HAZARDOUS AREA CLASSIFICATION (HAC) GUIDELINE

EGPC-PSM-GL-014

PSM GUIDELINES

The Egyptian Process Safety Management Steering Committee (PSMSC Egypt)
PSM TECHNICAL SUBCOMMITTEE (PSMTC)

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1. Introduction

The "Hazardous Area Classification (HAC) Guideline" provides guidance on the classification of areas around equipment handling or storing flammable fluids - or combustible liquid-produced vapors mixed with air under normal atmospheric conditions - and provides a basis for the classification of hazardous areas. An "area" in this context is always taken to be three-dimensional. Potentially explosive atmospheres occur in many industries in onshore and offshore petrochemical processing and refining plants and in places such as fuel filling stations, garages, workshops, etc. Failure to adopt correct and safe working practices could result in the ignition of explosive gases, not necessarily when the work is done but possibly at some future date.

This guideline is not developed for the plant designers who prepare the hazardous area classification drawings to help them in the design process. Although it provides them with valuable knowledge, it is prepared essentially for the asset owners to aid them in understanding the HAC concepts and how to prepare appropriate and helpful data for the plant designers, determine the expected deliverables from the designer (HAC drawings, HAC schedule, ...etc.,), and how to review and interpret the deliverables of the detailed design and engineering that developed by any electrical engineering discipline, and to use these data in the selection, inspection, and maintenance of the classified electrical equipment. The basis for the correct selection of fixed electrical equipment and the location of other ignition sources in those areas was described in the annexes.

2. Purpose

The main purpose of this guideline is to set out the essential criteria for classifying locations at petroleum facilities installation, both temporary and permanent, in which explosive atmospheres exist under normal atmospheric conditions. This will allow the proper selection and installation of electrical apparatus for use in a hazardous area. As well as guide the companies that assign the work of classifying hazardous areas to an external contractor/ expert to explain what documents must be provided to the contractors / external experts and the deliverables expected from them. Additionally, this guideline has also been prepared to achieve the following objectives:

- To define all alternatives for hazardous area classification purposes.
- To maintain safety requirements of the Ministry of Petroleum and Mineral Resources (MOP) to protect personnel, plant, and property from explosion hazards due to installing unclassified electrical installations in hazardous areas, i.e., maximize the safety of electrical equipment installed in potentially explosive atmospheres.
- To minimize the risk of accidents by adopting safe and sound engineering practices in the oil and gas industry.

Area classification aims to avoid ignition of those releases that may occur from time to time in the normal operation of facilities handling flammable fluids. The approach is to reduce the probability of coincidence of an explosive atmosphere and electrical or other sources of ignition. It is not the aim of area classification to prevent the ignition of major accidental releases of flammable materials that could extend to large distances from the release source. These larger accidental releases, which may result from major or catastrophic failure of process or storage equipment, should be dealt with by risk assessment and other procedures or processes, including relevant legislation requirements.

This guideline aims to provide comprehensive information for guidance in the classification of areas and to set out principles, definitions, and explanations of terms used for area classifications throughout COMPANIES' facilities. This guideline is a formal directive from the ENTITIES for use throughout all COMPANIES.

3. Scope

The guideline is intended to apply to all upstream, midstream, and downstream facilities and installations in processing, distribution, and drilling & production sites of the oil, gas and petrochemicals sector. This guideline does not apply to the classification of locations containing combustible dust or ignitable fibers or flyings.

This document stipulates the guided requirements applicable to the ENTITIES and their operational subsidiaries, state-owned companies, affiliates, and joint ventures. ENTITIES and their COMPANIES and contractors could ensure that all requirements listed herein are fully understood, implemented, complied with, and always monitored, including current facilities and existing and future projects during the whole project's lifecycle from feasibility to decommissioning.

4. Definitions

ADEQUATE VENTILATION: This is ventilation, natural, artificial, or a combination of both, sufficient to avoid the persistence of flammable atmospheres within enclosed areas but insufficient to avoid their initial formation and spread throughout the area.

AREA CLASSIFICATION: The division of a facility into hazardous and non-hazardous areas and the subdivision of hazardous areas into zones.

ATMOSPHERE EXPLOSIVE (ATEX): Used to directives 94/9/2014/34/EU and 1999/92/EC (known as ATEX 95 and ATEX137, respectively). Directive 94/9 establishing a single market for equipment used in potentially explosive atmospheres. Directive 1999/92 concerns common health and safety standards at places where explosive atmospheres may form. It establishes minimum requirements for the protection of workers, specifically requires areas to be classified where explosive atmospheres may form and provides a legal definition of the zones.

AUTO-IGNITION TEMPERATURE (AIT): See ignition temperature; also synonymous with spontaneous ignition temperature (SIT).

BLACK HEAT-TYPE HEATING: Black heat-type heating equipment is where the external radiant or convection heating surface operates at a temperature not exceeding 200 °C and has no internal ignition source.

BONDING: Provision of a low-resistance electrical conductor between plant sections, equipment, or structures.

CERTIFICATION: A procedure by which a third party gives written assurance that a product, process, or service conforms to specified requirements.

CLASS OF PETROLEUM LIQUIDS: System of classification of petroleum liquids, including crude oil and its products, into Classes 0, I, II (1), II (2), III (1), III (2), and unclassified based upon their flashpoints.

CLASS I LOCATION: A location in which flammable gases or vapors may be present in the air in quantities sufficient to produce an explosive or ignitable mixture.

CLASS II LOCATION: A location in which combustible dust is or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. Class II locations are not considered in this Guideline.

CLASS III LOCATION: A location where easily ignitable fibers may be present in the air. Class III locations are not considered in this Guideline.

CLASS I, ZONE 0 LOCATION: A location in which ignitable concentrations of flammable gases or vapors are present continuously or in which ignitable concentrations of flammable gases or vapors are present for long periods.

CLASS I, ZONE 1 LOCATION: A location in which ignitable concentrations of flammable gases or vapors are likely to exist under normal operating conditions, or in which ignitable concentrations of flammable gases or vapors may frequently exist because of repair or maintenance operations or because of leakage, or in which equipment is operated or processes are carried on that are of such a nature that equipment breakdown or faulty operations could result in the release of ignitable concentrations of flammable gases or vapors and could also cause simultaneous failure of electrical equipment in a mode so to cause the electrical equipment to become a source of ignition, or that is adjacent to a Class I, Zone 0 location from which ignitable concentrations of vapors could be communicated unless the communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided.

CLASS I, ZONE 2 / A CLASS I, ZONE 2 LOCATION: A location in which ignitable concentrations of flammable gases or vapors are not likely to occur in normal operation and, if they do occur, will exist only for a short period; or in which volatile flammable liquids (see definition of HVLs) or flammable vapors are handled, processed, or used, but in which the liquids, gases, or vapors normally are confined within closed containers of closed systems from which they can escape only because of accidental rupture or breakdown of the containers or as the result of the abnormal operation of the equipment with which the liquids or gases are handled/ processed/ used; or in which ignitable concentrations of flammable gases or vapors normally are prevented by positive mechanical ventilation but which may become hazardous because of failure or abnormal operation of the ventilation equipment; or a location adjacent to a Class I, Zone 1 location, from which ignitable concentrations of flammable gases or vapors could be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure is provided.

CLASS I LIQUIDS: Liquids have flashpoints below 100 °F (37.8 °C). Flammable (Class I) liquids are subdivided into Classes IA, “liquids that have flash points below 73 °F (22.8 °C) and boiling points below 100 °F (37.8 °C)”, Classes IB, “liquids that have flash points below 73 °F (22.8 °C) and boiling points at or above 100 °F (37.8 °C)”, and Classes IC “liquids that have flashpoints at or above 73 °F (22.8 °C), but below 100 °F (37.8 °C)”.

CLASS II LIQUIDS: Liquids have flashpoints at or above 100 °F (37.8 °C) and below 140 °F (60 °C).

CLASS IIIA LIQUIDS: Liquids have flashpoints at or above 140 °F (60 °C) and below 200 °F (93 °C).

CLASS IIIB LIQUIDS: Liquids have flashpoints at or above 200 °F (93 °C).

COMPANY: Refers to any operating company, subsidiary, affiliated, or joint venture companies belonging to an ENTITY.

CONFINED: An area around a potential release location that, due to large obstructions (e.g., walls), gives rise to local dispersion behavior approaching that of a semi-enclosed area.

CONGESTED: A congested leak location is one where a significant number of small-scale obstacles compromise the ventilation flow rate through that area.

CONTINUOUS GRADE RELEASE: A release that is continuous or nearly so.

DILUTION VENTILATION: Artificial ventilation is sufficient to maintain, generally as non-hazardous, an enclosed area containing a source of release or an aperture into a hazardous area.

