Guide to Choose the Right Protection Concept for Your HAZLOC Product

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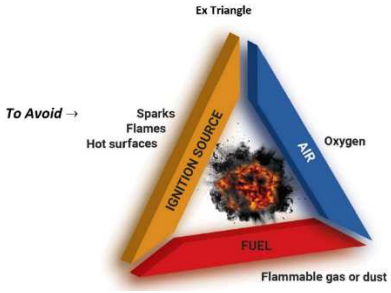
Abstract - Designing embedded or electrical products for industrial or process plants requires a logical and strategic roadmap to ensure compliance with international hazardous location (HazLoc) safety standards such as ATEX, IECEx, and UL. Identifying and selecting the right protection concept is complex and plays a crucial role in mitigating risks associated with explosive atmospheres while enabling future upgrades for deployment in stringent zone categories. This paper provides a structured design guide to assist manufacturers and product designers in choosing the most appropriate protection concept based on environmental conditions, zone requirements, and product functionality.

Keywords—Hazardous Locations, Protection Concept, Compliance,

Safety Standards, Explosive Atmospheres, Design for HazLoc.

I. HAZLOC (ATEX) Groups, Zones, EPLs, Categories

Principal - *To ENSURE Our Product Does Not Become an IGNITION SOURCE*



II. *GROUPS, ZONES, CATEGORIES Classification*

1) Equipment Category 1 [Zone 0]

a) *Intended Use:* Used in areas where explosive atmospheres, caused by mixture of air and gases, vapors or mists or by air/dust mixture, are **present constantly for longer periods or frequently**. **e.g. > 1000 hrs/year**.

b) Equipment Design Expectation:

- The operational parameters established by the manufacturer and ensuring a very high level of protection.
- Equipment in this category must ensure the requisite level of protection, even in the event of rare incidents relating to equipment, and is characterized by means of protection such as: **Either**, if one means of protection fails, another independent second means can provide the exquisite level of protection; **Or** the requisite level of protection is assured in the event of two faults occurring independently.

c) Conformity Requirements

- For All Equipment EC Type Examination plus Production Quality Notification (QAN) Or Product Verification.

2) Equipment Category 2 [Zone 1]

a) *Intended Use:* Used in areas in which explosive atmospheres caused by gases, vapors, mists or air/dust mixtures are likely to occur occasionally. **e.g. 10 to 1000 hrs./year.**

b) Equipment Design Expectation:

- The operational parameters established by the manufacturer and of ensuring a high level of protection.
- The means of protection in this category ensures the requisite level of protection, even in the event of frequently occurring disturbances or equipment faults which normally have to be taken into account.

c) Conformity Requirements

- *For electrical equipment & internal combustion engines:*

  EC type Examination plus Product Quality Notification or Conformity to type

  Suitable protection concept - ia, ib, d, e, p, m, o, q.

- For non-electrical equipment

  Storage of dossier plus Internal production control

  Suitable protection concept :
  fr – flow restricting enclosure
  c – constructional safety
  b – control of ignition source
  k – liquid emersion

3) Equipment Category 3 [Zone 2]

a) *Intended Use:* Used in areas in which explosive atmospheres caused by gases, vapors, mists, or air/dust mixtures are unlikely to occur or, if they do occur, are likely to do **only infrequently and for a short period only. e.g. < 10 hrs./year**.

b) Equipment Design Expectation:

- The operating parameters established by the manufacturer and ensuring a normal level of protection.
- Equipment in this category ensures the requisite level of protection during normal operation.

c) Conformity Requirements:

- FOR ALL EQUIPMENT
  Internal Production Control
  n – non sparking
  any other type of protection used for category 2

A. GROUPS, ZONES, CATEGORIES Classification Summary

Eqpt. Group	**Intended End Use**	**Remark**
I	Underground Mines	Group I equipment in underground mining environments where methane is present. Fire Damp
II	Other	Group II covers all other environments Group II is further divided into subgroups IIA, IIB or IIC IIA - propane (least incendiary) IIB - ethylene (more incendiary) IIC - hydrogen an acetylene (most incendiary)
III	Dust	

Type of Atmosphere Grouping		**Zone**	**IEC EPL**	**Eqpt. Cat**	**Presence of Ex. Atmosphere**	**Period of Presence**
Gas	I	0-Permanent Presence	Ga	1G	Continuously, long term, very frequently	> 1000 hrs./year
		1-Occasional Presence	Gb	2G	Occasionally	10 to 1000 hrs./year
		2-Rare Presence	Gc	3G	In frequently, short periods	< 10 hrs./year
Dust	II	20-Permanent Presence	Da	1D	Continuously, long term, very frequently	> 1000 hrs./year
		21-Occasional Presence	Db	2D	Occasionally	10 to 1000 hrs./year
		22-Rare Presence	Dc	3D	In frequently, short periods	< 10 hrs. /year

III. TEMPERATURE RATING (TEMPERATURE CLASS)

Temperature Class	**Ignition temperature range of the explosive gas-air mixture**	**Max permitted surface temperature of eqpt**
T1	Greater than 450ºC	450°C
T2	between 300°C and 450°C	300°C
T3	between 200°C and 300°C	200°C
T4	between 135°C and 200°C	135°C
T5	between 100°C and 135°C	100°C
T6	between 85°C and 100°C	85°C

IV. IGNITION PROTECTIONS: PROTECTION CONCEPTS

A. Ignition Protection Concepts

The ignition protection concepts used in hazardous areas, including the basic protection principles, suitability for different zones, typical Equipment Protection Levels (EPL), and relevant EN/IEC standards. Manufacture should take a care while designing the product as per provide design considerations in each protection concept.

1) Increased Safety (e)

a) ***Basic Concept of Protection*:** The protection principle of increased safety ensures that there are no arcs, sparks, or hot surfaces within the electrical equipment. The enclosure must have a minimum rating of IP54 (dust-tight and water-resistant).

- *Suitable for Zones:* Zones 1, 2
- *Typical EPL:* Gb, Gc

b) Key Design Consideration:

- Avoid **sparking components** (use crimped connections instead of soldering).
- Ensure adequate creepage and clearance distances.
- Avoid sharp edges and loose connections that can cause arcing.
- Heatloss (wiring and terminations)
- Enclosure (IP rating, impact strength etc.)

2) Non-Sparking Type (n)

a) Type 'n' (non-sparking):

- *Basic Concept of Protection:* Ensures that the equipment does not produce sparks under normal operation.
- *Suitable for Zones*: Zone 2
- *Typical EPL:* Gc

b) Type 'n' (closed-break):

- *Basic Concept of Protection:* The equipment is designed to contain any explosion or prevent it from spreading.
- *Suitable for Zones:* Zone 2
- *Typical EPL:* Gc

c) ***Type 'n' (sealed and hermetically sealed)****:*

- *Basic Concept of Protection:* The equipment is hermetically sealed to keep flammable substances out.
- *Suitable for Zones:* Zone 2
- *Typical EPL:* Gc

d) Type 'n' (restricted breathing):

- *Basic Concept of Protection:* Equipment is designed to restrict the entry of flammable substances into the equipment.
- *Suitable for Zones*: Zone 2
- *Typical EPL*: Gc

a) Key Design Consideration:

- Enclosure must be airtight to prevent gas ingress.
- Use non-porous seals and gaskets.
- Ensure proper ventilation to prevent internal pressure build-up.

3) Flameproof (d)

- *Basic Concept of Protection:* Flameproof protection involves enclosing electrical equipment in a casing that can withstand an internal explosion without allowing it to escape into the surrounding atmosphere.
- *Suitable for Zones:* Zones 1, 2
- *Typical EPL:* Gb, Gc
- *EN/IEC Standards:* 60079-1

a) Key Design Consideration:

- Enclosure must withstand internal explosions without rupturing.
- Flame path based on joints.
- Pressure piling.
- Heat-loss of built-in apparatus

4) Powder-Filled (q)

- *Basic Concept of Protection*: The equipment is filled with a powder that helps to quench any flames generated inside the enclosure, preventing ignition.
- *Suitable for Zones:* Zones 1, 2
- *Typical EPL:* Gb, Gc
- *EN/IEC Standards:* 60079-5

5) Intrinsic Safety (ia, ib, ic)

- *Basic Concept of Protection:* Intrinsic safety limits the energy (both spark energy and surface temperatures) to a level that is too low to cause ignition.
  - *ia:* Suitable for Zones 0, 1, 2.
  - *ib:* Suitable for Zones 1, 2.
  - *ic:* Suitable for Zone 2.
- *Suitable for Zones:* Zones 0, 1, 2
- *Typical EPL:* Ga, Gb, Gc
- *EN/IEC Standards:* 60079-11

a) Key Design Consideration:

- Use low-power circuits with limited voltage, current, and capacitance.
- Employ barriers (zener diodes or galvanic isolators) to restrict energy.
- Ensure spacing and creepage distances comply with IEC 60079-11.
- Design circuits with fail-safe components (e.g., resistors for current limiting).

6) *Pressurized Enclosure (px, py, pz, pd)*

- *Basic Concept of Protection:* Equipment is placed inside a pressurized enclosure that keeps flammable substances out.
- *Suitable for Zones:* Zones 1, 2
- *Typical EPL:* Gb, Gc
- *EN/IEC Standards:* 60079-2
  - *px:* Pressurized enclosure
  - *py:* Pressurized enclosure
  - *pz:* Pressurized enclosure
  - *pd:* Pressurized enclosure

a) *Key Design Consideration:*

- First a purging of ≥ 5 times the internal volume
- For EPL Gb redundant guarding of the flow required
- Then 'compensation of leak losses' + power on
- For EPL Gb mandatory power off when pressure drops

7) *Encapsulation (ma, mb, mc)*

- *Basic Concept of Protection:* Encapsulation involves enclosing the equipment in a protective material that prevents ignition.
- *Suitable for Zones:* Zones 0, 1, 2
- *Typical EPL:* Ga, Gb, Gc
- *EN/IEC Standards:* 60079-18
  - *ma:* Suitable for Zones 0, 1, 2
  - *mb:* Suitable for Zones 1, 2
  - *mc*: Suitable for Zone 2

a) *Key Design Consideration:*

- Use certified potting compounds with fire-resistant properties.
- Ensure no voids that could trap hazardous gases.
- Thickness of the potting.
- Internal free volumes are limited
- Ageing of the potting material
- Potting shall be non-hygroscopic

8) *Oil Immersion (o)*

- *Basic Concept of Protection:* The equipment is immersed in oil, which helps to prevent ignition by isolating the electrical components from the surrounding atmosphere.
- *Suitable for Zones*: Zones 1, 2
- *Typical EPL:* Gb, Gc
- *EN/IEC Standards:* 60079-6

a) *Key Design Consideration:*

- Submerge components in oil to prevent gas exposure.
- Select oils with high flashpoints (>150°C).

9) *Optical Radiation (Op pr, Op sh, Op is)*

- *Basic Concept of Protection:* These methods rely on optical radiation and safety shutdown mechanisms to prevent ignition.
- *Suitable for Zones:* Zones 1, 2
- *Typical EPL:* Gb, Gc
- *EN/IEC Standards:* 60079-28
  - *Op pr:* Optical radiation–inherently safe, protected by shutdown
  - *Op sh:* Optical radiation–shutdown protection
  - *Op is:* Optical radiation–inherent safety with shutdown

10) *Dust Ignition Protection by Enclosure (ta, tb, tc)*

- *Basic Concept of Protection:* This protection type involves using dust-tight enclosures to prevent ignition in dusty environments.
- *Suitable for Zones:* Zones 21, 22
- *Typical EPL:* Da, Db, Dc
- *EN/IEC Standards:* 60079-31
  - *ta:* Dust ignition protection by enclosure
  - *tb:* Dust ignition protection by enclosure
  - *tc:* Dust ignition protection by enclosure

This structured text provides a comprehensive breakdown of the various protection methods available to prevent ignition in hazardous areas, highlighting the suitability for different zones, EPL levels, and applicable standards. Each protection method ensures safety in specific environments, from flameproof enclosures to dust-tight solutions.

V. STANDARDS & PROTECTION Nomenclature

Protection Concept - Electrical-Dust	
Type of Protection (electrical -dust)	**Reference**
General Requirements	EN/IEC 60079-0
Enclosure -ta / tb / tc	EN/IEC 60079-31
Purge /Pressurised Ex p / Pxb / pyb / pzc	EN/IEC 60079-2
Intrinsic Safety - Ex i / ia /ib /ic	EN/IEC 60079-11
Encapsulation - EX m / ma /mb /mc	EN/IEC 60079-18

Protection Concept -Non - Electrical		
Type of Protection (non - electrical) (gas & dust)	**Reference (ATEX only)**	**IECEx**
General Requirements	EN 80079-36	IEC /ISO 80079-36
Flow Restricting Enclosure - fr	EN 13463-2	–
Flameproof - d	EN 13463-3	–
Constructional Safety - c / h	EN 80079-37	IEC /ISO 80079-37
Control of Ignition - b / h	EN 80079-37	IEC /ISO 80079-37
Pressurisation - p	EN 60079-2	
Liquid Immersion - k / h	EN 80079-37	IEC /ISO 80079-37

VI. Explosion Protection Levels EPLs Definitions

A. EPL Ga

Equipment for explosive gas atmospheres, ensuring a "very high" level of protection for use in explosive gas atmospheres, which is not a source of ignition in normal operation, during expected, or rare malfunction.

B. EPL Gb

Equipment for explosive gas atmospheres, ensuring a "high" level of protection, which is not a source of ignition in normal operation or during expected malfunctions.

C. EPL Gc

Equipment for explosive gas atmospheres, ensuring an "enhanced" level of protection, which is not a source of ignition in normal operation and which may have some additional protection to ensure that it remains inactive as an ignition source in the case of regular expected occurrences (e.g., failure of a lamp).

Note: EPL Da, EPL Db and EPL Dc are same as EPL Ga, EPL Gb and EPL Gc respectively.

VII. ATEX ASSEMBLIES Scenario Example (Plants, Installations, Production Lines, Skids, etc.)

In case of an assembly consisting of different compliant pieces of equipment as defined by Directive 2014/34/EU, which were previously placed on the market by different manufacturers; these items of equipment have to conform with the Directive, including being subject to proper conformity assembly may presume conformity of these pieces of equipment and may restrict his own risk assessment of the assembly to those additional ignition and other relevant hazards (as defined in Annex II) which become relevant because of the final combination. If there are additional ignition hazards, a further conformity assessment of the assembly regarding these additional risks is necessary. Similarly, the assembler may presume the conformity of components which are accompanied by a written attestation of conformity issued by their manufacturer (Article 6(2)) (*see also section § 74[II] on obligations of manufacturers*).

However, if the manufacturer of the assembly integrate parts without CE marking on it (because they are parts manufactured by himself or parts he has received from his supplier for further processing by himself) or components not accompanied by the written attestation of conformity, he shall not presume conformity of those parts and his conformity assessment of the assembly shall cover those parts as required.

VIII. SUMMARY OF REQUIREMENT FOR COMBINED PRODUCTS (ASSEMBLIES)

Table 1: Assembly Composed of CE-marked Components with Proven Conformity

Situation	**Details**	
Parts: Assembly Composition	Equipment, protective systems, devices (Article 1(1)), including non-CE-marked, and components not accompanied by a written attestation of conformity (Article 13(3)) (parts without proven conformity).	
Configuration: Assembly in market	Exactly defined configuration(s) A "modular system" of parts, to be specifically selected and configured to serve a specific purpose, maybe by the user/installer.	
RESULT: Manufacturer may presume conformity	Only parts with proven conformity.	
Conformity Assessment	Conformity assessment must cover: - All parts without proven conformity regarding all risks, and - All configuration(s) regarding all risks that might arise by the interaction of the combined parts, both to the intended use.	Conformity assessment must cover: -All parts that have proven conformity which is part of the “modular system”, regarding all risks, and -At least those of the possible and useful configurations, which are assessed to be the most unfavourable regarding all risks that might arise by the interaction of the combined parts, both with respect to intended use.
Information to be provided: a) by EU declaration of conformity b) by instructions for installation and use	a) Identification of the items in the "modular system" that are ATEX equipment in their own right, and which have been separately assessed. b) Instructions for selecting parts to be combined to fulfil the required purpose and instructions for installation and use sufficient to ensure that the resulting assembly complies with all relevant EHSRs of Directive 2014/34/EU.	a) Identification of the items in the “modular system” that are ATEX equipment in their own right, and which have been separately assessed: b) Instructions for the selection of parts, to be combined to fulfil the required purpose, and instructions for installation and use, sufficient to ensure that the resulting assembly complies with all relevant EHSRs of Directive 2014/34/EU.

Table 2: Assembly Composed of Non-CE-marked Components or Without Proven Conformity

Situation	Description	
Parts: Assembly composition	Equipment, protective systems, devices (Article 1(1)), all CE-marked (accompanied by an EU declaration of conformity) and components accompanied by a written attestation of conformity (Article 13(3)) (parts with proven conformity) (*)	
Configuration: Assembly in market	Exactly defined configuration(s) A "modular system" of parts, to be specifically selected and configured to serve a specific purpose, possibly by the user/installer.	
RESULT: Manufacturer may presume conformity	All parts	
Conformity Assessment	Conformity assessment must cover the whole configuration regarding all risks that may arise from the interaction of the combined parts to the intended use. See also **Note (*).**	Conformity must cover atleast the possible and useful configurations which are assessed to be the most unfavourable regarding all risks, which might arise by the interaction of the combined parts, to the intended use. See also **Note (*).**
Information to be provided: a) by EU declaration of conformity. b) by instructions for installation and use.	a) Identification of items in the assembly that are ATEX equipment in their own right, and which have been separately assessed. b) Instructions for installation and use, sufficient to ensure that the resulting assembly complies with all relevant EHSRs of Directive 2014/34/EU.	a) Identification of the items in the 'modular system' that are ATEX equipment in their own right, and which have been separately assessed: b) Instructions for the selection of parts, to be combined to fulfil the required purpose, and instructions for installation and use, sufficient to ensure that resulting assembly complies with all relevant EHSRs of Directive 2014/34/EU.

IX. ATEX Vs IECEx:

A. ATEX

- Jurisdiction is the European Union.
- Compliance with ATEX Directive, Essential Health and Safety Requirements (EHSRs), and European Standards (EN) is required.
- Certification bodies are known as an ExNB (Ex Notified Body) qualified by an official body within their ow country issuing notification to the EU Commission.
- Certificate is called EC Type Examination Certificate.
- Assessment and testing process is risk based per ATEX and EU Directives, e.g., Zone 2 can be self-declared due to lower risk).
- Certificates are available from the respective ExNB.

B. IECEx

- Global jurisdiction.
- Certification scheme requiring full compliance with IEC Standard.
- Ex CBs and Ex Testing Laboratories (Ex TLs) are evaluated and qualified according to a single international process and assessed by a team of IECEx assessors.
- Certificate is called a CoC.
- All product types require a CoC, regardless of zone of use of the product.
- IECEx certificates are all available for viewing on www.iecex.com.

Conclusion

Each protection concept has its unique function for preventing explosions which depends on hazardous zone classification, type of hazardous substance, and product application. Fundamentally, safe designs are ideal for low-power applications, while flameproof and increased safety methods suit larger equipment. Encapsulation and restricted breathing offers compact solutions, whereas pressurization is ideal for enclosures requiring access. Proper material selection, enclosure design, and compliance with IEC 60079 standards are crucial in ensuring safety and regulatory approval.

By integrating these design considerations early in development, engineers can create compliant, robust, and reliable HazLoc-certified products.

Acknowledgement

I am grateful to my iLensys team and mentor (Mr. Kishore Deshmukh) for their important assistance and contributions to this IEEE publication. Your dedication and collaboration have been crucial to its successful completion.

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