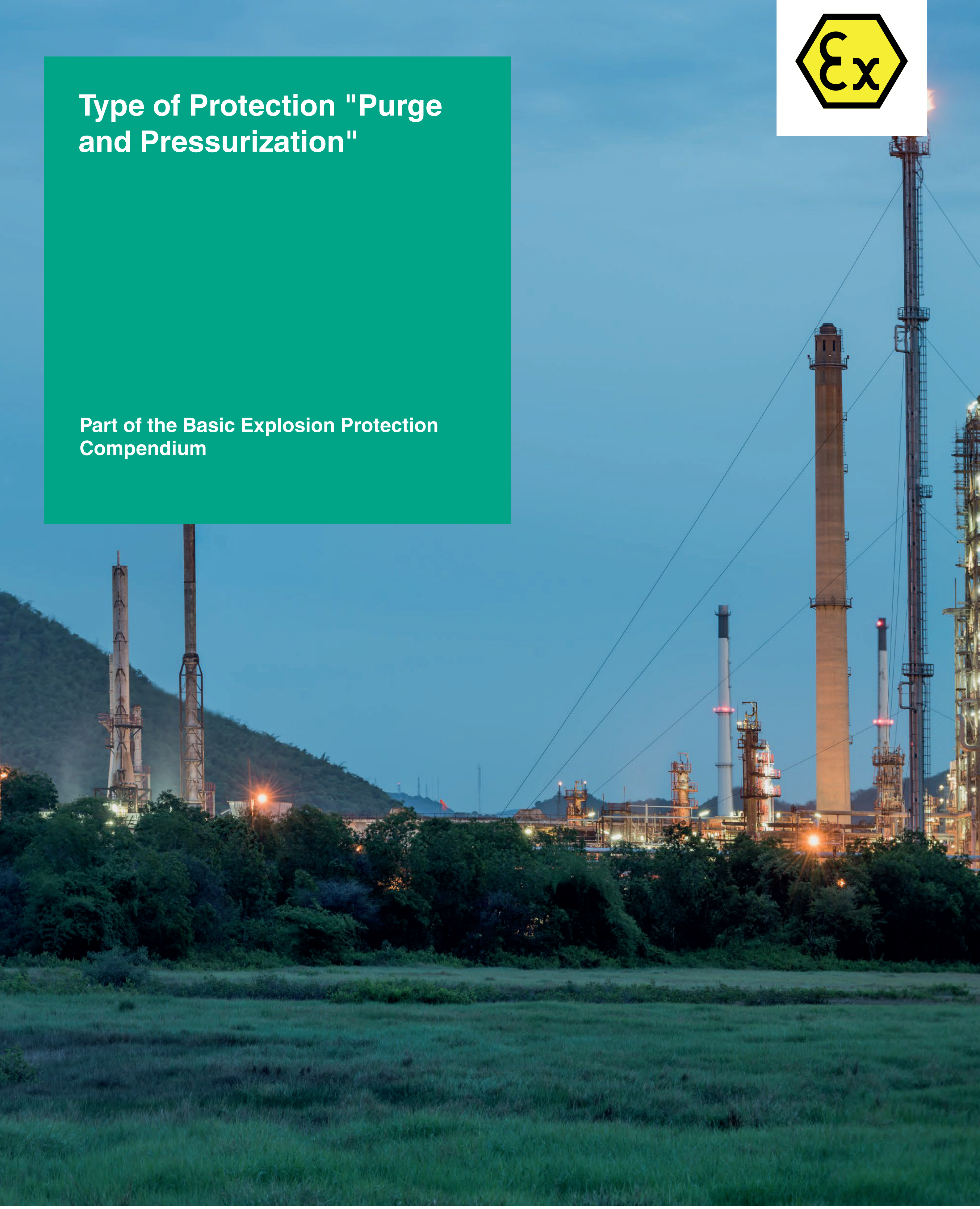
Type of Protection "Purge and Pressurization"

Part of the Basic Explosion Protection Compendium



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This document is one part of an explosion protection compendium series. The goal of this series is to give plant operators a general overview of explosion protection. This publication assumes that the reader already has general knowledge of hazardous areas and the classification of the location based on Class/Division or zone schemes. Further information on this topic can be found in our publication that is part of the explosion protection compendium "Types of Protection for Electrical Apparatus" which is available on our website.

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Ask us if you have any questions—we will be happy to help!

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Introduction

Purge and pressurization, or simply "pressurization" is a versatile protection method that can be used in a wide variety of applications. Based on the principle of segregation, it is one of the few protection concepts that can be used to provide protection for gas hazards or dust hazards. This protection method can be used in small equipment cabinets, in large and complex assemblies, and in motors and other rotating electrical equipment. While generally used for electrical equipment which will be the focus of this publication, it can also be used to protect non-electrical equipment.

The method also has the advantage of providing protection to standard ordinary location electrical equipment in hazardous areas. Similar to explosionproof or flameproof protection types, the protection concept is more cost-effective than having all electrical equipment designed for use in a particular area classification. Purge and pressurization does not include the heavy enclosures associated with those protection methods. Instead, the methodallows the simple implementation of affordable cooling methods, as well as am relatively easy installation of touch panel user interfaces.

This publication covers the protection concept in general with many specific references, especially for zone applications, based on IEC 60079-2. It is recognized that within the United States and Canada, NFPA 496 is the standard for Class/Division applications. Based on this, this publication uses details per NFPA 496. In either case, it is not the intent of this publication to provide specific guidance or interpretation of the associated standards, but to provide general guidance and information of the protection concept.

There are a few things to be aware of regarding NFPA 496. First, while NFPA 496 also covers zone-related areas as defined by the National Electrical Code NFPA 70® NEC® article 505, any direct references from NFPA 496 omit these zone-related references and only focus on the Class-/Division-related aspects for simplicity in this publication. Second, it is important to realize the structure of NFPA 496 is very different from IEC 60079-2. NFPA 496 is written as a general concept standard, covering issues that must be addressed. This standard does not, in many cases, give specific criteria that must be met or tested. This is in contrast to IEC 60079-2 that is a product-related performance standard. This standard contains a more defined set of performance-related requirements and tests to confirm that a specific design meets these requirements. This makes it difficult to draw a complete parallel between the two standards on specific requirements.

Finally, while the protection concept of pressurization can be used for rooms covered by IEC/EN 60079-13 and NFPA 496, this publication does not cover those types of applications.

Purge and Pressurization Terms

The following terms are used in this publication.

Pressurization

Technique of guarding against the ingress of the external atmosphere into an enclosure by maintaining a protective gas therein at a pressure above that of the external atmosphere.
Source: IEC 60079-2

Pressurized enclosure

Enclosure in which a protective gas is maintained at a pressure greater than that of the external atmosphere.
Source: IEC 60079-2

Pressurization control system

Also known as a pressurization system or a pressurizing system is a collection of safety devices used to monitor and maintain the safety upon which pressurization depends.

Pressurized equipment

An overall assembly of a pressurized enclosure, pressurization control system, and the protected equipment.

Protective gas

Air or inert gas used for maintaining an overpressure and, if required, dilution and purging.
Source: IEC 60079-2

Protected equipment

The equipment internal to the pressurized enclosure, protected by pressurization.

Overpressure

Pressure inside the pressurized enclosure above the surrounding potentially explosive atmosphere.

Minimum overpressure

The minimum amount of pressure required to maintain safety within the pressurized enclosure.

Maximum overpressure

The maximum pressure that can be safely handled by the pressurized enclosure.

Purge pressure

Pressure within the pressurized enclosure during the purge cycle.

Purge cycle

Period of time where a high volume of protective gas is sent through the pressurized enclosure for the purpose of flushing the enclosure and the contents of the enclosure.

Safety device

Device used to implement or maintain the integrity of the type of protection.
Source: IEC 60079-2

Ignition-capable equipment

Equipment that during intended operation constitutes a source of ignition for a specified potentially explosive atmosphere.
Source: IEC 60079-2

Pressurization Function Principle

To better understand the concept, consider the ignition triangle. Three things are needed to pose a fire or explosion threat in a gas- or vapor-related application:

1. A source of ignition
2. The right amount of oxygen
3. Presence of the correct amount of fuel

Due to this basic concept, ignition is not possible if a concentration of a material is below the minimum level, also known as the "lower flammable limit" or LFL. That is, provided that the oxygen content is not raised above what is normal for standard atmospheric conditions. The fact that all flammable or combustible materials have a minimum concentration to pose a fire or explosion hazard is one of the key concepts that is utilized as part of the protection method.