DRY BREAK COUPLING: A hose coupling is designed to minimize liquid leakage when the hose is disconnected. Each half of the coupling contains a valve that closes when the latches holding the halves together are released.

ENCLOSED AREA: Any room, building, or space has a three-dimensional space enclosed by more than two-thirds (2/3) of the possible projected plane surface area and sufficient size to allow personnel entry. For a typical building, this would require that more than two-thirds (2/3) of the walls, ceiling, and floor be present.

ENTITIES: Refers to the Egyptian General Petroleum Corporation (EGPC) and Oil and Gas Holding Companies, including the Egyptian Natural Gas Holding Company (EGAS), the Egyptian Petrochemicals Holding Company (ECHEM), and the South Valley Petroleum Holding Company (GANOPE).

FIRE RESISTANT: A term used to denote a defined standard of resistance to fire exposure.

FLAME ARRESTER: A device to prevent the backpropagation of flame. It can take the form of perforated plates, fine slots in metal blocks, wire mesh gauzes, crimped metal, or bunches of narrow metal tubes.

FLAMMABLE: Refers to any substance, solid, liquid, gas, or vapor, easily ignited. Adding the prefix 'non' indicates that the substances are not readily ignited but does not necessarily indicate that they are non-combustible. Any liquid is classified as flammable if it has a closed-cup flash point below 37.8°C (100°F), as determined by the test procedures and apparatus outlined in Section 4.4 of NFPA 30.

FLAMMABLE ATMOSPHERE: A mixture of flammable gases or vapors with air in such a proportion that it will burn when ignited.

FLAMMABLE LIMITS (OR RANGE): The lower and upper percentages by volume of gas concentration in agas–air mixture will form an ignitable mixture [1]. The upper limit is typically expressed as UFL or UEL, and the lower limit is expressed as LFL or LEL.

FLASHPOINT: The lowest temperature, corrected to a barometric pressure of 101.3 kPa, at which the application of a source of ignition causes the vapor of the test portion to ignite, and the flame propagates across the surface of the liquid under a specified condition of the test.

FLUID CATEGORIES: A categorization for area classification of flammable petroleum fluids by the point source method according to their potential for rapid production of flammable vapor on release to the environment. Four fluid categories are defined

GAS-FREE: A tank is considered gas-free when the flammable gases or vapor concentration is within safe prescribed limits. Gas-free does not imply the absence of toxic gases or oxygen sufficiency for vessel entry.

GROUP I: A term used to describe atmospheres containing firedamp (a mixture of gases, composed mostly of methane, found underground, usually in mines).

GROUP II: The group used to describe gases found aboveground is subdivided into IIA, IIB, and IIC.

GROUP IIA: Atmospheres containing acetone, ammonia, ethyl alcohol, gasoline, methane, propane, flammable gas, flammable liquid-produced vapor, or combustible liquid-produced vapor mixed with air that may burn or explode having either a maximum experimental safe gap (MESG) value greater than 0.90 mm (35 mils) or a minimum igniting current ratio (MIC ratio) greater than 0.80.

GROUP IIB: Atmospheres containing acetaldehyde, ethylene, or flammable gas, flammable liquid-produced vapor, or combustible liquid-produced vapor mixed with air that may burn or explode having either an MESG value > 0.50 mm (20 mils) and ≤ 0.90 mm (35 mils) or a MIC ratio > 0.45 and ≤ 0.80.

GROUP IIC: Atmospheres containing acetylene, hydrogen, flammable gas, liquid-produced vapor, or combustible liquid-produced vapor mixed with air that may burn or explode, having either an MESG value ≤ 0.50 mm (20 mils) or a MIC ratio ≤ 0.45.

HAZARDOUS AREA AND ZONE: A three-dimensional space in which a flammable atmosphere is or may be expected to be present in such frequencies as to require special precautions for constructing and using electrical apparatus. All other areas are referred to as non-hazardous in this context. In a hazardous area, three types of zones are recognized.

HAZARDOUS ATMOSPHERE: An atmosphere containing flammable gas/vapor in a concentration capable of ignition. (The term is synonymous with a flammable atmosphere and refers exclusively to hazards arising from the ignition. This is specifically mentioned when there is a hazard from other causes such as toxicity, asphyxiation, or radioactivity.)

HAZARD RADIUS: The source generates the largest horizontal extent of the hazardous area, independent of ground effects when situated in an open area under unrestricted natural ventilation. This is the distance the concentration of flammable vapor in the air has fallen to the lower flammable limit.

HIGHLY VOLATILE LIQUIDS (HVLs): Liquids with vapor pressures of more than 40 psia at 100 °F, such as butane, ethane, ethylene, propane, propylene, liquefied natural gas, natural gas liquids, and similar mixtures. Highly volatile liquids vaporize at low temperatures (have low flash points). When released into the atmosphere, these liquids vaporize—creating large volumes of cooled gases whose densities exceed that of air. HVLs should be treated conservatively considering the extent of the area affected, especially when released at or near ground level. Under such conditions, the heavy gases can travel along the ground for great distances if air currents do not assist dispersion. When HVLs are released at higher elevations or are directed upward at substantial velocity, diffusion and dilution of the upper-air mixture are faster, and the distance from the point of release where lower flammable limit (LFL) concentrations are present is less.

IGNITION TEMPERATURE: The ignition temperature of a flammable substance is the minimum temperature at which the material will ignite and sustain combustion. This is also known as auto ignition temperature (AIT).

INADEQUATE VENTILATION: Ventilation, natural or artificial, is insufficient to avoid the persistence of a flammable atmosphere within enclosed areas.

INCENTIVE SPARK: A spark of sufficient temperature/energy to ignite a flammable gas.

INTRINSICALLY SAFE: An intrinsically safe electrical circuit is one in which any sparking that may occur, under the conditions specified by the certifying authority and with the prescribed components, is incapable of causing ignition of the prescribed flammable gas or vapor.

LOCAL ARTIFICIAL VENTILATION: Air movement and replacement with fresh air by artificial means applied to a particular source of release or a local area within a more general area.

LOCAL EXHAUST VENTILATION (LEV): Either small-scale dilution ventilation (use of extractors etc.) or an enhancement of flow in obstructed areas to attain adequate ventilation.

LOWER EXPLOSIVE /FLAMMABLE LIMIT (LEL / LFL): The lowest concentration of flammable gas or vapor in air at atmospheric pressure can be ignited. That is expressed as a percentage by volume.

MAXIMUM EXPERIMENTAL SAFE GAP (MESG): It is a standardized measurement of how easily a gas flame will pass through a narrow gap bordered by heat-absorbing metal. MESG is used to classify flammable gases for designing and selecting electrical equipment in hazardous areas. The hazardous locations are classified into different groups depending on the respective MESGs of gases in the area.

MINIMUM IGNITING CURRENT RATIO (MIC RATIO): The ratio of the minimum current required from an inductive spark discharge to ignite the most easily ignitable mixture of a gas or vapor is divided by the minimum current required from an inductive spark discharge to ignite methane under the same test conditions.

MOBILE EQUIPMENT: Equipment mounted on its wheels or tracks or having some other facility for mobility.

NON-HAZARDOUS AREA: An area in which flammable atmospheres are not expected to be present so that special precautions for the construction and use of electrical apparatus or the control of non-electrical sources of ignition are not required.

OPEN AREA: An area in an open-air situation where vapor is readily dispersed by wind. Typically, air velocities will rarely be less than 0.5 m/s and frequently be >2 m/s.

OVERPRESSURE VENTILATION: Artificial ventilation of an enclosed area maintains the area at a controlled pressure above the ambient pressure.

PRIMARY GRADE RELEASE: A release that is likely to occur in normal operation.

SECONDARY GRADE RELEASE: A release unlikely to occur in normal operation and, in any event, will be of short duration.

SOURCE AND GRADE OF RELEASE: For hazardous area classification, a point from which a flammable gas, vapor, or liquid may be released into the atmosphere. Three grades of release are defined in terms of their frequency and duration.

STAGNANT AREA: A region where the degree of congestion is such that air velocities will always be below 0.5 m/s.

Temperature class (T class): One of six temperature values allocated to the electrical apparatus is derived from a system of classification according to the maximum surface temperature of the apparatus.

UNCLASSIFIED AREA: An unclassified area is an area that is not classified as Zone O, Zone 1, or Zone 2. "Unclassified Area" may not necessarily be considered "safe. " A good engineering judgment should be exercised to assess the hazard before using standard industrial electrical apparatus, conventional turbines, unprotected fired heaters, etc.

UPPER EXPLOSIVE /FLAMMABLE LIMIT (UEL / UFL): The concentration of flammable gas or vapor in air at atmospheric pressure above which combustion will not occur.

