# WHITE PAPER on Explosion Proof and Intrinsic Safety Solutions

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e)2 Engineering experiences

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*Explosion proof/intrinsic safety are two technologies which guarantee that under no circumstances will equipment emit energy to cause an explosion*


## Abstract

Oil refineries, petrochemical processing plants and even coal mines to a certain extent operate in the presence of combustible gases and vapors. So, it's very important for equipment, more specifically electrical and electronic equipment that operate in that atmosphere, not to cause a spark which can ignite the gases, leading to an explosion. Explosion proof/intrinsic safety are two technologies which guarantee that under no circumstances will equipment emit energy to cause an explosion.

The objective of this document is to describe how to do the mechanical and electronic design for electrical/electronic equipment deployed in a hazardous environment. This document does not cover barriers placed in safe areas, and focuses only on devices placed in hazardous areas.

## Abbreviations

| Sl. No. | Acronym | Full Form |
|---|---|---|
| 1 | ATEX | The ATEX directive, or the standard describing what equipment and work environment is allowed in an environment with an explosive atmosphere. ATEX is an acronym for “*ATmosphères EXplosives*” |
| 2 | Ex. | Acronym used to indicate that equipment is explosion proof |
| 3 | IECEx | IEC Standards for devices to be used in a hazardous region. Similar to ATEX |
| 4 | NEC | National Electric Code standards followed in North America |
| 5 | UL, FM | Underwriters Laboratories, Factory Mutual – agencies that conduct compliance tests and issue certifications |

*Complying to Zone 0 is the most challenging.*

## Introduction to Standards

For an electrical/electronic device to be used in a hazardous environment, it needs to be certified to ensure it does not under any circumstances emit energy that could cause an explosion. There is no one single standard universally followed for explosion proof certification.

- In Europe, compliance with **ATEX** Directive 94/9/EC is mandatory when installing and commissioning electronic or mechanical devices in hazardous locations
- In the United States, compliance is based on the National Electrical Code (**NEC**); in Canada it is the Canadian Electric Code (CEC)
- **IECEx**, namely IEC 60079, is an explosion-proof standard from the IEC, the international body on electrical standards, that is followed by the rest of the world

In fact, the list is more than shown above - CSA, ANZex, AUSEx, UL and FM are the other explosion proof standards, each having its own set of compliance requirements, though subscribing to a similar broad category of rules.

To which standard to comply? Unless there are rigid country/region specific mandates to be followed, IECEx certification should be considered. Products complying to IECEx can also comply to ATEX, while the reverse may not necessarily be true.

The table below gives the area classification as per ATEX/IEC and NEC. Based on the location of the equipment, the equipment needs to comply with the standards requirements for that area.

*Explosion proof/isolation/ intrinsic safety are three types of protection mechanisms*

| | Zone 0 | Zone 1 | Zone2 |
|---|---|---|---|
| ATEX & IEC | Explosive gases are present all the time, or for long periods of time | Explosive gases are likely to present in normal conditions (occasionally) | Explosive gases are not likely to present in normal conditions or are present for short durations |
| NEC | Division 1 | | Division 2 |
| | Explosive gases are likely to be present during normal operation and exist frequently during maintenance or repair | | Explosive gases are not likely to be present in normal conditions |

Note:

- IECEx has an additional area called a “Safe Area,” where explosive gases are not present at any time
- NEC has another classification based on explosive material called “Class.” Class I includes flammable gas, vapours, and liquids, Class II is combustible dusts and Class III is ignitable fibres and flyings. Divisions 1 & 2 are considered for each class.
- ATEX has two types of I.S. certifications - Ex ia and Ex ib. Ex ia may be used in Zones 0/1/2, Ex ib may only be used in Zones 1/2
- Products are also certified based on gases that are present in the atmosphere, known as gas groups as shown in the table below with Group IIC being the most severe. Devices certified for IIC can be used within any other gas atmosphere.

| Group | Gases |
|---|---|
| I | Methane gas in mining |
| IIA | Industrial methane, petrol |
| IIB | Ethylene, coke oven gas and other industrial gases |
| IIC | Acetylene, Hydrogen |

A flame-proof enclosure is the most common technique used in explosion proofing

## Protection Layers

There are three types of protection mechanisms to make a product usable in a hazardous atmosphere

- **Explosion Proof** - Enclose the equipment in an explosion-proof enclosure so any ignition or fire from inside the equipment is contained within the equipment and does not spread outside
- **Isolating** the explosive gases from a device. That could be by pressurization of the device to prevent outside atmosphere from entering or by immersing the electrical components in an inert oil so no sparks are produced.
- **Intrinsic Safety** – The electrical/electronic design includes protection mechanisms limiting the energy available for ignition under any circumstances. This is applicable for electrical/electronic equipment operating at low voltages (example 24 VDC), and not for motors that operate at high voltages. For Zone 0, intrinsic safety compliance is the only accepted technique, even if the device is explosion-proof for devices operating at low voltages

It is common to find devices, specifically those operating at low voltages, to be explosion-proof and intrinsic safe certified.

## Simple Devices

A simple device or apparatus does not generate or store more 1.2V or 100mA or 20mJ or 25mW. Such devices are incapable of causing ignition, and need no compliance to explosion proof or intrinsic safety.

General guidelines are given in standards like UL and ATEX to choose the thickness of the material based on the internal volume

## Mechanical Design considerations

Explosion proofing is very much a mechanical engineering design. Common techniques for implementing explosion proofing are explained below.

### *Flame Proof Enclosure*

This method is based on the concept of explosion containment. The ignition source is permitted to come in contact with the hazardous air/gas mixture. In case of an explosion, the explosion must remain confined within the enclosure. The enclosure is built to resist the excess pressure created by an internal explosion, thus impeding propagation to the surrounding atmosphere.

The resultant gas jet coming from the enclosure is cooled rapidly through the enclosure's heat conduction and the expansion and dilution of the hot gas in the colder external atmosphere. This is only possible by providing the right opening design at mating parts and other designed locations, as shown in Fig. 2, below.

The design should meet the safety factor for determining the strength of the enclosure.

| Enclosure Material | Safety Factor for Calculation | Safety Factor for Hydrostatic Pressure Test |
|---|---|---|
| Cast Metal | 5 | 4 |
| Fabricated Steel | 4 | 4 |
| Bolt | 3 | 3 |

The enclosure is required to withstand a hydrostatic pressure test of at least twice the maximum internal explosion pressure without rupture. Adequate gaps, clearance and length of joints should be given to release the gas with reasonably lower temperature. These parameters changes with Zone/Division of protection.

Below is a picture of Explosion Testing of the UL test set-up

*A flame-proof enclosure is common where high levels of power are required, as in motors*

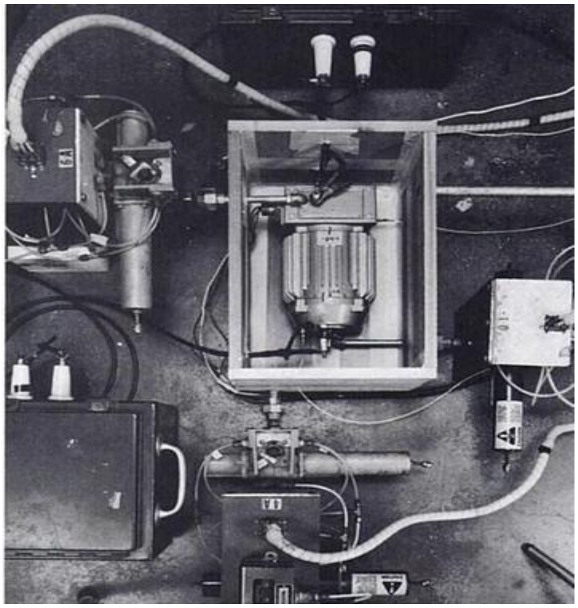

Fig. 1. UL Laboratories explosion proof test set-up

General guidelines are given in standards like UL and ATEX to choose the thickness of the material based on the internal volume. The internal volume decides the explosion pressure, and hence the factor of the safety requirement. If the factor of safety is not proved in theory, then a hydrostatic test needs to be carried out, as per the table given above.

As can be seen in the diagram, all the parameters listed below play a vital role in the design of the enclosure.

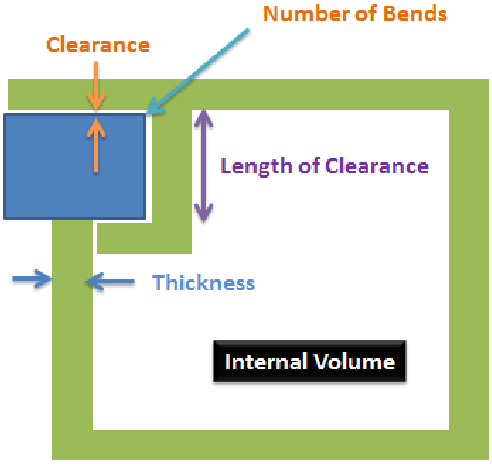


Fig 2. Design consideration for an enclosure

Purging or pressurization is a protection method that does not allow the unsafe air/gas mixture to enter the enclosure containing electrical parts which can spark or reach high temperatures

The table below gives an example of Group D for the length of flame path and clearance between mating components.

Metric (SI) Units

| Length of Flamepath (mm) | Max Gap of Flamepath (mm) for Enclosure Vol ($cm^3$) | | |
|---|---|---|---|
| Type of Joint | ≤ 100 | 100 < V ≤ 2000 | V > 2000 |
| Flange & Spigot | | | |
| 6 ≤ L < 12.5 | 0.15 | – | – |
| 12.5 ≤ L < 25 | 0.15 | 0.15 | 0.10 |
| 25 ≤ L | 0.20 | 0.20 | 0.20 |
| Shafts and Rods | | | |
| 6 ≤ L < 12.5 | 0.15 | – | – |
| 12.5 ≤ L < 25 | 0.15 | 0.15 | 0.10 |
| 25 ≤ L < 40 | 0.20 | 0.20 | 0.20 |
| 40 ≤ L | 0.25 | 0.25 | 0.25 |
| Shafts with Ball / Roller Bearing | | | |
| 6 ≤ L < 12.5 | 0.23 | – | – |
| 12.5 ≤ L < 25 | 0.25 | 0.23 | 0.15 |
| 25 ≤ L < 40 | 0.30 | 0.30 | 0.30 |
| 40 ≤ L | 0.38 | 0.38 | 0.38 |

Table. 1. Flamepath and gap reqd. for explosion proof requirement

This protection method is used where high levels of power are required, such as for motors, compressor, pumps, transformers, lamps, switches, solenoid valves, actuators, and for all parts that generate sparks. *It is also used in low-powered electronic devices such as transmitters.*

**Ingress Protection Seals**

Bearing seals made of brass which form labyrinthine “flame seal” paths are built into the assembly, as well as sufficient added structural strength to withstand an internal explosion. The flame seal path also changes with the type of explosive gas and Zone/ Division that the equipment is designed for.

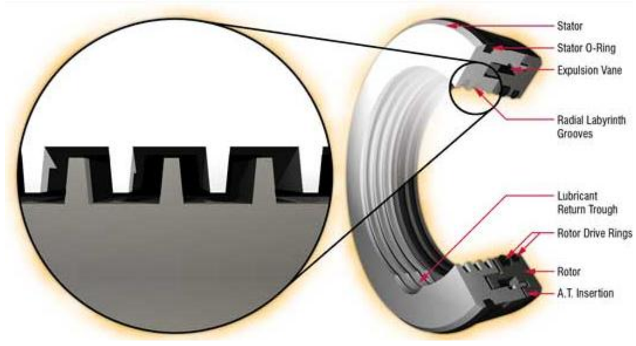


*Fig. 3. Labyrinth seal of explosion proof rotating equipment*

**Breather, Drains, Relief Valves, Grounding, etc.**

Special breather/drains made from non- sparking stainless steel are used with a special insertion to prevent the explosion from coming into direct contact with hazardous gases.

Grounding is very important for a hazardous environment, as improper arrangement can lead to a spark outside the equipment. Shaft grounding for rotating equipment is usually done inside the equipment itself, but for external grounding, special accessories are used.

### *Specific Mechanical Design Considerations*

One of the things to remember while designing an enclosure is that the two internal volumes should not be connected physically by another internal volume. In such cases, there is possibility of a double explosion, leading to an increase in internal pressure.

### *Purging / Pressurizing Method*

Purging or pressurization is a protection method based on the segregation concept. This method does not allow the unsafe air/gas mixture to enter the enclosure containing electrical parts which can spark or reach high temperatures. A protective gas—air or inert gas—is contained inside the enclosure with a pressure slightly greater than the external atmosphere.

*Segregation is accomplished by filling the enclosure with powder/oil/sand material so an arc generated inside the enclosure will not result in the ignition of the dangerous atmosphere*

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

As the size and volume of the enclosure keeps getting bigger, it becomes increasingly difficult to control the explosion pressure. With higher explosion pressure, the thickness of the enclosure increases in manifold ways, hence making the equipment unviable. In such equipment, pressurizing is an easier option.

### *Encapsulation*

The encapsulation protection method is based on the segregation of those electrical parts that can cause the ignition of a hazardous mixture in the presence of a spark or heating, by filling in resin that is resistant to the specific ambient conditions.

The filling method is commonly used for components inside Ex ‘e’ or Ex ‘N’ apparatus and for heavy-duty traction batteries.

The termination of wires and the interconnection between two wires are of utmost importance. Usually the interconnections are encapsulated by using an epoxy compound like Chico, depending on the environment (gases) to which it will be subjected, as shown in Fig. 4.

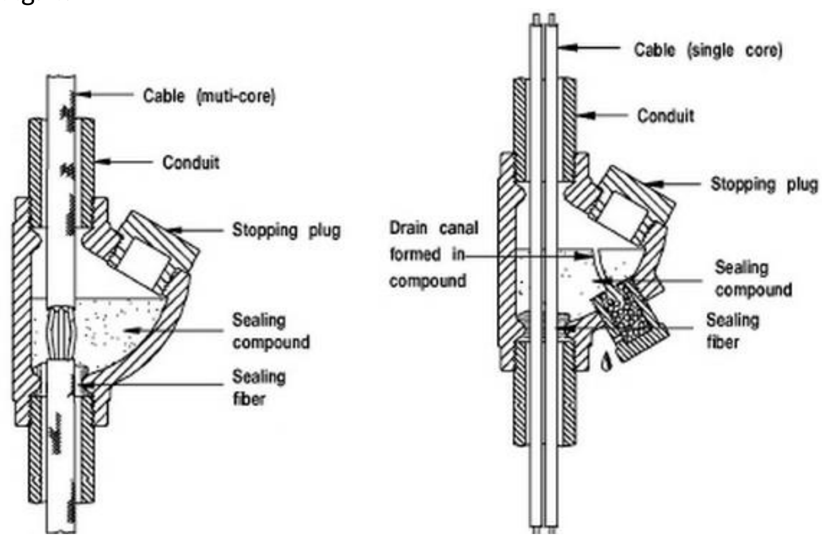


*Fig 4. Encapsulation of Electrical Cable*

### *Sand/Quartz/Powder-Filling/Oil-immersion Protection Method*

Segregation is accomplished by filling the enclosure with powder/oil/sand material so an arc generated inside the enclosure will not result in the ignition of the dangerous atmosphere.

The filling must be made in such a way as to prevent empty spaces in the mass. The filling material that is generally used is quartz powder, and its granularity must comply with the standard. According to the oil immersion protection method, all electrical parts are submersed in either non-flammable or low-flammability oil, which prevents the external atmosphere from contacting the electrical components. The oil often also serves as a coolant.

The filling, which may be sand, glass beads, or similar, is subject to special requirements, as is the design of the enclosure. The filling must not leak out of the enclosure, either during normal operation or as a result of arcing or other events inside the enclosure.

The method is primarily of use where the incendiary action is the abnormal release of electrical energy by the rupture of fuses or failure of components such as capacitors. The method is commonly used for components inside Ex ‘e’ or Ex ‘N’ apparatus and for heavy-duty traction batteries.

*Voltage and current are kept low so no spark can occur, and should they occur, possess so little energy that they are unable to ignite an explosive atmosphere*

## Intrinsic Safe Design Considerations

All electronic devices need the power to operate, and those installed in hazardous areas are no exception. For most such devices, the power comes from a control system installed in a safe area. There are three components, and all three together make a field device intrinsic safety.

- The primary device, like the transmitter, needs to be intrinsic safe
- The power for the device should come though the intrinsic safety barrier
- The field wiring should not be capable of causing a fire

Designing an electronic circuit for a device placed in a hazardous area should consider:

- Voltage and current are kept low so no spark can occur, and should they occur, possess so little energy that they are unable to ignite an explosive atmosphere.
- Operate zener diodes at 66% (2/3) of their ratings
- Creepage and clearance distances have to comply with values specified in the compliance standards
- Diodes are used when blocking is required; they are often in series with the output of part of a circuit that is potted
- Diodes are to be duplicated for redundancy wherever possible
- Resistors to be used reduce/constrain the instantaneous release of the charge from capacitors/diodes
- Use capacitors to block DC voltage as a safety measure, but there must two of them (duplicate) in series. There is a restriction on the types of capacitors - electrolytic and tantalum capacitors are not acceptable
- Fuses must be potted if they are used in a hazardous area. They must have a high breaking capacity ~ 1.5KA
- Transformers and opto-couplers can isolate intrinsically safe from non-intrinsically safe circuits
- Include the capacitive and inductance of cables connecting to the circuit
- The inductive value of the cable may also take into account the resistance of the cable (L/R ratio)
- As a high surface temperature could cause ignition, the maximum temperature of any faulty component on a circuit board must be within permissible limits
- Use of sensor/actuator devices to monitor various physical-technical variables (temperature, pressure, flow, speed, vibrations, etc.)

*As motors operate at high voltage, explosion proof is the only protection mechanism, not intrinsic safety.*

### *Cable Selection*

Intrinsic safety allows the use of conventional instrumentation cables to wire from the safe area to the hazardous area.

## Example – Motors

The motor is a very important prime mover in any industry, and the fact that 60% of electricity produced in the world goes through motors makes it all the more important. With the use of a motor for oil and gas, mining, paper, etc., the explosion proof motor is playing an increasingly important role.
As motors operate at high voltage, explosion proof is the only protection mechanism, not intrinsic safety.

As described above, the explosion proof motor enclosure is constructed will all the right clearance, thickness and components so as to withstand the explosion pressure with the prescribed factor of safety. This makes the overall construction very robust. Also, special attention is given to the electrical design so the motor does not become overheated under any circumstances.

Special consideration during design:

- Class F insulation
- Non-sparking brass shaft slingers
- Oversized conduit box with threaded conduit holes
- Wires connection sealed in Chico compound
- Non-sparking, corrosion resistant cooling fans
- Cast iron end plates and fan covers
- Stainless steel breathers and drains
- Oversized, double-shielded, anti-friction, sealed ball bearings with high temperature grease
- Low-loss steel laminations for higher efficiency
- Precision dynamic balancing
- High temperature polyester varnish impregnated armatures
- Dynamically balanced to reduce vibrations
- Special shaft grounding arrangement

Explosion-proof motors have a tight fit between mating parts to ensure the integrity of the explosion-proof enclosure. This can lead to an accumulation of moisture inside the motor due to condensation. Care should be taken when designing an explosion-proof motor, especially when installed outdoors and on intermittent duty. The selection of the right breather and drain is very important. The selection of the rotating component material should be non-sparking, therefore fans are usually made of antistatic plastic, bronze or aluminium with much less copper content. This prevents sparking from occurring outside the enclosure. Class F winding insulation provides greater protection

*The explosion-proof protection method is the most widely known, and has been used in applications for the longest period of time*

against high temperatures than other classes of insulation. Class H polyester varnish to impregnate the motor armatures also provides high temperature protection. And sometimes corona shielding is done for anti-static protection. Non-sparking brass shaft slingers are used on the motor shaft to provide a tighter shaft seal. No gaskets are used at the mating areas, especially between the conduit box and the motor body. Instead, the surfaces are machined to a high surface finish for good contact. Accessories like drains, greasing inlet/outlet and breather are usually welded to the body so they are not removed accidently.

*HCL can perform complete design, fabrication, pre-compliance testing, and assist in certification*

## Conclusion

The explosion-proof protection method is the most widely known, and has been used in applications for the longest period of time.

However, it is generally agreed that the intrinsic safety protection method is safer, more flexible and costs less to install and maintain. Certified devices could have a combination of the twom, i.e. the reactive techniques like explosion proof and mitigation techniques like intrinsic safety. Most of the time, equipment is designed for a particular zone/division, but if adequate care is taken, a modular design can be made so the equipment can cater to different zones/divisions without making too many changes in the assembly.

## How HCL Can Help

- **Complete Design and Project Management** – Based on high level requirements, HCL can create finely decomposed requirements, detailed hazard analysis prior after requirements and design stages, prepare complete mechanical and hardware designs to comply with zone 0 ATEX requirements.
- **Fabrication** – While HCL can undertake low volume manufacturing, it can also work with reputable vendors for mass production.
- **Pre-Compliance Testing** – Perform testing of equipment at HCL's state-of-the-art labs, simulating the exact tests that would be done by an external certifying agency. This is in addition to product functional testing.
- **Selection of Certifying Agency** – HCL can assist customers in selecting the right certifying agency for a product during the project execution stage.
- **Certification** – Support customers get product certification by working with an external certifying agency, providing all documentation, test results as required for certification, participation in audit review meetings and providing the necessary justification for the design.

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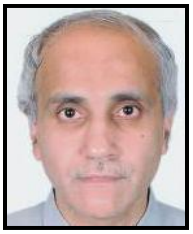


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