Ignition Triangle

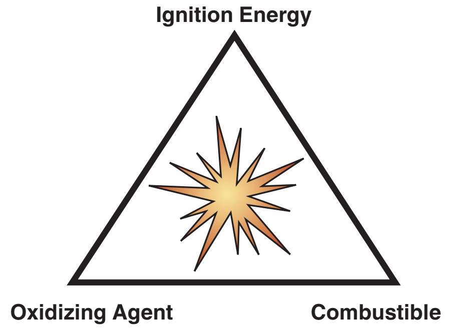

Figure 1 The ignition triangle consists of 3 components

Gas Applications

In general, pressurization works by maintaining an area within the pressurized equipment that is well below the LFL of the surrounding potentially explosive gas atmosphere.

An enclosure containing ignition-capable equipment first goes through a purge cycle. The intent of this is to flush the inside of the enclosure to the point that any remaining levels of gas trapped inside after the purge cycle time are well below the LFL of the flammable or combustible material(s) for which the pressurized equipment is designed. Immediately after this, a positive pressure is maintained within the protected equipment in relation to the surrounding potentially explosive atmosphere. This positive pressure, known as **minimum overpressure**, prevents the surrounding potentially explosive atmosphere from entering the now "clean" enclosure. Once the volume within the pressurized equipment is considered safe, energy can be applied to the ignition-capable electrical equipment within the pressurized enclosure and can be allowed to operate normally. If the minimum overpressure level is lost, the system either alerts the operator to take immediate action. Alternatively, the system initiates an automatic shutdown in order to maintain the safety of the equipment in the hazardous area.

Dust Applications

Adding to the three aspects above in the ignition triangle, dust explosions also involve confinement and dispersion.

Ignition Pentagon

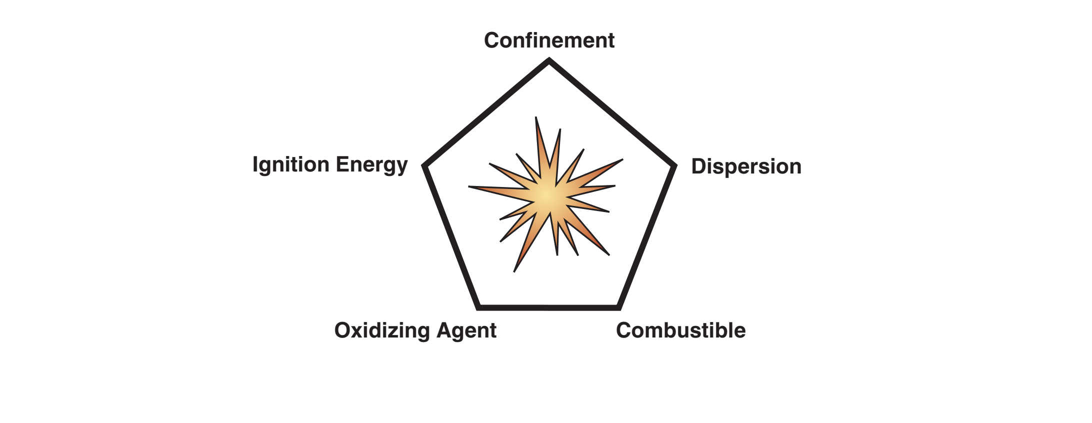

Figure 2 The ignition pentagon for dust adds confinement and dispersion

For dust applications, the purge cycle is replaced by a physical cleaning. This is done to remove all hazardous dusts from the internal components of the pressurized enclosure for the pressurized equipment. After that, the enclosure is pressurized.

Purging Enclosures in Dust Atmospheres

A high airflow purge cycle is not used when purging an enclosure in a dust hazardous area. First, such a purge cycle would likely cause a dispersion of the dust within the confinement of the pressurized enclosure. Also, the purge cycle airflow could cause dispersion outside of the pressurized enclosure. Dispersion in either area is a risk that needs to be avoided. The second reason is that the dust is likely not to be fully purged from the enclosure in the same way that the gas/vapor is purged.

The inside of the pressurized equipment is to be cleaned in a way that is not likely to create a dust cloud. For example, using a vacuum cleaner is preferred over blowing out the equipment with pressurized air. Another consideration is that the vacuum cleaner may also need to be classified for use in the hazardous area. Also, it is important to understand that all areas within the enclosure need to be cleaned. This means that any dust in the protected equipment also needs to be removed.

After cleaning the inside, the enclosure is closed and then immediately brought to the required positive **minimum overpressure**. Once again, this positive pressure prevents the surrounding potentially explosive atmosphere from entering the now "clean" enclosure. Once the area within the pressurized enclosure is considered safe, energy can be applied to the electrical devices within the pressurized enclosure and allowed to operate normally. In the event that the minimum overpressure level is lost, the system either alerts the operator to take immediate action or initiates an automatic shutdown in order to maintain the safety of the equipment in the hazardous area.

The above explanations generally describe pressurization in typical applications. The enclosures used are not perfectly sealed. Thus, a constant source of protective gas is needed to maintain the minimum overpressure. This typical pressurization scenario is known as **leakage compensation**. This will be the general focus of this publication. There are special applications for gas and vapor analysis applications, where the hazardous substance is directly plumbed into the pressurized enclosure as part of the pressurized equipment. For these applications, a modification to the pressurization principle, known as **dilution**, is generally implemented. For more information, see chapter "Applications Working with a Containment System (Dilution)".

Pressurization Control Systems

The protection concept of purge and pressurization is unique with respect to certain performance and logic control aspects. For example, the minimum overpressure must be monitored, and, if lost, action has to be taken to maintain the safety of the application. The required minimum safe overpressure level depends on the underlying standard and the kind of hazard that the application is to be protected from. The level ranges from
0.1 w.c. ... 0.5 w.c. (25 Pa ... 125 Pa). Such minimum safe overpressure levels can be challenging to accurately measure, and the protective gas flow measurements can also be equally challenging to determine especially with the added requirements for use in hazardous areas. Past systems relied on less accurate methods such as basic pressure switches. Modern systems are expected to be more accurate than systems of the past and have reading indications. Therefore, modern systems are often microcontroller-based, so they can handle this automation and measurement and provide other functionality.

Due to the requirements to monitor pressures and flows of protective gas, the general concept requires a minimum number of safety devices to make a protection control loop. This is where a pressurization control system comes into play. Depending on the level of risk reduction needed, the control loop can include human intervention.In this case, operating personneltakes the logically necessary actions based on informationprovided by the various safety devices of the pressurization control system. For example, operating personnel must determine when power can be applied to the protected equipment and when it must be removed. For both Class/Division applications and zone-based applications, therequired level of risk reduction, necessary safety devices, and other functionality are classified into three levels.

For Class/Division applications, the levels of pressurization covered by **NFPA 496** are defined as follows:

- **Type X** – Enables use of equipment suitable for unclassified locations within the protected enclosure where the equipment would otherwise be required to be suitable for Division 1 locations.
- **Type Y** – Enables use of equipment suitable for Division 2 locations within the protected enclosure where the equipment would otherwise be required to be suitable for Division 1 locations.
- **Type Z** – Enables use of equipment suitable for unclassified locations within the protected enclosure where the equipment would otherwise be required to be suitable for Division 2 locations.

For zone applications, **IEC 60079-2** gives a different definition to the applicable types:

- **pxb** – Level of protection where the pressurized enclosure provides equipment protection level Gb or Db.
  In general, this is the same principle as Type X. It allows for the use of ignition-capable equipment inside the pressurized enclosure for applications in Zone 1 or 21.
- **pyb** – Level of protection where the pressurized enclosure provides equipment protection level Gb or Db, with EPL Gc or Dc mounted inside the pressurized enclosure.
  In general, this is the same principle as Type Y. It allows for the use of Zone 2 or 22 equipment inside the pressurized enclosure for applications in Zone 1 or 21.
- **pzc** – Level of protection where the pressurized enclosure provides equipment protection level Gc or Dc.
  In general, this is the same principle as Type Z. It allows for the use of ignition-capable equipment inside the pressurized enclosure for applications in Zone 2 or 22.

While the levels of classification seem to have a number of similarities, the details required for each protection concept can be quite different. So, it is important to be aware of the specific requirements relative to the installation based on zone or Class/Division.

Safety Devices

As noted already, the protection concept requires a minimum number of safety devices to maintain the required safety aspects of the protection concept. Depending on the level of risk reduction needed, the requirements and the number of these safety devices vary.

The basic and most obvious safety devices are:

- Pressure transducer or switch
- Flow sensor or switch
- Timer
- Enclosure power switch

Additionally, an alarm or indicator, an enclosure door lock, and additional warnings and markings may also be required.

It is important to recognize that these safety devices must be properly rated to operate in the classified location where they are going to be installed. The pressurization concept cannot be used to protect these devices since these devices must perform their safety function even when pressurization is lost. For example, even if the pressure switch is placed inside the pressurized enclosure, it cannot rely on pressurization to protect it since it must be able to operate when a potentially explosive atmosphere is present within the enclosure. Thus, any powered electrical component in the hazardous area that is related to the control of the pressurization system must be rated for use in this classified location where it is operated.

Technology of Pressurization Control Systems

The market offers a variety of systems that come with different technology and features. Starting with simple mechanical systems without control loops, to automated versions with status feedback via a display and LEDs, up to systems that provide remote communication via wired and wireless communication protocols.

Pneumatic Control Logic

Pneumatic control is a low cost way of creating simple functional logic. It is easy to achieve the minimum control mechanisms for basic operations for some types of pressurization control systems without the need for electricity. However, pneumatic controls do come with the disadvantage that most parameters need to be set in the factory and can be difficult to maintain proper settings in the field. Also, the aging effects on the components used causes occasional leakage and set point drift. Thus, regular maintenance effort is needed. Furthermore, clogging of pressure hoses due to water or dust accumulation are known to also cause issues. Finally, these type of control tends to be limited in its operational temperature range, especially in cold environments.

Electronic Control Logic

Electronic controls can range in complexity from very simple to very complex. This has an effect on the overall cost the control system when compared to pneumatic control systems, especially if fabricated in small quantities. However, electronic control systems offer easy expansion of options and additional features. For example, features like a system bypass for maintenance, a temperature control, or a control system communication for remote status and configuration, along with added control options are all easily realized with an electronic control system.Electronic control systems can also provide the following advanced features:

- Minimize purge time by recalculation according to the actual flow
- Perform self-checks to reduce maintenance effort while removing responsibility from the operator
- Offer additional security by providing a tamper-proof design

Pressurization Control Operation

All pressurization control systems utilize at least one of three basic operation methods of control. Simple control systems likely rely on some level of manual operation while the most advanced control systems can be configured in a number of operation methods. Some of these methods are not valid for all protection levels. Certified pressurization control systems are identified for the protection levels they can achieve. If no certified control system is used, it is important to understand the limitations of each system.

Manual Operation

The traditional simple pressurization control systems are fully manual. Those systems rely on the proper operation by the staff on site. A label indicates the minimum purge duration, after which the cabinet can be energized. The timely shut-off if a problem is detected heavily depends on the swift reaction of the operator. These systems are very basic and generally are limited to Zone 2/22 and Division 2 applications.

Semi-Automatic Operation

A semi-automatic control system provides some aspects of the needed control automatically, while other parts require human intervention. Typically, these systems depend on a human to open a purge valve to start the purge cycle. Next, the system automatically handles the purge timer and then indicates when the purge valve can be turned off. Once the purge valve is off and the proper overpressure is present, the system automatically handles the powering of the protected equipment. That is, the system applies power to the protected equipment as well as removes power if a problem is detected. Semi- automatic systems can come in a number of configurations. Depending on how they are configured, it is possible to use these systems for all applications.

Automatic Operation

Many of the new modern pressurization control systems are designed to be fully automatic, requiring no human intervention in the needed safety control loop. These systems are able to detect that a minimum overpressure is present, start a purge cycle, control the purge time, turn off the purge valve once the purge cycle is complete, and control power to the protected equipment. However, some of these systems are also programmable and can be set up in a semi-automatic mode or even in a full manual mode. In semi-automatic mode, human intervention is required to start certain functions, but once initiated, the automated system will take over, for example on a purge cycle. In full manual mode, human intervention is relied on to both start and stop certain functions, for example the purge cycle. These systems also have the needed alarm control and indicator control. Thus, when used in semi-automatic or manual modes, the needed alarms and indicators can be added to the system. Automatic systems can also provide additional safety features like shutdown of the purge valve if internal pressures are too high, cycling the purge valve to help with internal temperatures or leakage compensation.

Type X and pxb

Control systems for applications where ignition-capable equipment is protected from potentially explosive Division 1 or Zone 1/21 atmospheres have the highest level of protection requirements, as expected. One major difference over the other levels of protection requirements is the general need for the control system to be automated. Type X and pxb pressurization control systems cannot depend on human decisions to control energy to the enclosure. Both, the application of and removal of energy to the pressurized enclosure, must be automated, based on signals from the required safety devices. Additionally, the pressure inside the pressurized enclosure must be directly measured and not inferred. In addition, the purge flow must be measured at the exhaust.

Figure 3 Left: 6000 series, Pepperl+Fuchs Type X pressurization control system; right: 6100 series, Pepperl+Fuchs Ex pxb pressurization control system

Type Y and pyb

Control systems for these applications do not require the level of automation that a Type X or pxb would, but the safety devices of the pressurization control system still must be rated for the respective Division 1 or Zone 1/21 location. These control systems can include human control in the safety loop, but many modern systems are also automated to alleviate the need for human monitoring and intervention, especially at start-up of the pressurized equipment.

Figure 4 6500 series, Pepperl+Fuchs Ex pyb pressurization control system

Type Z and pzc

These control systems also do not require the same level of automation as Type X or pxb systems. The level of automation found in these systems is the same as for Type Y or pyb systems, where human intervention can be used as part of the control loop. The major difference between Type Z and pzc and Type Y and pyb systems is that the safety devices do only need to be rated for the respective Division 2, respectively, Zone 2/22 location.

Figure 5 7500 series, Pepperl+Fuchs Ex pzc pressurization control system

Pressurized Equipment

The biggest mistake often made with the protection method is the assumption that an enclosure and a pressurization control system are all that are required for the protection concept. This misconception is even more persistent in cases, when the pressurization control system is already approved for use in the classified location. This is not true or correct. The control system and enclosure are integral parts. However, verification of airflow through the protected equipment to make sure it is thoroughly flushed during the purge cycle is equally important, along with other items of performance and information that are needed for the final installer or user of the pressurized equipment. Without a thorough evaluation of the complete assembly of the control system, enclosure, the internal protected devices, and the requirements for installation of the assembly, the pressurized equipment and installation are at risk. Certification is needed for the complete assembly or pressurized equipment prior to installation.

Figure 6 Example of 6000 pressurization control series solution to pressurize an equipped cabinet

In general, there are two ways to get the required certification on a pressurized piece of equipment. The first method is to take a piece of equipment to a certification body and have the equipment certified. This can be done either as a unit verification for the specific device or a group of devices, or as a type approval for the ongoing production. The type approval is the common approach for OEM equipment. The second method involves working with a certified assembly supplier. These suppliers are typically "panel shops" that can offer fully certified pressurized equipment within their scope-of-ability, based on the certifications they hold. Based on the certificates that this assembly supplier has, there is a limit to what they can build and certify. However, these suppliers are a great avenue to investigate if the application uses pressurization especially for one-of-a-kind applications, but also for OEM-type applications.

Pressurized Enclosure

As the item that defines the volume or area to be protected by pressurization, the pressurized enclosure must meet specific requirements. Some of these requirements are straight-forward. For example, IEC 60079-2 calls for a proof test to confirm no permanent deformation of the enclosure based on an overpressure test at 1.5 x the maximum overpressure. Depending on the size of the enclosure and maximum internal pressures, these forces can be quite high. Additionally, the following requirements can be additional items of consideration:

- Minimum IP or ingress protection
- Resistance to impact
- Key- or tool-only access door latches
- Requirements for non-metallic enclosures or parts of enclosures, especially with regard to IEC 60079-2 as required from IEC 60079-0

In addition, there are other good-practice aspects of enclosure design that mean the difference between a good or poor choice. Enclosures that are not a fully welded construction often leak too much, especially during the purge cycle. This is not necessarily a problem if the protective gas supply can compensate and keep up with the demand. However, a "leaky" enclosure uses more protective gas to purge and then pressurize when compared to one that has a better seal. Also, doors that do not have multiple latch points are likely to be a high leak point and pose a risk to personnel working around the enclosure since a single latch point represents a single point of failure.

Example

Overpressure required for a typical control cabinet

Consider a typical control cabinet with a door of 3 ft x 6 ft (0.9 m x 1.83 m). The surface area of this door is 2592 in^2 (1.67 m^2). At the minimum overpressure requirements found in NFPA 496 and in IEC 60079-2 for pzc of 0.1 w.c. (25 Pa), the force on the door is about 9.4 lbs (4.2 kg). This does not sound too bad, but still poses a risk when the door is opened under pressure if the person is not expecting the added force. Additionally, consider a purge cycle where the internal pressures can increase to about 4 w.c. (1000 Pa) or more. An internal pressure of 4.0 w.c. (1000 Pa) results in a force on the door of about 376 lbs (170.5 kg)! A typical single point latch is not likely to be designed to handle anywhere near this amount of force.

This simple example shows the high forces that an enclosure is subjected to during the overpressure tests. This illustrates the absolute need for a multiple-door-latch system, especially for large enclosures. It goes to show how the failure to consider these requirements can pose an operational danger. The considerations needed for the enclosure design and selection process are not to be taken lightly. Also, due to these strength requirements, in addition to UV and electrostatic concerns, plastic- or polymer-based enclosures are typically not used.

Since the specific use case for a pressurized enclosure can be unique, it is important to fully understand the application or work with an enclosure manufacturer that has experience designing enclosures for equipment protected by pressurization. The commonly known IEC "degree-of-protection (IP)" or UL "type" ratings evaluate enclosures with reference to substances leaking into an enclosure from the outside. But this protection concept adds internal pressure to the enclosure, generally working against the normal convention. So, even the highest rated solution can have a high leak rate when subjected to protective gas pressures in the other direction.

For these reasons, requirements concerning suitable door latches and suitable sealing methods and additional strength along with other possible requirements make it crucial to work together with an experienced supplier who can help to evaluate the individual requirements.

Pressure-Relief Vent

Many, if not all systems, need some sort of enclosure-protection vent or relief vent to help control the maximum overpressure of an enclosure for, both, gas and dust applications. These vents can be used as the exhaust point during a purge cycle in a gas application and for overpressure protection, or only for overpressure protection.Relief vents protect systems against maximum overpressure.They are designed to break open at a given pressure level. Think of it like a safety check valve designed to open at a given pressure.

However, in most cases the enclosure protection vent is also the exhaust point during the purge cycle. The vent is typically matched to a control system to fully support the purge cycle times. Also, this same matched vent monitors and measures the flow through this exhaust point for calculations of the purge cycle time for Ex pxb systems as required by IEC 60079-2 and often also on Type X systems. This is done, even though this measurement is not required directly at the outlet in NFPA 496. This ensures that the minimum needed volume of protective gas has passed through the enclosure. However, the exhaust point may not be enough protection to properly control maximum overpressure and additional relief points may be required.

Example

Risk of catastrophic failure

Protective gas is provided from a bottled source. Depending on the gas and the cylinder specifications, the bottle gas pressures can be very high. A regulator failure can deliver a very high flow of protective gas. If the enclosure is not sufficiently protected with an additional pressure relief, a catastrophic failure can occur because of the high line pressures and subsequent high flows and pressures in the pressurized enclosure.

In some cases, the vent can help to protect the purge application against the above described catastrophic failure caused by excessive high flow rate. That is, when the vent is properly equipped and working in conjunction with a modern purge controller. For failures that cannot be compensated by the vent alone, some modern purge controllers feature an integral overpressure emergency shutdown function. This function allows the user to set a maximum pressure or flow in the controller as monitored by the vent, at which a purge cycle would be interrupted and the main valve would be automatically closed. This way, the purge system is made safe with respect to machine protection and personal safety.

Spark and Particle Barriers

If the purged volume exhausts into a hazardous area, the standards have requirements for spark and particle barriers, depending on what is contained in the enclosure and the area classification that the exhaust is going into. This is due to the risk that ignition could occur if hot sparks or particles generated by an arcing motor, switching circuit, or any other electrical or mechanical activity inside the pressurized enclosure were to be swept out into the hazardous area. The intention of the spark and particle barriers is to prevent this.

Figure 7 Example of pressure relief vent spark and particle barrier Pepperl+Fuchs EPV 7500: The spark and particle barrier consists of a wire mesh

Vent Types and Mounting

Traditionally designed vents that rely on gravity to maintain a seal in the valve portion of the vent usually have one or a limited number of mounting direction modes. However, modern vent designs utilize a variety of valve sealing methods allowing of a number of mounting orientations, purge flow rates, and seal performance. This makes the design of pressurized equipment easier and more flexible. State-of-the-art vents come with different internal designs that are optimized for different requirements. These can be:

- Open vents with constant flow for dilution
- Flapper vents with high flow and low breaking pressure
- Poppet vents with maximum sealing for lowest leak rate

Protected Equipment

General

Protected equipment is any equipment contained in the pressurized enclosure that relies on the pressurization protection method in order to safely operate in the hazardous area. This can involve any number of devices, from large motors and other rotating electrical equipment to a simple sensor. The key thing to remember is that thorough evaluation is needed for the protected equipment to truly be protected. This is necessary to understand any internal areas in the protected equipment and to determine which areas must be purged.

Dead Volumes

Some volumes within a pressurized piece of equipment are small enough not to be a concern and are omitted for consideration. Both NFPA 496 and IEC 60079-2 allow volumes of 1.22 in ^{3}(20 cm^3) to be considered as volumes that do not need to be purged or protected by another means. This is provided that the total volume of such devices is not a significant portion of the total enclosure volume. In IEC 60079-2 the limitation in 1 % of total enclosure volume. In NFPA 496, this is limited by the following: the total of all volumes not purged cannot create an atmosphere that is above 50 % LFL within the enclosure, even if all devices considered release their possible flammable contents at the same time. This rule covers smaller devices like relays, fuses, etc.

Above this limit, all volumes must be properly evaluated and considered for purging.

Example

Possible dead spots in a standard PC

Consider a standard PC. The standard metal enclosure of a normal industrial PC generally does not have enough venting in it to allow for full flushing of the volume inside the PC. The standards call for this volume to be fully flushed as part of the purging process. Therefore, additional holes are required in the enclosure of the PC, or a direct air line to the PC enclosure to ensure it is flushed. Sometimes it is not possible or advisable to add such features to devices of this kind for performance or other reasons.

All of this needs to be considered when selecting devices for use in a pressurized enclosure. Some kinds of devices are designed in a way that makes it impossible to protect them with pressurization due to the inability to fully flush the internal volumes. Both NFPA 496 and IEC 60079-2 have specific requirements for the minimum vent-hole size and the position to consider when evaluating internal components that are protected by pressurization.

Another consideration when evaluating the performance of the purge cycle is an understanding of gas flow dynamics and, to a lesser extent, the protective gas density vs. the hazardous gas density. As noted before, the intent of the purge cycle is to flush the pressurized enclosure. It is important to know how the protective gas flows or "stirs" within the pressurized enclosure relative to the gas densities involved to flush all areas within the pressurized enclosure. The standards require that there are no "dead spots," where the purge cycle does not fully flush the area. When designing the layout for the internal equipment to be protected, along with the inlet and outlet locations for the protective gas and the purge flow volume, it is essential to help ensure that there are no dead spots. Constructional measures help to achieve a design that passes the flushing requirements successfully. These include:

- Internal baffles
- Additional internal tubing to direct protective gas
- Cross ventilation principles to develop the internal protective gas flow needed to flush the enclosure and its contents

A poor design, on the other hand, at a minimum will likely have a longer purge cycle than what could be possible if designed well to flush the pressurized enclosure and its contents. Worst case, the "dead spots" are never properly flushed and modifications are needed to remove these "dead spots."

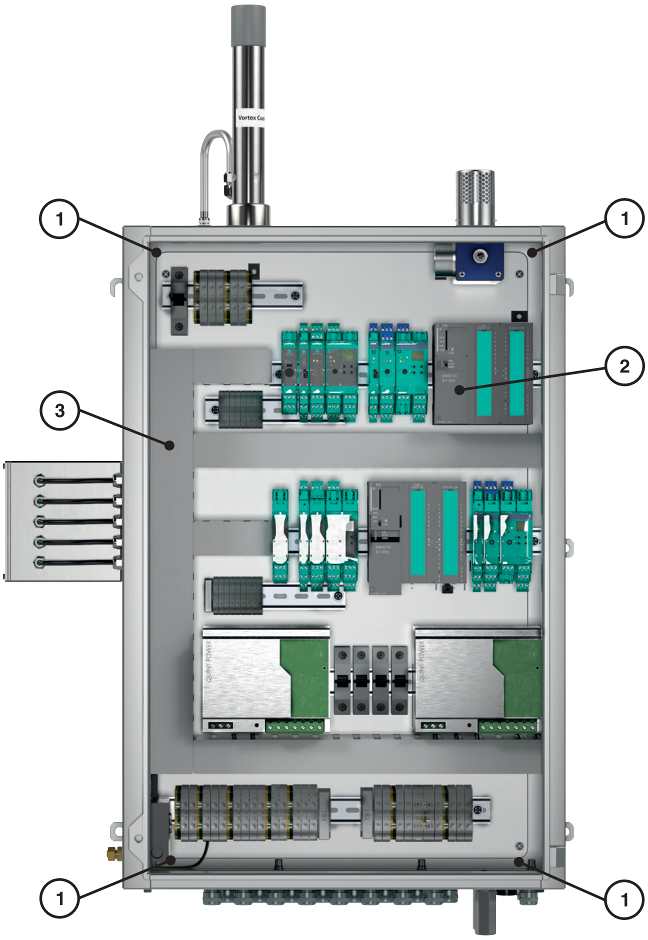

Figure 8 Examples of possible "dead spots" in a pressurized cabinet: Among others, these can include different sections.

1 Cabinet corners
2 Equipment without sufficient venting
3 Cable ducts that are too full

The goal in both standards is that proper and adequate air movement through all locations is such that there are no locations left with any appreciable gas or vapor concentration after purging.

IEC 60079-2

Applications can base purge time on five volume exchanges, but this is only for simple internal geometries. Often, determining the purge time requires a specific heavier-than-air and lighter-than-air gas test with a sampling system. This is to ensure that the purge time of the pressurized equipment is long enough to reduce the gas or vapor presence to the required minimum, regardless of hazardous gas density.

NFPA 496

The purge time is based on four volume exchanges. However, the expectation is that there are no "dead spots." Depending on the Authority Having Jurisdiction (AHJ), there may be some requirement to "prove" the lack of "dead spots" in a design using a method similar to the method used in IEC 60079-2.

Temperatures

The pressurized equipment has a temperature clasTemperaturess determined as part of the evaluation. For Type Y or Ex pyb pressurized equipment, the temperature of the protected internal equipment cannot exceed the marked temperature class of the pressurized equipment. Since the equipment that is required to be used in the pressurized enclosure for Type Y or Ex pyb needs to be properly rated for use in a hazardous area, this is a straight-forward design item to confirm.

In regards to the other purge types, it is permitted to have internal temperatures that exceed the marked temperature class, but some additional requirements are in place. For Type X and Ex pxb, the temperature class of the pressurized equipment is determined by evaluating the external pressurized enclosure surface temperatures. The internal surfaces can exceed the temperature. But there needs to be a warning on the enclosure stating that internal surfaces exist that exceed the marked temperature class, and an indication of the amount of time needed to allow these surfaces to cool once power has been removed. In addition to the warning, locks and timers can also be used to assure an appropriate cooling time has elapsed before access to the inside of the enclosure is allowed. Some pressurization control systems integrate temperature-monitoring inputs. These serve either for specific temperature sensors, or for standard PT-100 RTD to support cooling, and door locks with timers.

For Type Z or Ex pzc, a simple warning to not open the enclosure when an explosive atmosphere is present is all that is required.

The internal surfaces that need to be considered are not only the external surfaces of each device within the pressurized enclosure, but also the smaller components within these devices, like ICs, and other electrical devices. Depending on the temperature class of the pressurized equipment, these small components are permitted to exceed the marked temperature class, while not requiring the warning on the pressurized equipment. This is where a proper certification is key. Understanding these rules and limitations is critical to assuring proper safety of the pressurized equipment.

Single Enclosure

Example of a Single-Enclosure Purge Design

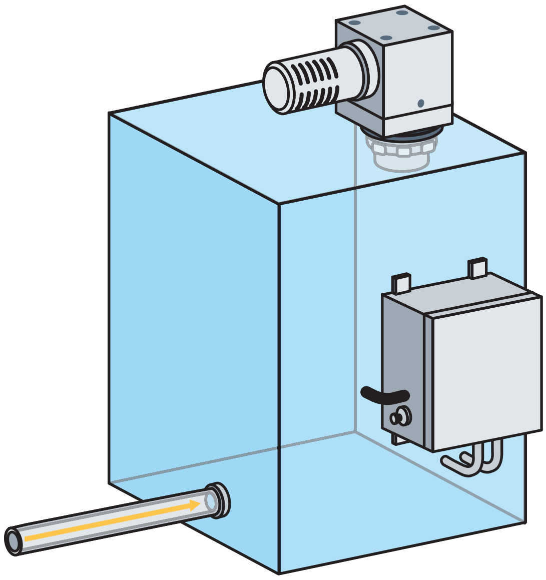

Figure 9 Example of a single pressurized enclosure: protective gas enters the enclosure through a small tube at the bottom and leaves the enclosure via a larger tube or relief vent on top

A typical installation is a single enclosure that is pressurized, where the protective gas is sourced from an air compressor or gas cylinder. In this scenario, the protective gas enters the enclosure through a small tube that is under higher pressure. In the illustration, this is the tube at the bottom, with an arrow indicating the airflow. The purged volume leaves via a larger tube or relief vent as shown in the illustration at a much lower pressure. A single enclosure system is the most straightforward type to construct and understand. The design and application is only monitoring a single enclosure with the safety devices, and protecting the contents on the pressurized enclosure. In this example, the pressurization control system, mounted to the outside of the enclosure, is monitoring the pressure within the enclosure via the black tube. If the enclosure pressure drops, action is taken for the equipment in the pressurized enclosure.

In principle, the enclosure size is not a limiting factor for this protection concept, and therefore has an advantage over other protection concepts, especially as the enclosure size increases. However, some of the requirements for protecting equipment in a small enclosure versus the requirements for protecting equipment in an enclosure that is very large are different. For example, while there is no limit to the purge time, generally the purge time is expected to be no longer than 30 minutes, with shorter times counting as ideal.

Example

Purging comparison of a small and a large enclosure volume

If we take an IEC-60079-2-based design that uses five times the enclosure volume as the basis of the purge time, a small enclosure of 10 ft^3 (0.3 m^3) needs to have 50 ft^3 (1.416 m^3) of protective gas to properly purge.

In contrast, a large enclosure of 450 ft^3 (12.7 m^3) needs 2 250 ft^3 (63.71 m^3) of protective gas for a proper purge cycle. For the smaller enclosure, this results in a purge volume of about 1.6 CFM (45 l/min) to do a complete purge cycle in 30 minutes. The vent size, protective gas source, and protective gas control for purging and pressurizing an enclosure of this size is manageable. To handle the large enclosure in 30 minutes, we need a purge flow of 75 CFM (2120 l/min). This obviously requires a much more substantial protective gas source, and if the supply and enclosure pressures are to remain similar to those in the case of the small enclosure, larger tubing and vent exhaust sizes are needed.

Multiple Enclosures

One of the advantages of pressurization is that the protected equipment does not need to reside all in the same enclosure. It is possible to have several enclosures pressurized by the same single source of protective gas so that they all get flushed and protected. This configuration can be handled in a few different ways in terms of power application and removal, and where the pressure and flow are monitored depending on the connection configuration.

Example of a Multiple-Enclosure Purge Design

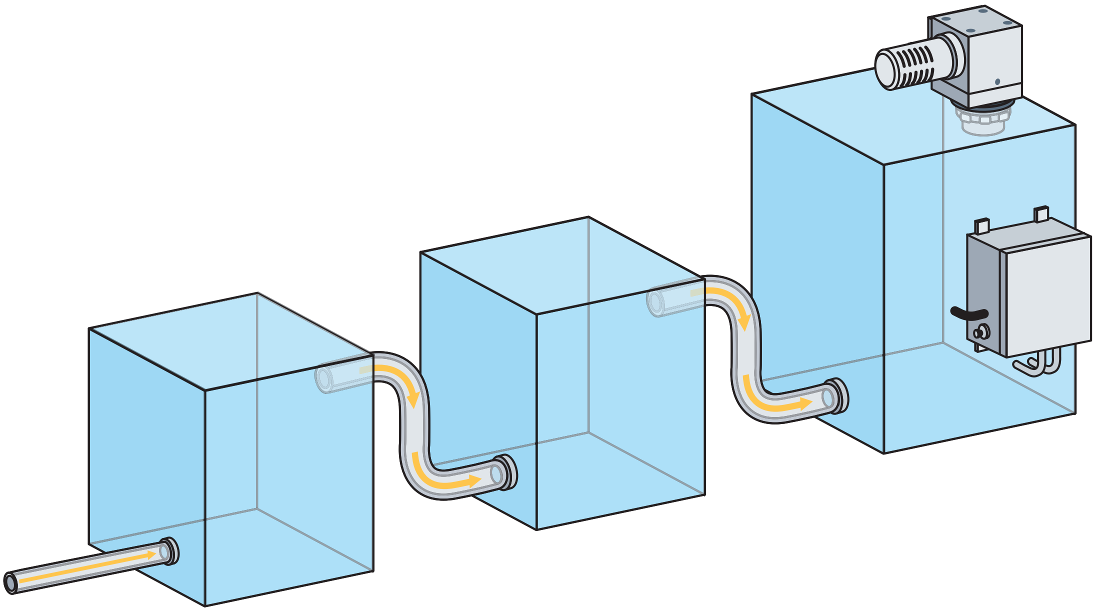

Figure 10 Example: Series connection of multiple purged enclosures: protective gas enters the first enclosure (left) at the bottom tube and leaves the enclosure via a larger tube at the back, before it enters the next enclosure in the series of connected enclosures; the protective gas leaves the last enclosure in line via a larger tube or relief vent on top

In a series connection of multiple enclosure, the high-pressure protective gas flows into the first enclosure enters at the bottom tube. The arrows indicate the airflow direction. This airflow then leaves the first enclosure at a much lower pressure via a much larger tube or pipe. In the illustration, this is the tube leaving the back of the enclosure. The arrows indicate the airflow direction. This airflow may not be in the second and subsequent enclosures due to problems in the first enclosure or upstream enclosures. Also, in any configuration, care must be taken to understand how a loss of pressure in one enclosure affects the others, and to make sure that the right number and type-of-safety devices are used.

Focusing on our series example, the pressure of all three enclosures can be assumed based on the last enclosure in the series. This is because the last enclosure can only have the proper pressure and flow if the two upstream enclosures that are feeding into it do. Any loss or change in pressure or flow in the first two upstream enclosures has an effect on the last enclosure. So if a door or another enclosure entry is opened in any of the upstream chained cabinets, the last enclosure does not have sufficient pressure and the control system identifies this. Further, if the last enclosure in line does not have the pressure needed, all three enclosures must be considered to have lost pressure. This requires action to be taken, even if it does eventually not apply to all enclosures. In this example, the last enclosure could be the one that has lost pressure, possibly leaving the other two at a sufficient minimum overpressure. But since there is no method to monitor the first two enclosures, it must be assumed that pressure was lost in all enclosures. Grouping enclosures in this way normally does not lower plant availability, however, since the shutdown of one section usually shuts down the complete process stream. In this configuration, the first enclosure typically has a slightly higher pressure than the last enclosure to compensate for leakage of pressure in the overall system.

Another item to consider in this setup is the tube size between enclosures. If the tube size is too small, the purge pressures in the upstream enclosures may be much higher than in the last enclosure. This is due to the flow restriction of the tubes, and could result in the purge pressure being quite high in the upstream enclosures if attempting to purge with high flow volumes.

Devices in Enclosure Walls

The requirements and considerations that must be given to devices that are installed into the wall of a pressurized enclosure may not be as straightforward as expected.

1. **Ensuring completion of the enclosure:**

   First, it should be understood that the device installed into the wall of an enclosure is completing the enclosure. Therefore, depending on the standard being followed, this device is subject to enclosure-based performance criteria, e. g.:

   - Impact resistance over temperature
   - UV performance requirements
   - Water and dust ingress protection
   - Electrostatic requirements
   - Flammability requirements
   - Any pressure-related tests
   - ...

2. **Ensuring the pressurized envelope of protection:**

   Second, even if the electrical connections are within the pressurized enclosure, this is not necessarily enough to guarantee that the device is sufficiently protected by pressurization. If the device is to be protected by pressurization, it is important to verify that all ignition risks of the device, electrical and thermal, are completely within the pressurized envelope of protection. This envelope of protection cannot be compromised even if the device is damaged.

   For example, a Division-2 or Zone-2/22 device can be incorporated into the wall of a Division-1 or Zone-1/21 pressurized piece of equipment. Many of the related performance criteria noted in 1. above –like impact resistance and ingress protection– are likely covered, based on this. However, the device in the wall might not be designed to enable proper protection with pressurization. One consideration would be if the device sustains damage which, in turn, compromises the full safety for pressurization. Therefore, it is important to conduct a thorough risk assessment to verify that the device is properly protected against all ignition risks. This includes risks from external damage or any other conceivable factors that might happen. It is vital for the protection concept that the device remain protected by pressurization in all cases and also not negatively impact the overall protection concept in the event of a failure. If a device cannot be sufficiently protected by pressurization when taking into account all of these considerations and others relevant to the pressurized enclosure, then another protection concept is needed for these devices.

It is also important to note that the small volume exception in the standards discussed above cannot be applied to the volume of these devices and leveraged to consider them safe. For this to apply, this volume must be fully contained in the pressurized volume and otherwise properly protected without any possibility of external influence that could expose them to the external hazardous area. The reason is that these devices are not fully within, and protected by, pressurization. Both NFPA 496 and IEC 60079-2 allow volumes of 1.22 in^3 (20 cm^3) to be considered as volumes that do not need to be purged or protected by any other means. The expectation in either case is that the volume is completely within the pressurized enclosure, and an envelope of protective gas is fully around the volume in question. In this manner, even if the small amount of gas that may be within the device does ignite, the spread would be limited due to the protection afforded by the pressurized area completely surrounding the non-pressurized volume. Obviously, a volume that meets the volume criteria, but is effectively adjacent to the hazardous area, is not sufficiently protected by pressurization because an ignition within this un-purged volume could ignite the adjacent hazardous area.

Figure 11 Example of devices in an enclosure wall

Motors and Other Rotating Electrical Machines

When it comes to electric motors or other rotating equipment, pressurization is an excellent protection concept to consider, especially as the machine size increases. Within pressurization, there are some specific considerations for rotating electrical machines. First, the standards recognize that the purge volume within rotating machines can be considered differently than an ordinary pressurized enclosure. For both standards, an ordinary pressurized enclosure application considers the empty volume as the volume for purging calculations, regardless of what is in it.

For rotating equipment, this is treated differently. In NFPA 496, it is the volume within the enclosure, minus the volume of the internal components (e. g., the rotor, stator, etc.) In IEC 60079-2, it is the same free volume as calculated in NFPA 496, but including the rotor volume. According to both standards, you may lower the purge volume that is to be considered when determining purge time, taking into account the internal aspects as indicated.

Obviously, this greatly lowers the volume to be considered in some motor designs. However, IEC 60079-2 does not permit a simple multiplier on the number of volume exchanges like it does for some enclosures. The five times volume (or any multiplier number) purge time cannot be used, you must test within IEC 60079-2 for sufficient purging. For NFPA 496, the number of purge volumes that must to be exchanged, increases from four to ten, but is based on the free volume as described.

Secondly, there is a situation within this type of equipment often referred to as the "low-pressure point." Depending on the design, there may be a point where, without a proper amount of overpressure within the machine housing, a vacuum or a pressure point lower than the external atmosphere exists. This is due to the rotation of the motor shaft and air movement in the equipment, especially in equipment with cooling ventilators to circulate air within the housing. Evaluation over a variety of operating conditions may need to be considered to determine the worst-case location, and operation speed for the low pressure point to verify that all operating conditions are covered.

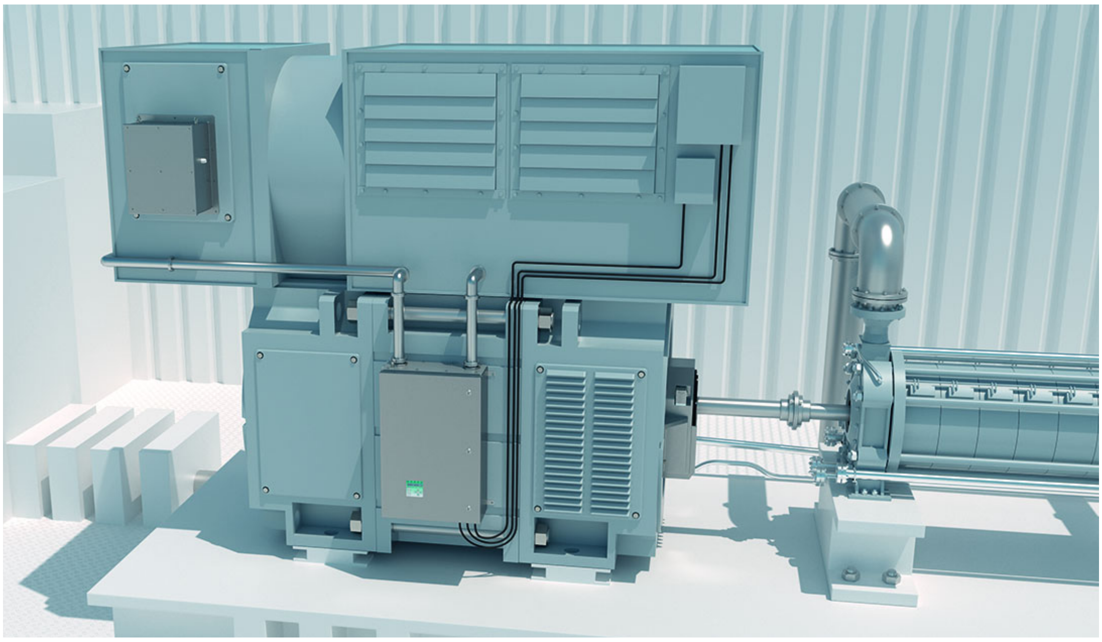

Figure 12 Example of pressurizing a motor application

Installation Requirements

Given the nature of the protection concept, you need to consider some specific installation requirements for a piece of pressurized equipment. The requirements depend on the hazardous area classification of the location for installation if the location has operating personnel in the area, and any country, regional, or local laws. The following sections give some details unique to this protection concept.

Location of Alarms and Indicators

Alarms and indicators associated with pressurized equipment are required to be placed where the operating personnel or other personnel can see or hear them and are able to take the necessary steps needed to maintain the required safety. Having these devices in an area that is conspicuous and attended, helps to assure that workers are able to take the actions needed.

Since the time in which the reaction to the alarm has to be performed is not exactly defined and –as the responsibility to carry out this reaction is with the user– it is recommended to consider, if possible, automatic systems.

NEC®/CE-Code-Based Class/Division Requirements

The first requirement is that the equipment installed in hazardous areas must be suitable for the area of installation. The equipment is suitable if it appropriately certified and listed by an approval body that is accredited as a National Recognized Testing Laboratory (NRTL) in the USA, and by the Standards Council of Canada (SCC) in Canada. Examples of approved certifiers are UL, CSA, or ETL. Another way of identifying suitable equipment is having evidence acceptable to the Authority Having Jurisdiction (AHJ) that the equipment is safe to operate in the hazardous area. This option is often used by those installing pressurized equipment. In either case, the end user cannot just place a pressurized control system onto an enclosure and then operate the equipment in the hazardous area. A concise evaluation is needed to ensure the safety in the classified location of the complete assembly.

Within Canada, the specific requirements for installation of pressurized equipment can be found in the CE Code under Rule 18-062. The specific details in this rule are relatively minimal, so the remaining text focuses on the NEC® and NFPA 496. As with any installation, thoroughly consult local and national laws and regulations to ensure appropriate compliance.

According to NFPA 496 and the NEC® for pressurized equipment installed into areas in the US and Canada under the Class/Division scheme, there are a few details worth noting.

Pressurized enclosures that are installed into Class I, Division 1 areas require conduit seals that are rated for the location ("explosionproof") on all entries within 18 inches of the pressurized enclosure on each conduit that is not purged and pressurized. If the conduit is pressurized, the volume of the conduit has to be considered when determining the total enclosure volume. Also, ensure that the conduit is properly flushed during the purge cycle with thorough consideration where the purge cycle forces the possible gas or vapor that is trapped in the conduit out of the conduit so that the possible hazardous mixture is not introduced into an area that is not appropriately protected. Proper transitions may still be required between Division boundaries, even when the conduit is pressurized, especially when the conduit leaves the hazardous area. As a matter of practicality, conduit seals are often used instead of purging conduit, unless the conduit is a short run to a second purged enclosure.

For Division-2 installations, an explosionproof conduit seal is not required for a conduit terminating into a pressurized enclosure. However, the concerns with the conduit being pressurized and where the pressurization protection stops must be addressed. For that reason, conduit entries still have some sort of seal. This seal is not required to be rated explosionproof for the area.

NFPA 496 has a number of warning markings that may be needed depending on a number of items. These warning markings include the following information:

- Indication that the equipment is pressurized
- Existence of hot internal parts inside the enclosure
- Presence of an asphyxiation hazard when using inert gas for the protective gas
- Duration of the initial purge time before power can be restored to the equipment

These warning markings are subject to verification that are placed in an area that is easily visible, and available for reference prior to an action. Specifically for Canada, these warnings must be in French and English. The 2021 edition of NFPA 496 includes acceptable French translations for the required warning messages.

IEC 60079-14-Based Zone Requirements

According to the IEC requirements found in IEC 60079-14, pressurized equipment must have a certification for the complete solution prior to installation. This is to ensure that all the aspects including the small details are taken care of as noted above.

Due to this requirement, OEMs typically have their complete product or pressurized equipment properly certified. However, there are applications where custom equipment needs protection by pressurization for use in a hazardous area, and the standard certification path does not make sense due to quantity. There are a few options in these situations. For one thing, the OEM can work together with a certification body to have a unit verification done to assess the single piece or a small run of equipment for compliance to the standards. This option only covers those units actually assessed. If the OEM builds more of the same, they need to go through this process again on the next unit or batch of units built. As an alternative, the OEM can work together with a well-established explosion protection company that offers a so-called "catalog certification" or "solution certification." The companies that offer these sorts of options have one or more certificates issued by a certification body that more or less operate as a framework. These certificates allow the company to offer a range of custom abilities to design, build, test, and apply a certification mark to the pressurized equipment within the limits of the certificates they hold. So, just like a standard certification that limits an OEM to what variations they can have on a product, these "catalog" solutions are also limited to what can be built and varies based on company and certificate. Also, while a specific 3rd party inspection is not needed for each design, regular auditing is necessary to assure proper compliance and safety are maintained.

Protective Gas Source

When planning the installation of the protective gas source, a number of factors can play into a successful installation. One area that is often overlooked is the volume of air that needs to be delivered to the pressurized enclosure, especially for the purge cycle. The following details can all have an effect on the volume of protective gas that can be delivered to a pressurized enclosure at a given line pressure:

- Internal tube diameter
- Tube material
- Number of bends
- Tube length
- Regulators
- Restrictions
- Other loads on the pneumatic system
- Other factors

To complicate the determination at many installation locations, most evaluations for the pneumatic installations are based on typical air tool demands. Many air tools and other loads that are usually considered on a pneumatic system at a single point do not have the same high-volume demands needed for purging a single enclosure. Usually, 20 CFM ... 40 CFM (570 l/min ... 1130 l/min) or more are required during the purge cycle at this single point. Failure to take this into account can result in an air volume or air pressure that is too low for the pressurization control system to work correctly, and can cause disruptions in other parts of the pneumatic system.

Enclosures do not have to be purged and pressurized by a compressed gas source like an air compressor. Instead, a pressurized air ducting system can be used where a ventilator or some other source of positive airflow is being drawn from a non-classified location to purge and pressurize the protected equipment. In this case, it is important to consider the air duct work as part of the enclosure volume that must be purged and pressurized. Installations using a motor-driven blower or another forced air setup require a method to monitor airflow, but monitoring the motor rotation or ventilator rotation is not a preferred method to ensure positive airflow. Mechanical failures can be present that prevent proper airflow, and still indicate a correct motor running condition.

Finally, for all installations, but especially for those using compressed gas (air or inert) minimizing the losses of the system to ensure maximum efficiency of the air system is important. Producing compressed gas is not free. Thus, systems that use less compressed gas are more efficient and have lower energy costs. This includes leaks in the tubing and connections to the enclosure, but it also includes the enclosure itself.

Compressed Air

The typical protective gas used is compressed air, which is usually delivered from an air compressor. It is expected that the air is clean, dry "instrument-grade" air, oil-free as well as moisture-free, and free of any other general contaminants. Along with right tubing installation as noted above, proper sizing of the air compressor is important to ensure that the system is available, regardless of the demand on the overall pneumatic system. Another important key is to ensure that the air compressor is always pulling air to compress from a non-hazardous area. It is a requirement for all installations that the intake for the air compressor be placed in a non-classified location or non-hazardous area.

Bottled compressed air is also a possibility, and is often used in remote locations. Again, the compressor used to fill these cylinders is to be in a location such that the air in the cylinder is free from any flammable gases or vapors. Additional dryers and filters may be needed to ensure the air entering the enclosure is clean and dry.

Inert Gas

In addition to compressed air, some systems use a compressed inert gas like nitrogen. Some applications require this due to the nature of the assembly and the equipment being protected. In these situations, the goal is not to keep the gas or vapor ("combustible" cf. illustration) level below the LFL of the material, but to keep the oxygen ("oxidizer" cf. illustration) content low, breaking the triangle and removing the threat. An excellent example of this type of application is an analyzer with a flammable liquid entering the pressurized enclosure. For more information, see chapter "Applications Working with a Containment System (Dilution)".

A concern with inert gas use is the risk of asphyxiation. Since the goal is to remove the oxygen content, care must be taken when working with this type of pressurized equipment, especially when servicing the equipment. Both NFPA 496 and IEC 60079-2 have requirements for warning markings of asphyxiation when an inert gas is used as the protective gas.

Also, due to the costs associated with bottled inert gas, or systems that generate inert gas, these applications are typically kept to small, well-sealed enclosures to minimize losses and minimize the gas usage.

Figure 13 Example of bottled inert gas: Nitrogen

Energy Source Considerations

The obvious source of energy going into a pressurized enclosure, the main power feed, is controlled by the pressurization system. Generally, the disconnection of this power is to happen outside of the pressurized enclosure, using a method that is suitable for the hazardous area.

Example

Installation with high-power contactor

An installation requires a high-power contactor. To remove power from the pressurized enclosure, this contactor is placed into a proper enclosure of its own, usually an explosionproof or flameproof enclosure, with the output of the contactor then going to the pressurized enclosure. This way, all power is removed from the enclosure when pressure is lost.

In addition to this obvious point of power, other areas are of equal concern. This can concern the Ethernet, especially Power over Ethernet (PoE) connections, USB, 4 mA ... 20 mA signals, and other data and I/O signals where a device inside of a pressurized enclosure receives power from an outside connection. These connections also require to be switched in a safe way for the installed area, not relying on pressurization as part of the safety. Also, if there are fiber-optic connections that could provide an ignition source, these also need to be handled correctly.

For applications that contain cells or batteries in the pressurized enclosure, some additional considerations are needed since the energy source cannot be removed when pressure is lost.

IEC 60079-2 has specific requirements in Annex G and Annex H depending on the equipment protection level required. NFPA 496 does not contain any specific requirements or details for cells or batteries, but in general the concern is the same. Thus, referring to the UL or CSA versions of IEC 60079-2 is prudent. This does not only concern those cells or batteries specifically added for an uninterruptable power supply (UPS) or other backup power in the enclosure, but also smaller cells or batteries that are part of the equipment. In general, computers or PLCs contain a small coin cell for memory backup and BIOS support. This energy source and larger sources of energy must be properly addressed within pressurized equipment.

Applications Working with a Containment System (Dilution)

The basic principle of pressurization is to have a higher pressure in the pressurized enclosure, so no flammable substance can enter the pressurized enclosure from the outside atmosphere. However, there are applications like analyzers, where this basic concept would not provide the complete level of safety, due to a gas or vapor with an even higher pressure being brought into the pressurized enclosure via a containment system.

For applications where a flammable gas or vapor, or liquid is brought into an enclosure with ignition-capable equipment, a form of pressurization known as dilution can be used to protect the equipment. But there are limitations. A number of aspects influence what needs to be considered. The section of the equipment where the flammable material is handled is known in the pressurization standards as a "containment system." These containment systems are classified based on their ability to release the hazardous substances during normal operation and during abnormal conditions. Under normal conditions, the two states considered are no release or limited release. For abnormal conditions, limited or unlimited release may need to be accounted for, depending on the containment system. Additional aspects that need to be considered are if the substance is a gas or vapor, or a liquid, if it contains its own oxidizer, the type of electrical equipment in the enclosure, the upper flammable limit (UFL) of the material, and if the area outside of the enclosure is rated as hazardous.

All of these considerations influence if pressurization can be used at all. If so, it must be decided which level of pressurization protection is needed, and what the limitations are on the protective gas that can be used.

The concept of dilution is to provide a constant metered flow of fresh protective gas to maintain safe conditions inside of the pressurized equipment so that the ignition capable equipment is protected from the flammable material. There also needs to be a minimum overpressure maintained, like there is for leakage compensation pressurization, to protect the ignition-capable equipment from the outside surrounding potentially explosive atmosphere.

For most applications, the protective gas is typically air. The delivery rate of the flow needs to exceed the potential worst-case leakage rate of the containment system, so the LFL is never reached outside of a set region within the pressurized enclosure. For liquids, the protective gas is nitrogen because it is difficult to impossible to fully calculate the rate at which the liquid turns to a vapor or a gas due in part to the nature of the liquid. In many analyzer applications, the liquid is a combination of a number of volatile or flammable materials, which is exactly why it is being analyzed! This makes it very difficult to truly understand the dilution rate of air needed to maintain a safe margin below the LFL. Therefore, the dilution is to maintain a low oxygen content, not a low vapor content. Nitrogen can also be used with most gases as well to dilute, but there are limitations to this. If the material has a UFL greater than 80 %, like acetylene, then the only choice for protective gas is air.

Figure 14 Gas analyzer solution by Pepperl+Fuchs

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Index

Numerics

A

B

C

D

E

U

V

W

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Explosion Protection

- Intrinsic Safety Barriers
- Signal Conditioners
- FieldConnex® Fieldbus
- Remote I/O Systems
- Electrical Ex Equipment
- Purge and Pressurization
- Industrial HMI
- Mobile Computing and Communications
- HART Interface Solutions
- Surge Protection
- Wireless Solutions
- Level Measurement

Industrial Sensors

- Proximity Sensors
- Photoelectric Sensors
- Industrial Vision
- Ultrasonic Sensors
- Rotary Encoders
- Positioning Systems
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