VENTILATION: A general term to indicate air movement and replacement by fresh air. Natural ventilation refers to ventilation caused by wind or convection effects. Artificial ventilation is caused by air purges or mechanical means, e.g., fans.

WORK PERMIT: A document issued by an authorized person to permit work to be carried out safely in a defined area under specified conditions.

ZONE 0: That part of a hazardous area in which a flammable atmosphere is present for long periods (typically more than 1000 hrs/year).

ZONE 1: That part of a hazardous area in which a flammable atmosphere is likely to occur in normal operation (typically 10 to 1000 hrs/year).

ZONE 2: That part of a hazardous area in which a flammable atmosphere is not likely to occur in normal operation and, if it occurs, will exist only for a short period (typically less than 10 hrs/year).

5. Abbreviations

ACGIH	American Conference of Government Industrial Hygienists.
BOP	Blow Out Preventer.
EPSR	European Pillar of Social Rights
EU	European Union
LFL	Lower Flammable Limit
LPG	Liquified Petroleum Gas
MESG	Maximum Experimental Safe Gap
MIC	Minimum Igniting Current
MOP	Egyptian Ministry of Petroleum and Mineral Resources
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PPM	Parts Per Million
SCF	Standard Cubic Foot
SOH	Source of Hazard
TLV	Threshold Limit Value
TPEF	Technical Person with Executive Function
TWA	Time Weighted Average
UFL	Upper Flammable Limit
UPS	Uninterruptible Power Supply

For other definitions and abbreviations, refer to the PSM Glossary of Definitions and Abbreviations Guideline (EGPC-PSM-GL-011).

6. Basics of the Hazardous Area Classification

An explosion is a sudden reaction involving rapid physical or chemical decay accompanied by an increase in temperature, pressure, or both. This typically exists in chemical plants, refineries, tanks, loading facilities for flammable gases, and vapors of flammable & combustible liquids. It is a fact that gases, vapors, and mists escape during the production, processing, transportation, and storage of flammable substances in the petroleum, chemical, and petrochemical industries, as well as in the processing of natural gas and many other sectors. These flammable substances form an explosive atmosphere with oxygen in the air. If this atmosphere is ignited, explosions can severely harm human life and property. Protective standards have been developed in most countries to avoid the danger of explosions to ensure that a high level of safety is observed. These requirements include removing one side of the ignition triangle to provide explosion protection, i.e., inhibiting the ignition of a potentially explosive atmosphere can eliminate danger at the source.

Selecting electrical installations aims to reduce the hazard to an acceptable level. The most certain method of preventing an explosion is locating electrical equipment outside hazardous (classified) areas whenever possible. In situations where this is not practical, installation techniques and enclosures are available that meet the requirements for locating electrical equipment in such areas.

Area classification is the assessed division of a facility into hazardous and non-hazardous areas (see definitions) and the subdivision of the hazardous areas into zones. All other areas are non-hazardous in this context, though they may, in part or whole, form part of a wider restricted area within the facility where all work is carried out under special controls. Hazardous areas are divided into four zones based on the likelihood of occurrence and duration of a flammable atmosphere. Zone 0, Zone 1, Zone 2, and non-hazardous areas (see definitions).

Hazardous area classification is a rigorous method of determining where an explosive environment may exist. In general, hazardous areas are defined by:

- The type of hazard or hazardous material.
- The likelihood of its presence in flammable concentration.
- The auto-ignition temperature of the hazardous material.

An explosive atmosphere can be created by gas, vapor, dust, or even fibers. The probability that any hazard exists in combustible concentration is determined by the specifics of the plant or system under consideration. For example, a natural gas vent line is much more likely to contain such a hazard than a lube oil line—unless the oil line’s flanged joint is leaky.

Also, plant design must protect against the auto-ignition of combustible substances. A good example of this type of hazard is a flammable gas encountering a hot surface. Codes define various temperature classes to guide designers as they specify equipment.

Hazardous (classified) areas are those where fire or explosion hazards may exist due to flammable gases, vapors, and liquids. Hazardous area classification (HAC) determines the existence and extent of hazardous locations in a facility containing substances. The result of the process is usually called the HAC of the facility. In the context of electrical equipment, the following terms: hazardous area classification, hazardous locations, hazardous (classified) locations, and classified areas are synonymous with HAC. Hazardous area classifications explain how to select and install electrical equipment and wiring to minimize the likelihood of igniting a flammable or explosive mixture.

For a fire or explosion to occur, all three of the following statements must be true:

- The flammable or combustible material is present.
- The material is mixed with air in the proportions required to produce an ignitable mixture.
- There is sufficient energy to ignite the mixture.

The above conditions constitute the well-known "fire triangle." In the context of HAC, the source of energy is understood to be the facility's electrical system.

Notes:

- For further explanation of the hazardous area classification basics, see Annexes C, D, and E.
- Although there is some information in the annexes regarding the IEC (zoning concept), NEC, and API 500 (division concept), this guideline adopts what is mentioned in API 505 and EI 15. This information is intended to educate operators with the knowledge needed to interpret the documents they may already have on the hazardous area classification, which have been prepared under either of the two approaches.

7. Steps of the Hazardous Area Classification

The first step of the HAC is to assemble a team (the team here isn't the designing team) with a fundamental understanding of the facility's operational areas, electrical equipment, processes, and maintenance requirements. The team then collects the required data for developing Hazardous Area Classification. This step compiles the appropriate flammability data for the hazardous materials of interest. For example, flashpoints (liquids), minimum ignition energy (MIE), minimum ignition temperature (MIT), gas or vapor density, auto-ignition temperature (AIT), minimum igniting current (MIC) and maximum experimental safe gap (MESG). The required data also includes brief descriptions of the process and its operations & maintenance (O&M) manuals and cleaning details, process flow diagrams (PFD), piping and instrumentation diagrams (P&ID), layout drawings with typical plans and elevations showing the position of all equipment, including operational vents/drain...etc., sources of ignition such as heaters/ roadways/ flares/ workshops/ hot work areas ... etc., knowledge of the equipment features and the mode of operation, and ventilation details, considering whether open, congested, stagnant or enclosed areas.

Then, the team identifies potential sources of liquid, vapor, gas, and any flammable or explosive material releases in both normal and abnormal conditions, estimate the duration of leaks or releases and determines if there is an ignitable mixture likely to occur during any release or leakage because of repairs or maintenance.

The designer receives the required data, and a site visit may be required. Then, in addition to reviewing building and equipment layout drawings, the designer reviews the identification of the potential release sources, estimates the grade of release, evaluates the ventilation effectiveness, applies the proper guidelines (such as API 505, EI 15,..etc.) to assign a class, zone rating to the areas under investigation, including the size of the area covered. Then, the designer should prepare hazardous area classification schedules and drawings that include detailed design and engineering information.

The last step in the HAC is documentation. It is an essential component of HAC. This documented information must include ratings of equipment used in the hazardous areas. All HAC steps are illustrated in Figure 1.

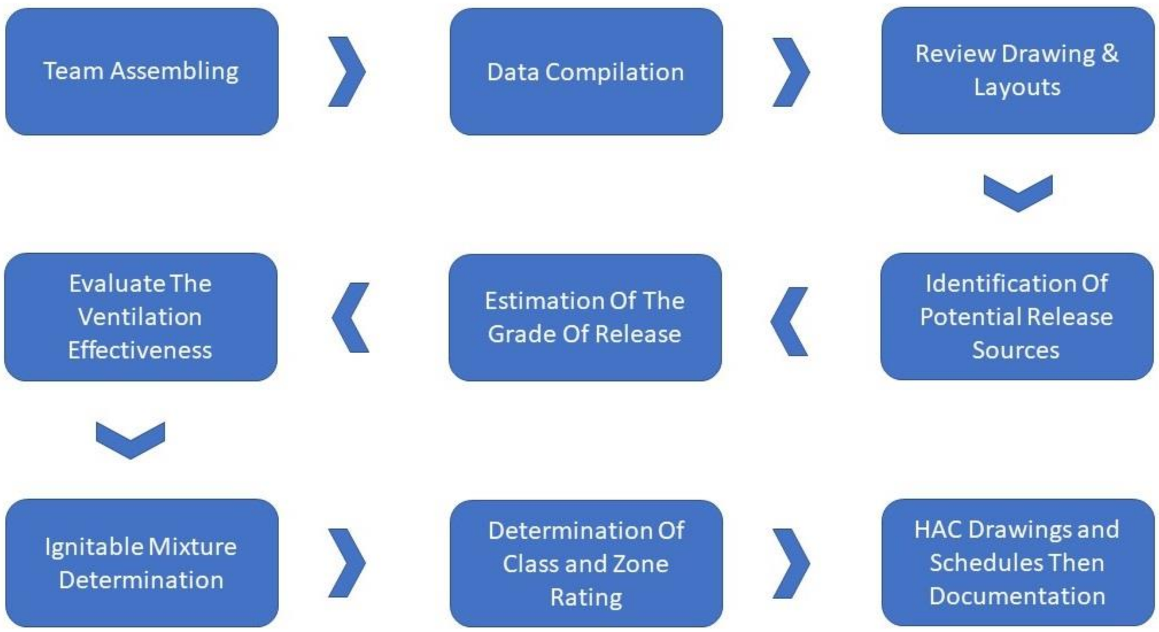

Figure 1. *Steps of the Hazardous Area Classification.*

8. The Approaches to Hazardous Area Classification

This guideline briefly presents methodologies to be used in hazardous area classification. It gives some advice on selecting the appropriate approach to use:

- The first and most used approach is *The Direct Example Approach*, which can be used in limited cases for common facilities.
- Suppose the direct examples (such as those stated in the references e.g., API RP 505, and EI 15 Annex D) do not match the design of the site's equipment or the surrounding working environment, and the release hole size and grade release rate are known. In that case, *The Point Sources Approach* can be used.
- Where the release hole size and/or grade release rate is unknown, *The Risk-Based Approach* can be used to calculate the release rate and hazard radii.

8.1 The Direct Example Approach

The Direct Example Approach can be used as the basis for the classification of those oil and gas industry operations that are carried out in an open area, unless otherwise noted, in facilities similar in layout and material handled so that they can be classified directly from typical examples. This approach should only be applied when the facility under consideration does not differ significantly from the direct example in terms of layout, type of equipment, class of flammable fluid, or the pertinent temperature, pressure, or ventilation state.

The direct examples in API RP 505 (Chapters 6 to 14), NFPA 820 (Annex A), and EI 15 (Annex D) are based on engineering judgment. However, the notes associated with the diagrams should always be reviewed, and, where necessary, consideration is given to any circumstances departing from these general design criteria. The distances shown may be modified by using The Point Source Approach.

Notes:

- The hazardous area zone dimensions are based on the maximum ambient temperature. A maximum ambient temperature has been assumed in the relevant standards diagrams (such as EI 15 and API 505) to be around 30 °C. In Egypt, the designer must assume the maximum temperatures range in the coastal regions is an average of 30°C. Still, it varies widely in the inland desert areas, where they reach 45°C during the summer day. For products handled above a temperature of 30 °C, the extent of the hazardous area may be greater than the recommendations given in this approach. In more pronounced cases, e.g., high vapor pressure condensates, very light hydrocarbon petrochemical feedstock, or blending components, the appropriate fluid category should be used, and The Point Source Approach should be adopted.

- NFPA 820 (Annex A) defines the direct example drawings for hazardous area classification of sanitary sewage sumps and wastewater treatment and collection facilities. It is important to note that NFPA 820 covers “Pumping Stations, " a broad term inclusive of most wastewater pump systems. For this reason, NFPA 820 is pertinent in all in-ground wastewater pumping systems.

8.2 The Point Source Approach

For installations or processes due to variabilities of temperature, pressure, equipment, and the degree and type of ventilation, the extent of flammable release that would occur may vary greatly, making individual assessment necessary. This is known as the “Point Source Approach. Developing area classification boundaries using the “Point Source” concept involves creating the classified area boundaries for all individual potential sources and then superimposing all of the boundaries created by the individual point sources to develop a composite classified area boundary for all sources combined.

The Point Source Approach for area classification in some cases is preferred. When flammable fluids are handled under pressure and at a temperature below their flash point, they may form a flammable mist. In this case, fluid that can be released onto a hot surface, such as a steam pipe or engine exhaust, may form a flammable vapor.

When flammable fluids are handled under pressure or the release of gas or vapor under pressure, it may substantially alter the outline of the limits of the classified location. Also, low-velocity movement (e.g., movement caused by a mild breeze) may extend these limits in the direction of air movement. However, higher velocity air movement (e.g., a stronger breeze) can so accelerate the dispersion of gases or vapors that the extent of the classified location would be greatly reduced. The nature of the release (that is, whether it is a high-pressure spray-type mist or a low-velocity stream or drip) also significantly impacts the extent of the classified location. Thus, dimensional limits recommended for Zone 0, Zone 1, and Zone 2 locations are based on experience and theoretical diffusion of gases or vapors of the types prevalent in petroleum operations. Several techniques are available to analyze gas and vapor dispersion, including specific plant experience and computer simulation programs. These techniques may be used with good engineering judgment to modify standard area classification boundaries for specific applications.

Flammable fluids that have flash points >100 °C, such as Class III (2) liquids, may substantially alter the outline of the limits of their classification zones when they are handled in temperature over their flash point.

If Direct Examples Approach of area classification of common facilities in open areas (which are provided in API RP 505 and EI - Part 15 Annex D) are being used, these should be supplemented using the Point Source Approach, where appropriate, for equipment not specifically covered by the direct example approach.

The point Source methodology involves the identification of the point sources and associated release conditions, determination of the grade of release, determination of the fluid category, establishment of the zone classification, determination of the hazard radii, determination of the hazardous area, and combination of the hazardous areas from different point sources. To determine a hazardous area classification:

1. Assemble pertinent information, including codes, standards, practices, and references; process and operating descriptions; process flow diagrams and material and heat balance chart; piping and instrumentation diagrams; equipment arrangement drawings and plot plans; and commissioning, testing, operating, and safety procedures.
2. List all flammable and combustible materials and their pertinent properties, such as ignition temperatures and flashpoints.
3. Locate material release sources, such as open process points, control valves, pump seals, drains, metering points, sampling points, and vents.
4. Determine an area's Class and Group from the chemicals present.
5. Determine the degree of hazard (Zone 0, 1, or 2) by assessing the likelihood/ probability of the presence of flammable and combustible materials.
6. Review the plant's equipment layout drawings and determine the extent (or distance from the source) of hazardous areas.
7. Consider using recognizable boundaries (walls, floors, ceilings, and column lines) to delineate Classified Areas. This approach will greatly simplify both design and installation.

For more information about The Point Source methodology, refer to API 505 Annex D and EI Model Code of Safe Practice - Part 15 – Chapter (3).

8.3 The Risk-Based Approach

For systems where the release rate (hole size and pressure) is unknown, unspecified, and with variable quantity, a risk-based approach may be used as outlined in the EI Model Code of Safe Practice - Part 15 - Annex C Part 2. The Risk-Based Approach provides a means of adjusting release frequency and hazard radii to fit specific process scenarios. It is proposed to determine the hole size for a secondary grade release. A secondary grade release, as defined before, would not be anticipated to occur during normal operation. Examples include pump/compressor seal failure, leaks from valves and flanges, or operational errors. A competent person should carry out this process via credible and certified simulation modelling software.

9. Hazardous Area Classification for Special Type Building

9.1 Laboratories

Laboratories are usually considered general-purpose area electrical classification due to their limited flammable and combustible liquids, high ventilation rates, and closed systems. NFPA 45 (Fire Protection for Laboratories Using Chemicals) states in section 5.5.2 that: “Laboratory work areas, laboratory units, and chemical fume hood interiors shall be considered unclassified electrically concerning Article 500 of NFPA 70 unless operations are determined to cause a hazardous atmosphere."

It goes on to state in the annex A.5.5.2 that: “A qualified design professional and owner safety officer should review the laboratory conditions through hazard analysis and/or risk assessment to determine if a hazardous (ignitable) atmosphere could be developed within the laboratory work area, laboratory unit, and/or fume hood. If a hazardous atmosphere could be developed, these areas should be electrically classified per NFPA 70, Articles 500-505.”

Every laboratory should be subjected to a hazard analysis and risk assessment, at least warranting the potential for requiring a higher area electrical classification. The issues that must be considered in this risk assessment, as examples are:

- If the lab is a pilot plant, we cannot apply NFPA 45. Many pilot plants handle flammable or combustible materials, even in normally closed systems.
- The area outside a hood or specialty-design ventilated enclosures should be electrically classified.
- When a technician needs to do a small open transfer in a laboratory with limited hood space. The flammable or combustible gas or vapor released during this transfer could easily contact the electrical heater, which is usually over the autoignition temperature of most materials, even at lower oven temperatures.
- The heating glass tubes with flammable gases, which, if they break, can lead to a fire or explosion inside the furnace, mixing flammable liquids or combustible liquids heated to above their flash point in an open container with an electric mixer too close to the liquid surface.
- Some types of instrumentation use very small internal gas flames and, in principle, could ignite any surrounding explosive atmosphere if, for instance, there was a release of vapor from some operation nearby. In addition, an explosive atmosphere could form from a leak in the fuel line to the flame or some cases, from flammable liquids in the instrument. Such instrumentation needs specific consideration in the risk assessment. If the maximum leak size is very small, any release will form an explosive atmosphere of a negligible extent.

Precautions in these risk assessments are likely to include good handling techniques to minimize spills, sills or other liquid retaining methods to minimize liquid spread, proper support for glass equipment, placing electrical equipment where it will not be splashed because of a spill as far as practicable. Constant supervision by trained staff so electrical equipment can be rapidly isolated, others warned of any dangers, and if safe to do so, first aid fire fighting started. Most importantly, the risk that a fire following a spill will rapidly involve other containers of flammable liquids or other dangerous chemicals should be considered. Any necessary improvements to the storage arrangements for such chemicals should then be implemented. Where these and similar precautions have been adopted, the risk assessment may conclude that there is no need for hazardous areas to be specified.

9.2 Battery Rooms

A battery room intended to accommodate the electrical batteries being charged is a potentially dangerous area. Indeed, charging the battery (particularly those made from lead-acid) releases a dangerous gas (hydrogen). So, the hazardous area classification of a battery room is required due to the potential presence of hydrogen gas (Group B).

These batteries are usually recharged in reserved areas or ordinary indoor places. Of course, during the charging operation, they emit a certain quantity of gas (hydrogen and oxygen). These places must be classified per standards for categorizing hazardous areas with the presence of gas. Batteries' lifetime and their gas emission depend on the recharge method. Valve Regulated Lead Acid batteries, defined in many ways on the commercial documentation (recombination, sealed, airtight, maintenance-free), are regulated with valves.

All the batteries emit a certain quantity of gas, and there’s a difference in emission depending on the battery construction. However, there’s a difference in the emission frequency depending on the intended use of the battery, and it discharged and recharged periodically and, hence, produces a gas emission rate.

During recharge, a battery emits a certain quantity of gas (hydrogen and oxygen). The amount of gas emitted is very variable and depends on the following:

- The type of cell (Lead, Nickel-Cadmium).
- Construction technology (valve-regulated battery or open cup).
- Profile of charging.
- Charging stage.

Gas emission depends on the charging current; therefore, it’s greater during a boost charge than the float charge. A certain emission of gases is also present during the equalized charge. A risk assessment should be performed to answer the key questions that are presented to determine the hazardous area classification of a battery room's interior and exterior.

Consequently, electrical equipment installed in battery rooms should be Zone 1 or Zone 2 certified according to all standards regarding safe electrical installation in potentially explosive atmospheres.

The gas emissions for each battery cell are regulated by valves spread from the safety valve forming around the valve itself, a potentially dangerous zone. To understand the extension of this area, refer to the following:

- EN 50272-2 standard is relevant to stationary batteries. It depicts a method for the calculation of classified area extension. The extension is usually of some decimetres, based on hypothetical explosive volume.
- EN 50272-3 relevant to traction batteries. It indicates, conventionally, an extension of the area of 0.5 m.

These assessments take account of any malfunction of the charging system or battery cells. These two standards are useful, along with other standards (such as API/EI/IEC/EN 60079-10 ..etc.), to classify exactly the danger zone.

10. Effect of Ventilation on Area Classification

10.1 General

Ventilation comprises the movement of air within and through a volume to introduce fresh air (fresh air implies being free from flammable contaminants) into and removal of contaminated air from the volume and the mixing of air and contaminants within the volume. Gas or vapor released into the atmosphere will eventually be diluted by dispersion in free air until its concentration is at a safe limit (below the lower flammable limit (LFL)).

With increased ventilation, the extent of the zone will normally be reduced. Obstacles that impede ventilation may increase the extent of the zone. On the other hand, some obstacles, for example, dikes, walls, or ceilings, may limit the extent. A compressor shelter with a large roof ventilator and the sides open sufficiently to allow free air through all parts of the building is considered well-ventilated. It should be treated as an outdoor area (i.e., "medium" degree and "good" availability).

The time is taken for this to occur, and the size and spatial location of the gas cloud depend upon the nature of the release, the vapor properties such as density relative to the air, the movement of the air, and the presence of turbulence to promote mixing. Where the release is not into completely free air (i.e., not into an open area), then the airflow, or ventilation, is also a factor in determining the gas or vapor dispersion rate. However, it is important also to consider whether any recirculating motions may lead to a gradual accumulation of gas or vapor over time in a sheltered or obstructed open or enclosed area.

The processes of movement of air and removal of contaminated air occur, to differing degrees, in any ventilation process. The limiting cases are:

- Efficient displacement without mixing: Here a contaminant is swept out of a volume without much mixing. This is sometimes referred to as 'displacement ventilation. By inference, high contaminant concentrations may exist within the volume and be emitted from it.
- Gradual displacement with good mixing: Here any contaminant is well-mixed through the volume. A large part or all the volume can become contaminated, while displacement removes the mixture of air and contaminant. A special case of this is sometimes referred to as dilution ventilation.

A single parameter typically quantifies the ventilation of an enclosed space – the number of air volume changes per hour. However, ventilation is a complex subject. In carrying out an assessment, it is necessary to consider both the type (natural or artificial) of ventilation and, within the type, the degree of ventilation to be provided, its reliability, and the consequences of its failure. These considerations need to consider the potential size of the release and the affected volume, which may be a subdivision of a larger volume, for example, a bay in a large warehouse.

The main disadvantage of using a method based on the number of air changes per hour is that the requirement is unrelated to the release size. Therefore, the same level of ventilation is required for an enclosure containing potentially large releases as for one that may contain very small releases. Also, a definition of adequate ventilation in terms of an air change rate will require huge volumes of air to be moved to achieve the criterion in large enclosures. However, in practice, the dispersion of small releases relative to the enclosure's size will behave similarly to a release outdoors. Therefore, the air change rate is not critical to the gas dispersion.

It shows that providing sufficient ventilation to limit the average concentration to 25 % LFL for a specified release in an enclosed area generally achieves the objective of adequate ventilation for Zone 2. Although this demonstrates that the overall level of ventilation is sufficient, it does not demonstrate that the local ventilation is adequate. It is the local ventilation effectiveness that will determine how the release disperses. Therefore, the 25 % LFL criterion must be a minimum requirement, as other factors need to be considered. If such a criterion is only just met, then further effort may be required to ensure adequate ventilation local to the release point.

While using the 25 % LFL criterion does achieve this objective, large gas clouds may still occur, particularly in large enclosures. In these cases, consideration should be given to measures to reduce the potential leak size, e.g., the use of alternative equipment or improved maintenance regimes. This guideline provides a general concept about ventilation issues and their relationship to HAC in this section.

For further background information on ventilation and its effect on the area classification in areas containing sources of release, examples on how to determine adequate ventilation rates, and other detailed information, see EI Model Code of Safe Practice - Part 15 - Chapter 4 and Annex F, and API RP 505- Chapter 6.6, Annex A, and Annex B. Figure 2 can also be used to determine how to assess the degree of ventilation for any given situation.

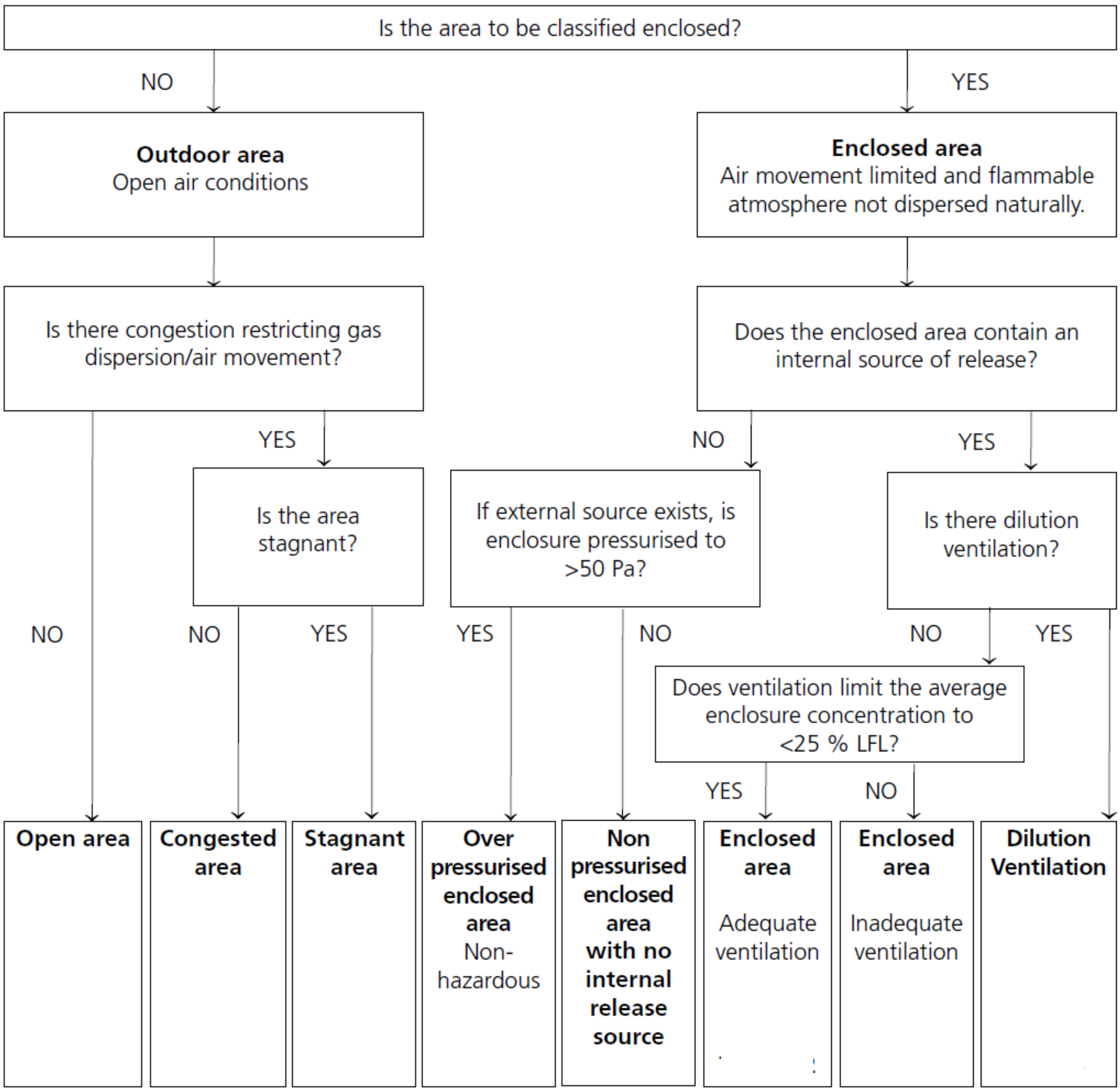

Figure 2. *Procedure for assessing type and degree of ventilation* [2].

10.2 Ventilation Conditions in Battery Rooms

As for any dangerous area, its extension also depends on ventilation conditions, and it will be minor in the external environment compared to the internal environment. Concerning this aspect, it’s necessary to underline that in environments where the batteries are recharged, you must still provide good room ventilation. The ventilation systems of battery rooms can be realized with artificial ventilation or natural ventilation.

A good solution is to realize a system of artificial air extraction in correspondence with each battery using a special hood. This allows confining in the best way the area where there’s a gas emission and, with a suitable extraction range, reducing the potentially explosive area a few centimetres around the vent openings, even under the most severe recharge conditions.

Normally, general room ventilation is used without using hoods in stationary battery rooms and small locals for traction battery charging. Ventilation of this type can be realized with an artificial extraction system or with natural ventilation. In any case, the ventilation range should be sized based on the total flow of gas emitted from all the batteries presents.

11. The Required Data for Developing Hazardous Area Classification

Suppose a COMPANY assigns the task of classification of hazardous areas to an external contractor/ expert to explain. In that case, the data, information, and documentation must be provided to the contractor/ external expert as determined by the assessment methodology. This information includes PFDs that provide information about the process stream, plot plans that serve as the backgrounds for area classification plan drawings, MSDSs that are the source of process information about each component in the process stream, and P&IDs that provide a lower-level view of the process for equipment identification and process arrangements. The information can include:

1) Brief descriptions of the process and its operations & maintenance (O&M) manuals and cleaning details. A process flow diagram showing flows, temperatures, and pressures.
2) A listing of all the flammable and combustible materials used in the facility, their pertinent properties (flash point, ignition temperature, density, etc.), and how and where the materials are handled. As well as the material properties (e.g., gas group and T class).
3) Flashpoints or, where more complex conditions requiring a point-source release approach apply, the boiling ranges or other relevant physical characteristics of the fluids handled that will enable the fluid category.
4) Where relevant, a piping and instrumentation diagram would also indicate drain/ sample points, etc., and line/valve sizes (for example, for the processing plant).

5) A layout drawing with typical plans and elevations showing the position of all equipment, including operational vents, drain/surface water systems, storage areas, and tanker loading areas. In addition, this should show sources of ignition such as heaters, roadways with unrestricted access, flares, workshops, hot work areas, etc.
6) Knowledge of the equipment features and the mode of operation.
7) Ventilation details, considering whether open, congested, stagnant, or enclosed area(s). For congested or enclosed areas, the positions of openings such as doors, windows, and inlets/outlets will be needed. The location of below-grade areas, such as pits and pipe trenches, should also be specified.

12. Hazardous Area Classification Expected Deliverables

In the new installations, the expected deliverables from the plant designer regarding the hazardous area classification comprise hazardous area classification schedules and drawings that include detailed design and engineering information. A hazardous area classification drawing outlines areas where flammable liquids, gasses, or vapors are handed, processed, or stored. It is created based on input from the PFDs, P&IDs, and the Equipment Location Plan. The drawings usually include plot plans with a 3D perspective to illustrate the elevation of hazardous areas. The drawings intend to communicate to engineers, operators, and contractors' information on the hazardous material that may be present and the probability that it is in the atmosphere. This knowledge allows engineers and designers to select the right equipment and for contractors to know how to install the equipment properly. The deliverables must include the following:

- Hazardous Area Classification (HAC) Schedule.
- Hazardous Area Classification (HAC) Drawings.

A hazardous area classification drawing outlines areas where flammable liquids, gasses, or vapors are handed, processed, or stored. It is created based on input from the PFDs, P&IDs, and the Equipment Location Plan, and the Equipment Location Plan. The drawing intends to communicate to engineers, designers, and operators' information on the hazardous material that may be present and the probability that it is in the atmosphere. This knowledge allows engineers and designers to select the right equipment and for operators to know how to install the equipment properly.

Area classification records can comprise detailed drawings with notes and/or can be in the form of tabulations. The area classification drawings should be of sufficient scale to show all the main equipment items and the buildings in both plan and elevation. The positions of all openings, such as doors, windows and ventilation inlets and outlets, and utility entries, if not sealed vapor-tight, should be included, as the careful positioning of these openings can affect the sizing of related external hazardous areas.

Records should be marked up to show the boundaries of all hazardous areas, and zones present using the shading convention adopted in IEC 60079–10–1, shown in Figure 3. It is acceptable to indicate any requirement for small local zones/areas, e.g., around pumps and control valves, in a note on the drawing.

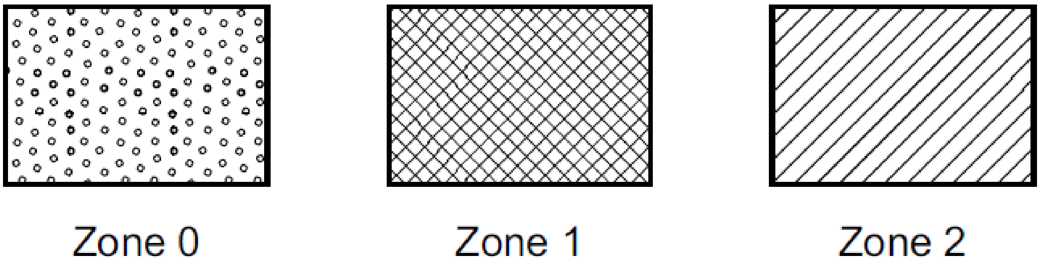

Figure 3. *Hazardous area zone classification shading convention* [3].

Note:

- The drawings and/or notes should indicate where the classification depends on the correct operation of a dedicated ventilation arrangement. It should consider and indicate the effect of a failure of such an arrangement.
- The preparation of the area classification drawing provides an opportunity to verify that the coverage of all sources of release has been comprehensive, i.e., it is not good practice to denote small pockets of non-hazardous areas within a general hazardous area.
- It may be desirable to adopt physical plant features, e.g., roads or access ways, as a readily defined zone boundary line, provided the zone boundary from any source is within these limits.
- The drawings should be updated to consider new or modified equipment, changes in installation protection, experience in the installation operation, methods or frequency of operations, and reclassification due to measurements in and around hazardous areas.

13. Hazardous Area Classification Management

Area classification should be incorporated into COMPANIES' process safety management systems. The person responsible for coordinating the area classification should be identified and competent in this field. The work, which requires an interdisciplinary approach, should be carried out by persons with full knowledge of the process systems and equipment, in consultation with process safety, loss prevention, and electrical engineering personnel, as appropriate. Agreements on the area classification should be formally recorded, regularly reviewed, and updated. Records, such as drawings and/or tabulated data sheets, should include the type of protection selected to meet the zone requirements and the equipment's apparatus sub-group and temperature class (T class).

In classifying a new facility or a modification to an existing facility, the area classification should be carried out before the design and layout of equipment are finalized. The area classification should be reviewed, and drawings modified on completion of the design before any change is made to existing plants.

The COMPANY operating a facility is responsible for ensuring that area classification has been carried out on installations handling flammable fluids. Where a facility has been designed and built on a turn-key basis, the plant designers should have carried out an area classification study and passed it over with other documentation to the operating company at the end of commissioning.

14. References

[1] National Fire Protection Association (NFPA), "Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas (NFPA 497)," 2021.

[2] Energy Institute , "Model Code of Safe Practice Part 15, Area classification for installations handling flammable fluids," 2015.

[3] International Electrotechnical Commission (IEC), "Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres (IEC 60079-10-1:2020)," 2020.

[4] American Petroleum Institute (API), "Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2 (API RP 505)," 2018.

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[7] National Fire Protection Association (NFPA), "Standard for Fire Protection in Wastewater Treatment and Collection Facilities (NFPA 820)," 2020.

[8] National Fire Protection Association (NFPA), "Standard on Fire Protection for Laboratories Using Chemicals (NFPA 45)," 2019.

[9] Engineering Equipment and Materials Users Association (EEMUA), " Practitioner's Handbook for Electrical Installation, Inspection and Maintenance in Potentially Explosive Atmospheres (EEMUA 186)," 2010.

[10] A. Bahadori, Hazardous Area Classification in Petroleum and Chimerical plants - A Guide to Mitigating Risk, CRC Press, 2008.

[11] A. McMillan, Electrical Installations in Hazardous Areas, Butterworth-Heinemann, 1998.

[12] European Union (EU), "ATEX 2014-34-EU Guidelines," 2020.

[13] European Union (EU), "ATEX Directive," 2020.

15. List of Annexes

- **Annex A -** Hazardous area apparatus selection, installation, inspection, maintenance, and testing.
- **Annex B -** How to Read ATEX and IECEx Markings of Electrical Equipment for Hazardous Areas.
- **Annex C -** Classes, Groups, Divisions, and Zones Concepts.
- **Annex D -** The Auto-Ignition Temperature (AIT) and the Temperature Class (T Class).
- **Annex E -** Zones Versus Grade of Release.

Annex A - Hazardous Area Apparatus Selection, Installation, Inspection, Maintenance, and Testing

A.1. General

This section guides the selection of explosion-protected apparatus according to the classification of the hazardous area, the maximum temperature and gas grouping features, and the apparatus's suitability for environmental conditions. EPSR creates duties concerning explosion-protected apparatus intended for use in hazardous area applications. EPSR divides this apparatus into four categories:

1. Equipment.
2. Protective systems.
3. Devices.
4. Components.

EPSR further divides explosion-protected apparatus into two groups; Group I apparatus is for use in mines susceptible to firedamp (methane) and is considered no further in this guideline; Group II apparatus is for use in areas in which mixtures of air with gases or dust cause flammable atmospheres. In the UK, relevant apparatus in hazardous area applications must be selected based on EPSR unless the risk assessment required by DSEAR Regulation 5 finds otherwise. Gases vary in ignitability; these differences are accounted for by dividing gases into temperature classes and subdivisions (groups).

There are several types of explosion protection, and it is acknowledged that they do not all provide the same level of protection and are considered suitable for different zones. In the past, there has been a direct link between the type of protection and the zone, without taking account of the operational requirements. Thus, the current EN 60079-14 “Explosive atmospheres. Electrical installations design, installation, and erection standard” allocate specific types of protection to specific zones, though it also has the concept of “equipment protection level” (EPL). EPL applies equally to electrical and non-electrical apparatus and introduces a degree of flexibility to allow equipment of a higher or lower category than that normally required for the zone in question to be used, e.g., where:

- Equipment is temporarily taken into a zoned area, and alternative effective precautions are provided to control the risk. For example, arrangements to isolate or shut down equipment to prevent the release of a flammable substance.
- Workers can be excluded from the hazardous area and will not be at risk of igniting an explosive atmosphere.
- Equipment of the required category is unavailable, but a lower category can be used with other protective measures to achieve effective precautions.

EN 60079-14 defines three EPLS: Ga, Gb, and Gc. Category Gc apparatus is defined as not containing sources of ignition that occur continuously or frequently in normal operation. In addition, for category Gb apparatus, even sources of ignition that can occur in rare situations, such as malfunctions of the apparatus, should be avoided. In addition, for category Ga apparatus, even sources of ignition that can occur in rare situations, such as rare malfunctions, are to be avoided. These are matters determined by the apparatus's manufacturer and will be detailed in the Declaration of Conformity, which accompanies the product. These EPLS correspond to Zone 2, Zone 1, and Zone 0 apparatus for typical consequences from accidental ignition. This would be the norm where no additional risk assessment has been performed. However, it may be possible to adjust the zone rating of the apparatus subject to a risk assessment such as that required by DSEAR.

Types of protection and construction details required for electrical apparatus to be used in hazardous areas have been consolidated into one main EU harmonized standard, EN 60079-0 “Explosive atmospheres - Equipment - General requirements.” Types of protection and construction details required for non-electrical apparatus to be used in hazardous areas are in the EN 13463 series of EU harmonized standards, with the basic methods and requirements discussed in EN 13463-1 “Non-electrical equipment for use in potentially explosive atmospheres - Basic method and requirements”. Also, note that the explosion protection of a given apparatus may deteriorate in adverse environmental conditions; in particular, ingress water and other materials into explosion-protected apparatus is likely to invalidate its explosion protection concept. Such apparatus, therefore, generally has an ingress protection (IP) rating.

A.2. Apparatus Selection

Where possible, the apparatus should be located outside of any hazardous areas. Where not possible, the most important aspects to be considered are:

1. Hazardous area classification, both type and extent.
2. The maximum surface temperature of the apparatus: this is the equipment's temperature classification (T Class), which must not exceed the ignition temperature of associated gases or vapors.
3. The category or subdivision of Group II apparatus.
4. The apparatus construction concerning environmental conditions, e.g., the IP rating or the construction materials.

Notes:

- Aspects relating to general electrical requirements, for example, fault rating of apparatus, are not covered by this guideline but should be considered.

- Area classification zoning restrictions should be considered when introducing and using any temporary electrical equipment or mobile equipment capable of generating a source of ignition in a facility

1. Selection Based on Hazardous Area

The types of protection considered suitable for installations located in hazardous areas are given in Table A1 for electrical apparatus and Table A2 for non-electrical apparatus. EN 15233 "Methodology for the functional safety assessment of protective systems for potentially explosive atmospheres" gives information on requirements for 'protective systems' as defined by EPSR; Table A3 lists the current EU harmonized standards for 'protective systems.' 'Components' are covered implicitly by the standards for the apparatus into which they are designed to be incorporated. There are no EU harmonized standards for 'devices' as defined by EPSR. Outside the EU, the criteria appertaining to use will be those of relevant IEC standards and/or any specific regulatory requirements of the country of use.

Table A1. *Selection of electrical equipment & systems according to hazardous area.*

Zone	Types of protection (titles abbreviated)	EU Harmonised Standard	ATEX Equipment Category
0	'ia' Intrinsically safe apparatus or system. Protection by restricting electrical energy within the apparatus and the interconnecting wiring exposed to a potentially flammable atmosphere to a level below that which can cause ignition by either sparking or heating effects.	EN 60079-11	II 1 G
	Category 1G equipment if specifically certified in zone 0 (see note 3).	EN 60079-26	
1	Any explosion protection types are suitable for Zone 0, plus:- 'd' Flameproof enclosures. Protection by use of an enclosure for electrical apparatus that will withstand an internal explosion of any flammable gas which may enter it without suffering damage to the enclosure and without communicating the internal combustion to any external flammable gas or vapor for which it is designed through any joints or structural openings in the enclosure.	EN 60079-1	II 2 G
	'ib' Intrinsically safe apparatus or systems. As for 'ia,' but with less demanding fault tolerance requirements.	EN 60079-11	
	'p' Pressurization, continuous dilution. Protection using the pressure of a protective gas to prevent the ingress of a flammable atmosphere into a space that	EN 60079-2	

Zone	Types of protection (titles abbreviated)	EU Harmonised Standard	ATEX Equipment Category
	may contain a source of ignition, where necessary, the continuous dilution of the atmosphere within a space that contains a source of flammable gas, to maintain the value of the gas to air ratio below to the LFL.		
	'e' Increased safety. Protection by additional measures applied to electrical apparatus to give increased security against the possibility of excessive temperatures and arcs and sparks during the service life of the apparatus. It applies only to electrical apparatus, no parts which produce sparks or arcs or exceed the limiting temperature (see note 2) in normal service.	EN 60079-7	
	'm' Encapsulation. Protection by enclosing parts that could ignite a flammable atmosphere, by either sparking or heating, in a compound so that a flammable atmosphere cannot be ignited.	EN 60079-18	
	'o' Oil immersion. Protection by immersing the electrical apparatus in oil so a flammable atmosphere above or outside the enclosure will not be ignited.	EN 60079-6	
	'q' Sand/powder filling. Protection by an enclosure filled with a mass of granular material such that, if an arc occurs, the arc will not be liable to ignite an outer flammable atmosphere.	EN 60079-5	
2	Any explosion protection types are suitable for Zones 0 and 1, plus: - 'n' Reduced risk. A type of protection applied to an electrical apparatus such that, in normal operation, it is not capable of igniting a surrounding flammable atmosphere, and a fault capable of causing ignition is not likely to occur.	EN 60079-15	II 3 G
	'ic' Intrinsically safe apparatus or systems. As for 'ia' and 'ib,' but with less demanding fault tolerance requirements.	EN 60079-11	

Notes:

1. Certification of electrical apparatus by a Notified Body is required for Zone 0 and Zone 1. Still, it is not required for Zone 2 use – a manufacturer's Declaration of Conformity specifying the standards the equipment is manufactured will be required.
2. It may be a combination of the above types of protection.

Table A2. *Selection of non-electrical equipment according to hazardous area zone.*

Zone	Type of protection (titles abbreviated)	EU harmonized	ATEX equipment category
1	'd' Flameproof enclosure. As for electrical apparatus.	EN 13463-3	II 2 G
1	'c' Constructional safety. Protection by constructional techniques and good engineering practice to protect against hot surfaces, sparks, and adiabatic compression.	EN 13463-5	II 2 G
2	'fr' Flow restricting enclosure. Protection by preventing any surrounding flammable atmosphere from entering via ventilation, diffusion, or breathing caused by temperature changes.	EN 13463-2	II 3 G
Note 1	'b' Control of ignition source. Protection by sensors that detect an impending operation that may cause ignition, and initiation of a protective response (whether manual or automatic)	EN 13463-6	Note 1
Note 2	'k' Liquid immersion. Protection by immersion in a protective liquid or coating with a flowing film of protective liquid.	EN 13463-8	Note 2

Notes:

1. Type 'b' apparatus may provide ignition protection either as an independent means, in addition to, or in combination with other types of ignition protection categories 1G, 2G, or 3G.
2. Type 'k' apparatus can achieve ignition protection in category 3G, where there is no ignition source in normal operation, category 2G, where there are also no ignition sources under foreseeable malfunctions, or 1G, where there are no ignition sources under rare malfunctions.
3. Certification requirements for non-electrical apparatus are discussed in EI - Model code of safe practice - Part 1 (The selection, installation, inspection, and maintenance of electrical and non-electrical apparatus in hazardous areas) - Annex B.

Table A3. *Selection of protective systems.*

Type of Protective System	EU Harmonized Standard
Flame arrester	EN 12874
Explosion suppression systems	EN 14373

2. Selection According to Temperature Classification ('T' Class)

Since flammable gases/vapors can be spontaneously ignited by contact with a hot surface, it is necessary to specify an appropriate 'T' Class, such that the maximum surface temperature attained externally or internally where the gas can penetrate, under the most adverse conditions including recognized overload and fault conditions, at an ambient temperature of 40 °C will not exceed the ignition temperature of the gas to which it may be exposed. Apparatus which may be exposed to higher ambient temperatures require special consideration, and an ambient other than 40 °C may be adopted in the case of cold climate conditions. The ignition temperature of the gas is measured in a standard apparatus; however, ignition temperature is not an inherent property of the substance but also depends on the test method. The data are given in the EN 60079 series of standards; consequently, in this model, the code is conservative. So, no additional safety margin should be required but note that EN 1127-1 specifically requires a margin of safety. The most conservative temperature class should be specified for mixtures, or laboratory tests should determine the temperature class. Note that for 'components' having a total surface area of not more than 10 cm^2, EN 60079-0 allows relaxation of temperature limits by 50 °C for T1, T2, and T3, and 25 °C for T4, T5 and T6. The determined ignition temperatures of many gases and vapors are given in IEC 60079-20, a selection of which is given in Table A4.

Apparatus should only be used in areas where the maximum temperature reached under normal operation, including allowable overloads, of any relevant part or surface of the apparatus, accessible to external gases or vapors, does not exceed the ignition temperature of the gases, and vapors involved. The relevant surfaces are only external for types of protection 'd' and 'p.' For types of protection, 'e' and 'n' internal surfaces are also relevant but note that some apparatus uses multiple types of protection, and the most demanding will apply. EN 60079-0 and EN 60079-14 classify surface temperatures into the maximum permitted temperature for each of the six 'T' classes. Table A4 lists the 'T' classes, associated maximum surface temperatures, and typical compounds with an ignition temperature requiring apparatus of the given 'T' class. Apparatus with a lower maximum surface temperature, i.e., a higher temperature class, may be used instead of a higher maximum surface temperature (lower 'T' class), but not the converse.

Table A4. *Apparatus temperature classification.*

'T' class	Maximum Surface Temperature	Typical substances in the 'T' class
T1	450 °C	Methane – Hydrogen - Chloromethane
T2	300 °C	Ethylene – Butane – Acetylene - Ethanol
T3	200 °C	Naphtha - Kerosene
T4	135 °C	Diethyl ether - Benzaldehyde
T5	100 °C	-
T6	85 °C	Carbon disulfide

Notes:

1. Data were taken from IEC 60079-20.
2. An ambient reference temperature of -20 °C to +40 °C is normally assumed.
3. Apparatus may be certified as having a maximum surface temperature not greater than one of the specified 'T' classes given above. Alternatively, the apparatus may also be certified by the maximum surface temperature of the apparatus as established by a test at a specified ambient temperature.
4. Where it is intended to install and use apparatus in a maximum ambient temperature greater than 40 °C, the manufacturer should be consulted. Labelling should be fitted, giving the working ambient temperature and the 'T' class appropriate to that temperature. Confirmation is also required, from the manufacturer, that the apparatus is, in fact, suitable for working at the maximum local ambient temperature, as specified at the time of ordering.
5. The surface temperature limitations apply under normal load conditions and certain overload conditions specified in the appropriate standard.

3. Selection According to Grouping and Sub-Division

EU standards divide apparatus into two groups:

- Group I: Electrical apparatus for use in mines susceptible to firedamp (methane).
- Group II: Electrical apparatus used in hazardous areas, other than in mines, susceptible to firedamp. Group II apparatus is further subdivided according to the nature of the potentially explosive atmosphere in which it is intended to be used.

Flammable gases are categorized and placed into sub-divisions according to their ease of ignition. The following test criteria determine the sub-division:

- Maximum Experimental Safe Gap (MESG): based on flameproof equipment to determine the gap through which an ignited gas will not pass and possibly ignite an external gas.
- Minimum Ignition Current (MIC): based on tests for intrinsic safety used to determine the minimum ignition current for each gas.

Current sub-divisions for a small sample of typical gases are given in Table A5.

Table A5. *Gas sub-divisions.*

Representative gas	Gas sub-division	MESG (mm)	MIC (mA)	MIE (mJ)
Propane	IIA	>0.9	70	0.25
Ethylene	IIB	>0.5 <0.9	45	0.082
Hydrogen	IIC	<0.5	21	0.016
Acetylene	IIC	<0.5	24	0.019
Note: MESG values are assigned for the gas sub-divisions, not the named gases. MESG and MIC data from IEC 60079-20, MIE data from Handbook of Explosion Prevention and Protection, Hattwig and Steen.				

Equipment certified for a more onerous sub-division may be used in a less demanding sub-division, but the converse is not true (this is particularly relevant with mobile or portable apparatus which may be used in a variety of locations), i.e.:

- Equipment certified to gas sub-division IIC may be used with IIC, IIB, and IIA gas sub-divisions.
- Equipment certified to gas sub-division IIB may be used with IIB and IIA gas sub-divisions.
- Equipment certified to gas sub-division IIA may be used with IIA gas sub-division only.
- All conditions must have been adhered to where the type of protection category 1G is employed.

Type 'i' and energy-limited type 'nL' applications

MIE should also be considered. EN 60079-11 Explosive atmospheres. Equipment protection by intrinsic safety 'i' relates circuit parameters to current and voltage in assessing type 'i' circuits. