility. All equipment is classified based on three criteria:

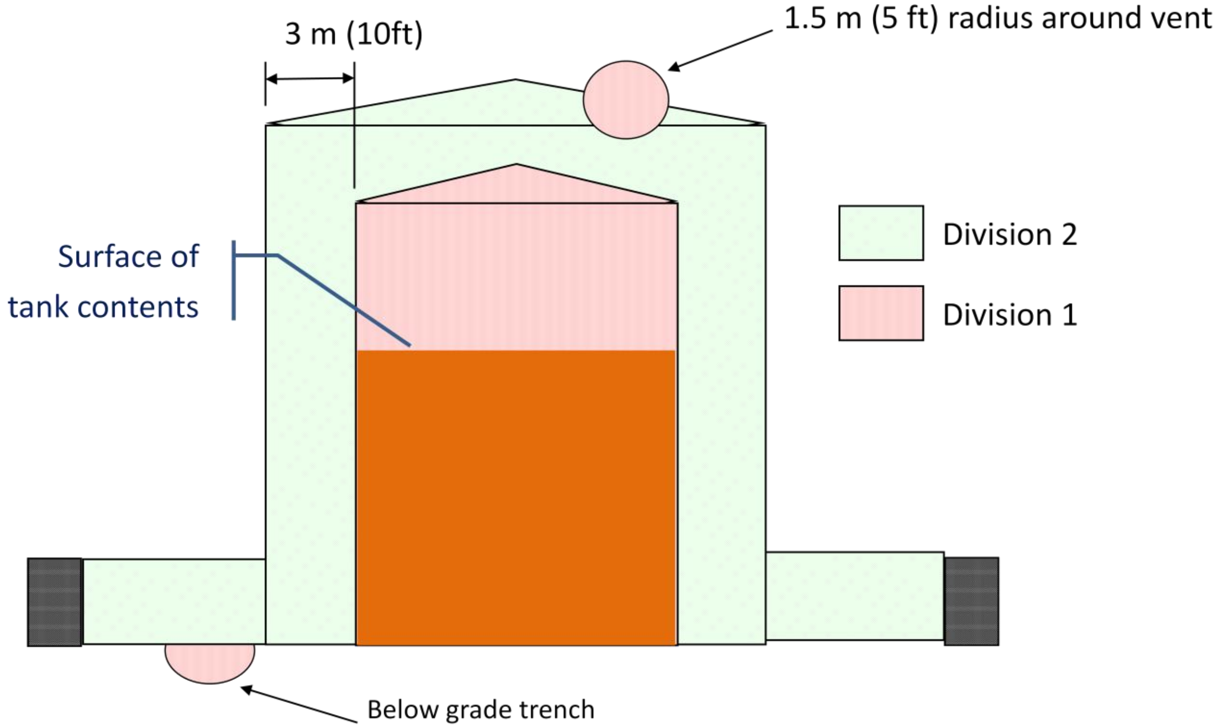
1. Apparatus or Gas group which determines the maximum spark or energy that can be present without causing an explosion;
2. Likelihood of the flammable material being present;
3. Temperature rating which is the maximum surface temperature an apparatus can attain without causing ignition.

### North American (NEMA) System

In North America, the most commonly used Area classification method uses the Class, Division and Group system per the National Electric Code (NEC chapter 5). This system defines Class I hazardous locations as operation in the presence of flammable and explosive mixtures of specific vapors and gases with air. Class II hazardous locations must operate in the presence of combustible dusts in air, while Class III areas relate to operation in environments where fibers are present.

Divisions are determined based on the likelihood of the combustible material being present. Division 1 means a hazardous atmosphere is likely to be present in normal operation. Division 2 means a hazardous atmosphere is unlikely to be present in normal operation, commonly taken to mean approximately 1 hour per year.

Combustible material will naturally disperse in the ambient environment. The following diagram from the American Petroleum Institute shows how dispersion affects the Division classification space around a potential source of flammable material.




Derived from API Recommended Practice 500A

The third component of the North American classification system is the Group letter, summarized in the table below. Groups provide an indication of how readily the material combusts, with A being the most dangerous and G the least.

| Class I | | Class II | |
|---|---|---|---|
| Group | Contains | Group | Contains |
| A | Acetylene | E | combustible metal dusts |
| B | combustible process gases containing more than 30 percent hydrogen by volume | F | Carbon black, charcoal, coal, or coke dust with more than 8% total volatile material |
| C | Ethylether, ethylene, or gases or vapors of equivalent hazard | G | Other combustible dusts such as flour, grain, wood, plastic, or chemicals |
| D | acetone, ammonia, benzene, butane, cyclopropane, ethanol, gasoline, hexane, methane, methanol, naphtha, propane, or gases or vapors of equivalent hazard with methane as the normal reference point | | |

Therefore, in a typical refinery in which gases are normally contained, the most common area classification is Class I, Division 2, Group D.

IEC System

The IEC standard, which is included in North American electrical codes and can therefore be used in North America, is based on a Zone and Gas Group classification system
The Zone concept is similar to the Division rating used in North America where Zone 0 is defined as an environment in which an explosive atmosphere is continuously present for long periods. Zone 1 is an area where an explosive atmosphere is likely to occur in normal operation, typically between 10 and 100 hours per year. Zone 2 is often referred to as a remotely hazardous area as it defines a location for which an explosive atmosphere is not likely to occur in normal operation, and if it occurs it will exist only for a short time, typically less than 10 hours per year.

The IEC also uses a combustible material classification system as per the following table.

| Group | Gas |
|---|---|
| I | All underground coal mining applications. Based on firedamp (methane) as the combustible material |
| IIA | Industrial methane, propane, gasoline and most industrial gases. |
| IIB | Ethylene, coke oven gas, and other industrial gases |
| IIC | Hydrogen, ethylene, carbon disulphide |

The following table compares the two classification systems.

| Definition | IEC | NEC |
|---|---|---|
| explosive mixture is continuously present or present for long periods | Zone 0 (gas) | Cl I Div 1 (gas) |
| | Zone 20 (dust) | Cl II Div 1 (dust) |
| explosive mixture is likely to occur in normal operation | Zone 1 (gas) | Cl I Div 1 (gas) |
| | Zone 21 (dust) | Cl II Div 1 (dust) |
| explosive mixture is not likely to occur in normal operation and if occurs it will exist only for a short time | Zone 2 (gas) | Cl I Div 2 (gas) |
| | Zone 22 (dust) | Cl II Div 2 (dust) |
| | | Cl III Div 1 (fiber) |
| | | Cl III Div 2 (fiber) |

| Gas | IEC | NEC |
|---|---|---|
| Methane | I | |
| Acetylene | IIC | A |
| Hydrogen | IIC | B |
| Ethylene | IIB | C |
| Propane | IIA | D |
| Metal Dust | | E |
| Coal Dust | | F |
| Grain Dust | | G |

The two systems use a different and almost opposite approach when assigning severity letters to the combustibility of the materials. However, both systems use a larger number for the Zone or Division with lower risk.

Having a uniform method to determine the level of risk of a combustion incident facilitates the availability of standard methods of protection. These methods of protection can reduce the overall risk and potential to an acceptable level.

**Protection Systems**

Protection systems are designed to allow for safe operation of electrical equipment in hazardous environments. In general, protection systems are separated into 3 categories which the IEC defines as Energy Limiting, Containment, and Segregation. A fourth category, Refined Mechanical Design, is similar to Energy Limiting—so the balance of this paper will concentrate on the three primary types of protection.
Energy Limiting

This method of protection uses Intrinsically Safe (IS) systems. IS systems are designed to operate with inherent safety for a particular area classification. IS systems limit the current and voltage, and hence power. In the event of a short or arcing anywhere in the circuit, there will be insufficient energy to cause an explosion, and the equipment in the IS system can be worked on while electrically live.

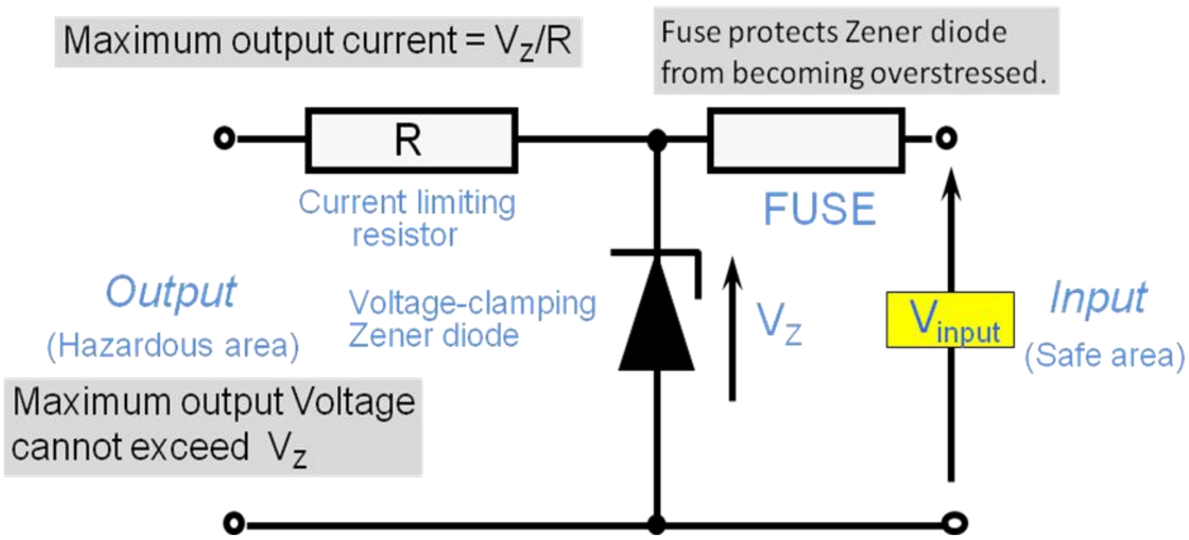
IS relies on the correct design of power, signal and apparatus. The majority of IS systems are simple and contain a single source of power in a safe area connected to a single piece of intrinsically safe apparatus in a hazardous area. The most common applications for IS systems are process transmitters and valves that typically require milliamps of current at low voltages. Such systems are discussed in detail in an appendix of IEC 60079-11.
Intrinsic safety uses three levels of protection. Each level of protection balances the probability of an explosive atmosphere being present against the probability of an ignition capable situation. The three levels are ia, ib and ic. These levels are based on a combination of ability to continue operating within design constraints with faults plus an associated safety factor as follows:

ia – Offers the highest level of protection and is generally considered as being adequately safe for use in the most hazardous locations (Zone 0 / Division 1). For ia systems to obtain this rating, a failure requires two simultaneous faults in the protection system. During the assessment of safety, a factor of safety of 1.5 is used.

ib – Is the next level of protection and is designed to remain within tolerances with one fault and a factor of safety of 1.5. As a result, ib is considered safe for use in less frequently hazardous areas (Zone 1/Division 1).

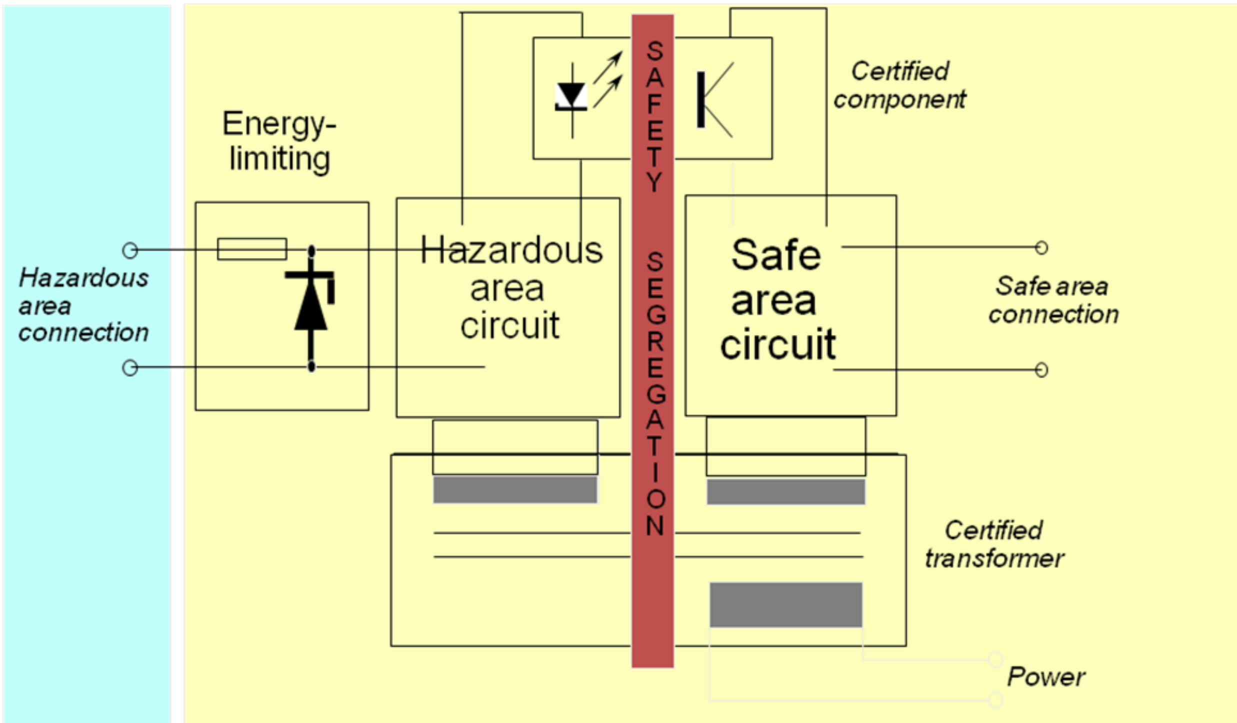
ic – Devices are assessed in normal operation with a unity factor (1.0) of safety and are generally acceptable in infrequently hazardous areas (Zone 2 / Division 2).
The following figure shows the resistive network used to manage the energy level in an IS Barrier.

# Voltage and current limiting network




The Safety Barrier limits the energy entering the Hazardous area by using zener diodes to clamp the voltage and a current limiting resistor to limit the current.

For those applications where higher voltage is needed by the field apparatus, or in cases where a field powered (4-wire) device needs to provide an IS output, a galvanic isolator is frequently used. As the name implies and as the following figure illustrates, isolators have a separate power supply (lower right) and a design that isolates all electrical components from each other. Isolation is typically accomplished via optical means.




Like the other two protection methods, IS has strengths and weaknesses as summarized below:

### Strengths

- IS level ia is the only protection system certified for use in Zone 0. North American Division 1 classified area requirements can be met by other means as well.
- Because IS manages the energy below the level that could result in an explosion, the possibility of explosion is eliminated.
- Live maintenance can be performed on the field apparatus without the need for Hot Work Permits.
- Because there are no mechanical components, IS systems require little maintenance.
- No special cables are required for safety, though they may be used for mechanical integrity.
- Because this protection method limits energy, it’s well suited to low power devices such as field instruments.

### Shortcomings

- IS isn’t widely used in North America, so there’s some lack of familiarity with the technique and its associated design and maintenance practices.

- Entity calculations are required for each loop or system, although these calculations can normally be done for a range of similar devices.
- IS systems must be kept separate from other non-IS cable and circuits by distance and mechanical separation.
- Design for higher power apparatus like valves and for longer cable requires more complex design, usually requiring galvanic isolators.

Containment

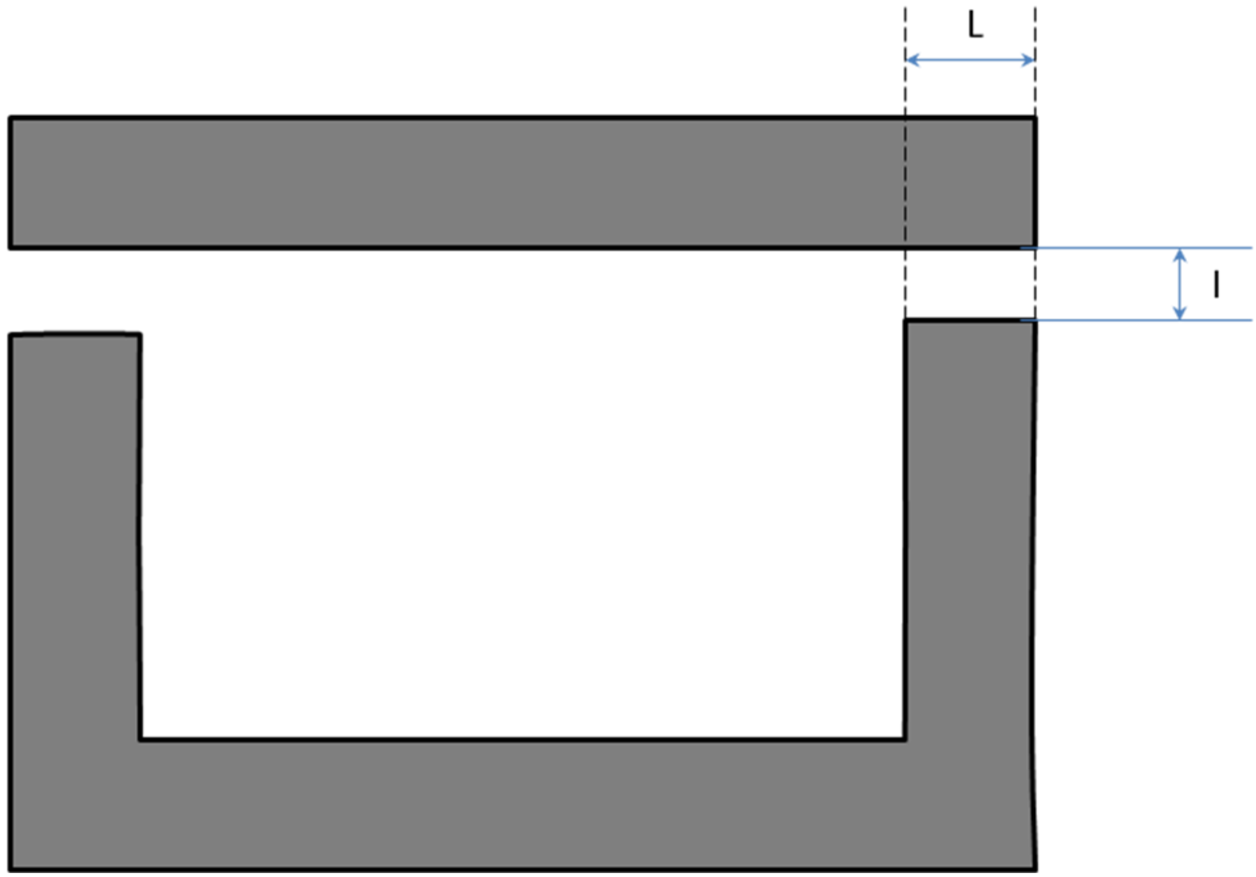
Containment is the most widely used method of hazardous area protection in North American, and it's commonly referred to as explosion-proof or flameproof. Should a combination of spark and gas occur within an enclosure sufficient to cause an explosion, this protection method will contain the explosion and prevent it from propagating or spreading outside the explosion-proof enclosure. In order to be considered suitable for this application, an explosion-proof enclosure must meet three criteria:

- Contain an internal explosion without permanent distortion.
- Guarantee that the explosion cannot be transmitted to the surrounding atmosphere.
- Exhibit a temperature at all points on the surface that's lower than the spontaneous ignition temperature of the surrounding gases or vapors.

An explosion-proof enclosure does this through both mechanical integrity and strength and heat dissipation so that in the event of a conflagration—the temperature levels of the surface of the enclosure remain below the Temperature rating in the area (see Sidebar). The explosion-proof enclosure also ensures that vapors escaping from the enclosure are below the energy level that could propagate an ignition in the ambient environment.

For this reason, explosion-proof enclosures are designed to have a tortuous path that any potentially escaping gases must flow through before reaching the outside atmosphere. For smaller enclosures, typically fittings, this tortuous path is via the minimum required number of threads. For larger enclosures, the flange effectively works as both a path of high resistance and a cooling fin.

Experimental studies of explosions have shown that correct values for the flange width (L) and for the gap (I) make it impossible for an explosion to spread outside an enclosure. The following figure shows these dimensions.




These width and gap values are directly linked to the explosive capacity of the atmosphere in question and are classed in four gas groups. For example, the value of the gap I for a flange 12.5 mm (0.5") long and for a volume < 100 $cm^3$, dependent on the explosion group, is as follows:

I : = 0.4 mm (0.016") (flanged path)
II A : = 0.3 mm (0.012")(flanged path)
II B : = 0.2 mm (0.008") (flanged path)
II C : = 0.15 mm (0.006") (spigot path)

All the values for the gap I as a function of the seal L are given in the EN/IEC 60079-1 standard

.
Because the entries through which cables enter the enclosure are also potential sources of ingress or egress of flammable materials, there are specific rules related to these holes as well. As a minimum, any holes which are not used for cable entries must be blanked using the appropriate blanking plugs.

When two enclosures are coupled with conduit, a single fire break or conduit seal is sufficient. The conduit seal must be less than 450 mm (15") from any enclosure containing a source of ignition during normal operation. The thickness of the filling material in the conduit seal must be at least equal to the inside diameter of the conduit, but never less than 16 mm (0.63"). A general rule of thumb is that when used, the conduit seal is normally installed within approximately 150 mm (6") of the enclosure.

Conduit is the most commonly used method of connecting enclosures to each other and other parts of the facility. One benefit of conduit is that it not only protects the cable, but also provides structural integrity to span open distances when required. When used, conduit must be chosen from the following two options:

a) Threaded high strength, drawn or continuous welded steel conduit according to IEC 60614-2-1; or
b) Metal or composite flexible conduit, for example metal conduit with a plastic or elastomer sheath, for which the mechanical strength is classified as "high" or "very high" according to IEC standard 60614-2-5.

The conduit itself must have a minimum of five threads so that the threads can be engaged between the conduits and the explosion-proof enclosure or between the conduits and the connector (5 threads engaged for metric threaded, 3.5 threads engaged for NPT).

The conduit can contain cables with one or more insulated conductors without a casing. However when the conduit contains at least three cables, the cross-section of these cables must not exceed 40% of the inside cross-section of the conduit.

Not all installations use conduit between enclosures as the Electrical Code now also allows for use of suitable forms of Tray Cable as well.

One more set of rules that pertain to explosion-proof enclosures is that unless the equipment has actually been tested at smaller distances, the flame path exit must be placed at a distance exceeding the distance defined below from any solid object that doesn't form part of the equipment. These solid objects typically consist of steel reinforcement, walls, protection devices against the weather, installation supports, tubes or other electrical equipment.

| Gas Group | Minimum distance (mm) | Minimum distance (inch) |
|---|---|---|
| IIA | 10 | 0.394 |
| IIB | 30 | 1.18 |
| IIC | 40 | 1.57 |

### STRENGTHS

- Should an explosion occur, it won't propagate outside the enclosure.
- Protection is 100% mechanical in nature rather than electronic, so it's not prone to failure after installation.

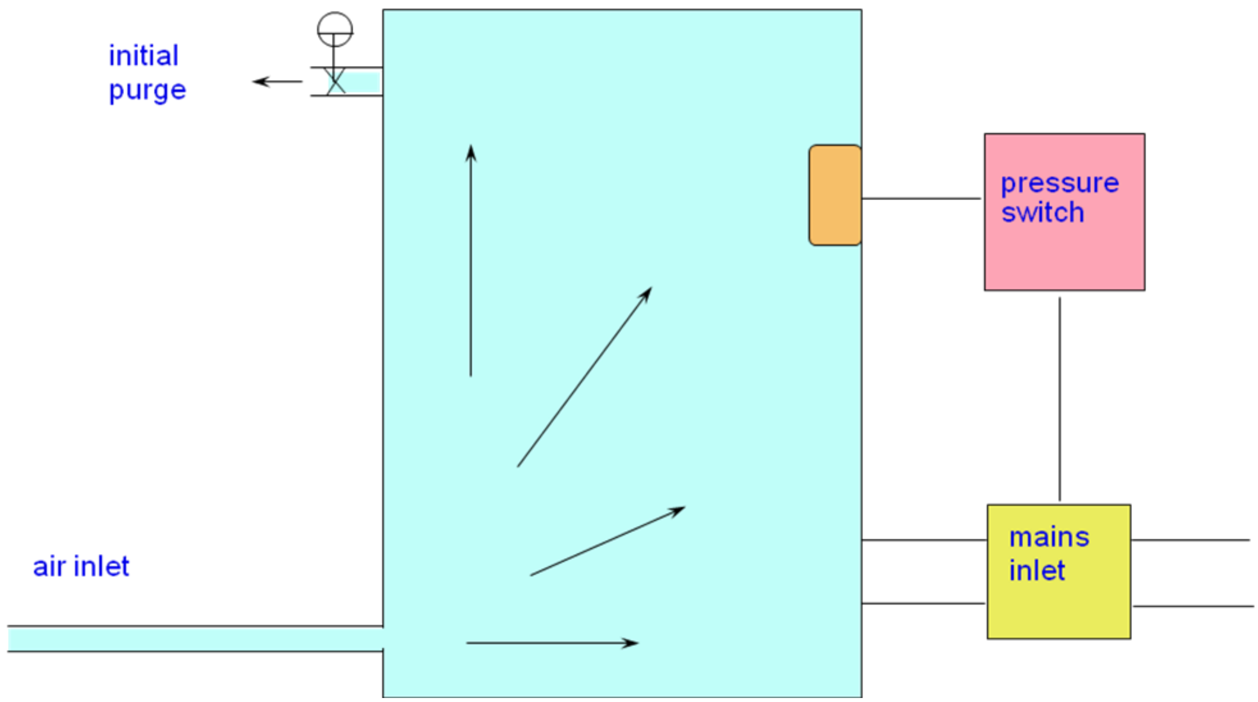
- Other than proper techniques to maintain the integrity of the seals, this form of protection requires very little maintenance.
- There are no moving parts, resulting in minimal wear and hence long life of components.
- It's possible to use high power equipment in a hazardous environment.

### SHORTCOMINGS

- There's no easy means of detecting if the integrity of the enclosure and its ability to contain an explosion has been compromised. A scratch across the face of the flange or improper tightening of the enclosure bolts can compromise the protection of the enclosure.
- If the equipment isn't properly installed (improper seals, incorrect torque tightening of bolts, non-engaged threads), the integrity of the enclosure is compromised.
- Because it's difficult to determine the affect of an explosion on the equipment inside the enclosure, it's also difficult to predict how the process connected to that equipment will be affected in the event of an incident.
- The cost of a large enclosure increases exponentially with size because the enclosure must be able to withstand the pressures associated with an explosion.
- Glass isn't able to withstand high pressures, so if windows are installed in an enclosure they are limited in size. This means that gauges and displays are often difficult to read, and must be strategically placed within the enclosure to align with the window.
- Depending on the type of enclosure selected, it's often difficult to access the components mounted within it.
- Because the unit is designed to control heat and "breathe", it's susceptible to vapor condensing on the inside surfaces. If there isn't a mechanism to drain this liquid, it can lead to short circuits.
- The thick walls of the enclosure require a larger temperature differential to the atmosphere, the result being that the inside of the enclosure typically has some degree of heat buildup. Most enclosure manufacturers provide heat calculation software to help determine the extent to which this will occur.

Segregation

The final protection option is based on preventing hazardous gas, dust or fibers from contacting the potential source of ignition. This is done by purging the equipment with a non-flammable gas to remove potential flammable materials, and by maintaining a positive pressure differential between the electronics enclosure and the ambient atmosphere. The following figure illustrates the components of a typical segregation system.




Pressurization is done by bringing compressed air or inert gas within an enclosure to a pressure where there will be no ingress of hazardous gas, dust or fibers. Both purging and pressurization are required in a Class I (gas) atmosphere. Only pressurization is required in a Class II (dust) atmosphere.

Most purging applications require a minimum enclosure pressure of 2.5 mm (0.10 inches) of water. A minimum enclosure pressure of 12.7 mm (0.50 inches) of water is required to protect against ignitable dust. In rare circumstances, enclosure pressures as high as 63.5 mm (2.5 inches) of water may be required to offset sudden atmospheric pressure fluctuations, such as may be found on offshore drilling platforms.

Average protective gas consumption during pressurization at a 2.5 mm (0.10 inch) enclosure pressure should fall somewhere between 99.5 to 3500 l/hr per cubic meter (0.1 to 3.5 scfh per cubic foot) of enclosure volume.

Specifics on the rules related to purging can be found in National Fire Protection Association (NFPA) 496. NFPA 496 specifies recommended practices for pressurization and purging, and describes the requirements for the three different types of purge systems.

Type X – Protects general purpose equipment installed in Division 1 Areas. This system reduces the classification within protected enclosures from Division 1 to non-hazardous. The controller/logic must automatically control electrical power to all protected equipment.

Type Y– Protects Division 2 rated equipment in Division 1 Areas. This system reduces the classification within protected enclosures from Division 1 to Division 2. All protected equipment must be rated for Division 2. Automatic power control disconnects aren't required, but visual and/or audible alarms must be initiated when there is loss of pressure.

Type Z – Protects general purpose equipment in Division 2 Areas. This system reduces the classification within protected enclosures from Division 2 to non-classified. Automatic power control disconnects are not required, but visual and/or audible alarms must be initiated when there is loss of pressure.

Type X systems are the most expensive to purchase, install and maintain. Type Z systems are the least expensive.

Purging is required for equipment in Class I Areas to remove flammable vapors from a protected enclosure before energizing the electronics. Purging exchanges a known volume of protective gas while maintaining a minimum positive enclosure pressure of 2.5 mm (0.10 inches) of water.

The 2003 edition of NFPA 496 recommends four volume exchanges for all enclosures, and 10 volume exchanges for all motors. Special conditions exist for enclosures such as gas analyzers and chromatographs that contain a flammable gas. Refer to NFPA 496 2003 for more information on analytical systems.

In all instances of this type of protection, alarms are connected directly to the enclosure and monitor the differential air pressure between the enclosure and the outside environment.

These alarms are activated by a reduction in flow or pressure within the protective enclosure. The alarms have a direct connection to the enclosure, eliminating the need for an alarm on the protective gas supply. Other restrictions on the alarm include:

- The alarm must be located where the operator can see it easily.
- The alarm must take its measurement from the enclosure only.
- Alarms located in the hazardous area must be rated for the area so that they can continue to operate safely in the event of loss of the primary means of protection.
- Valves cannot be connected between the alarm sensing point and the enclosure as this might isolate the alarm from the space it should be monitoring.

In addition to the above, the enclosure itself must withstand an internal pressure of five inches of water without sustaining permanent deformation, and must resist all corrosive elements in the surrounding atmosphere. A pressure relief device must be used to protect

the enclosure against pressurization system control failure and to allow proper purging system operation.
A number of manufacturers make self-contained electronics/controllers that can be connected to appropriate enclosures to provide purging and pressurization in compliance with the electrical codes. The units require only electricity and purge gas to complete the installation.

### STRENGTHS

- The differential pressure and flow of gas through the enclosure reduces heat, moisture and dust buildup.
- The code requires continuous system status indication, so failure is easily detected and can be corrected.
- The design inherently prevents contact of hazardous gases with working electronics sufficient to cause ignition because, in the event of failure, the electronics are deactivated.
- No special enclosures are required, and as a result, the cost of protection per unit of volume decreases with enclosure size.
- Protects enclosures of up to 12.74 $m^3$ (450 $ft^3$) while allowing use of practically any enclosure shape.

### SHORTCOMINGS

- Must be supplied with a continuous source of purging gas (instrument air, nitrogen, etc) that must not be hazardous.
- Contains moving parts such as flow meters, differential pressure gauges, switches and valves—making it prone to wear.
- Type X systems require automation to ensure that sufficient purge gas has flushed the enclosure before activating the electronics, and to deactivate the electronics in the event of failure of the purge gas.
- Because the equipment in the enclosure is not suitable for the surrounding environment without purging, Hot Work Permits are required when maintenance is performed.

This form of protection is most commonly found in installations where larger volume enclosures are required.

## Conclusion

No single protection solution can meet every need, so the engineer responsible for the design must make a choice by balancing the factors summarized in the advantages and shortcomings ascribed to each of the three protection methods. The following table summarizes the advantages and shortcomings of each protection methods on a relative basis.

| **Factor** | *Intrinsic Safety* | *Explosion-proof* | *Purging* |
|---|---|---|---|
| High power protection | Poor | Good | Good |
| Live working | Good | Fair | Poor |
| Enclosure size | Fair | Fair | Good |
| Installed cost, large enclosures | Fair | Poor | Good |
| Required maintenance effort | Good | Fair | Poor |
| Operating cost | Good | Good | Poor |
| Available design expertise | Fair | Good | Fair |
| Indication of failure | Poor | Poor | Good |
| Local display | Good | Poor | Good |
| Access | Good | Poor | Fair |

A key selection factor is the availability of a suitable purge gas. Once installed, perhaps the biggest difference among the protection methods is the degree to which human factors play a role in ongoing reliability. The majority of installations select the protection method based on available design expertise and maintenance personnel, with past operating experience also playing a key role.

Advantech provides a long-line of industrial automation products such as managed and unmanaged Ethernet switches, serial and programmable device servers, media converters, Modbus gateways, industrial monitors, PACs, I/O modules, and embedded automation computers that meet many of the requirements mentioned in this paper.

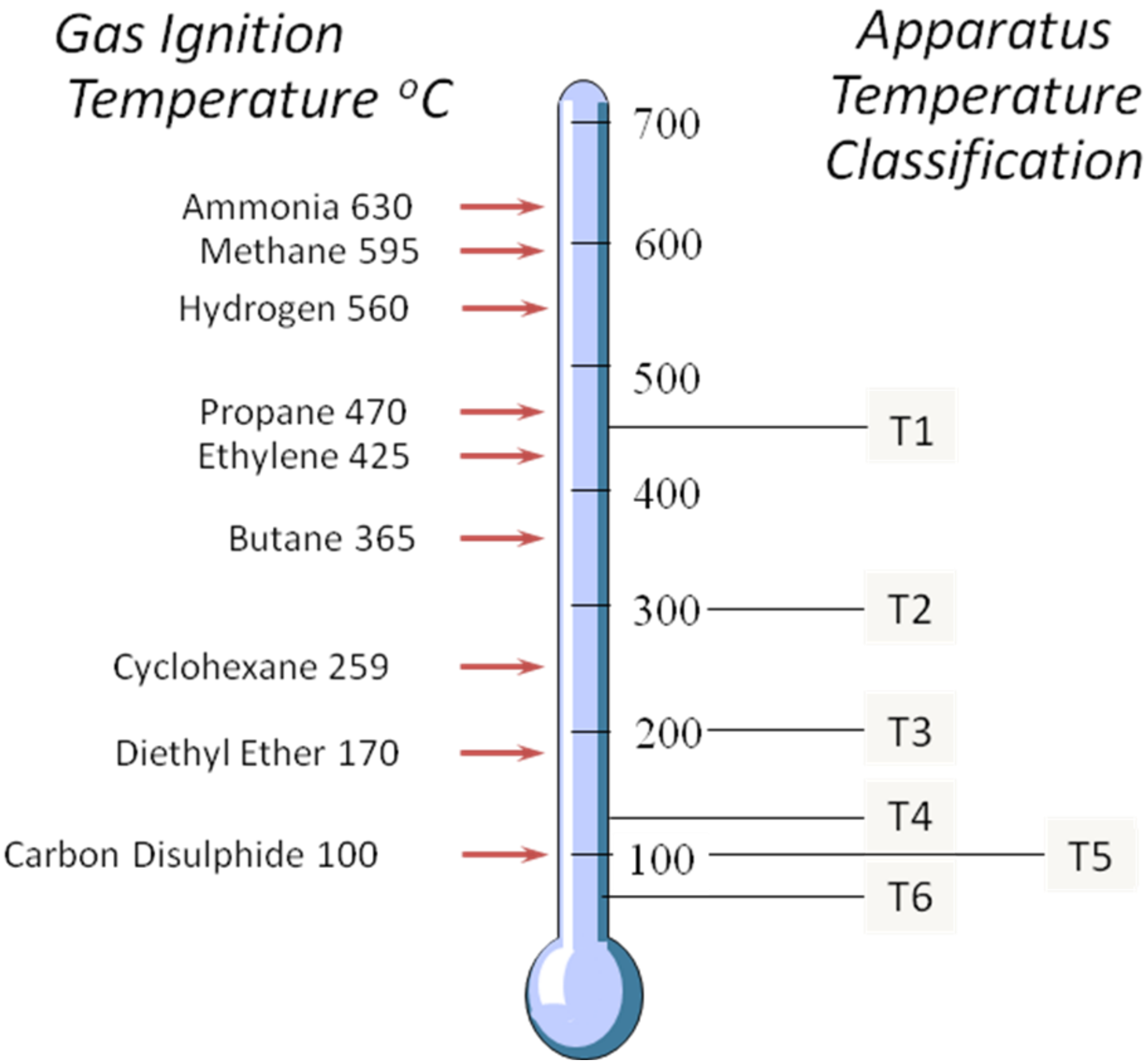
SIDEBAR: TEMPERATURE RATING

If a material or surface gets hot enough, it can start a fire. For this reason, all apparatus used in automation has a temperature rating, using a standard which is slightly different in North America than in the rest of the world.

| **T (temperature) class** | | **° F** | **° C** |
|---|---|---|---|
| **North America** | **ATEX** | | |
| T1 | T1 | 842 | 450 |
| T2 | T2 | 572 | 300 |
| T2A | | 536 | 280 |
| T2B | | 500 | 260 |
| T2C | | 446 | 230 |

| | | | |
|---|---|---|---|
| T2D | | 419 | 215 |
| T3 | T3 | 392 | 200 |
| T3A | | 356 | 180 |
| T3B | | 329 | 165 |
| T3C | | 320 | 160 |
| T4 | T4 | 275 | 135 |
| T4A | | 248 | 120 |
| T5 | T5 | 212 | 100 |
| T6 | T6 | 185 | 85 |

The above table is based on a maximum ambient temperature of 40 $^oC$ (104 $^oF$). If the ambient temperature is above this maximum, the limits need to be de-rated. The following figure illustrates the various temperature ratings versus gases that might be found in a hydrocarbon processing facility.




Most manufacturers tend to design their devices for the industry in which they are expected to be used, and in most cases the devices operate well below the most commonly required gas group rating. Most electrical components and instruments are typically designed to have a maximum surface temperature of either 60 $^{o}$C (140 $^{o}$F) or 40 $^{o}$C (104 $^{o}$F) so as not cause a burn to a person inadvertently coming in contact with the device. These surface temperature ratings are well below allowable limits.

Although temperature ratings of electrical components and instruments typically aren't an issue, the surface temperature of enclosures in which these components and instruments are housed must be considered for hazardous area installations.

References:

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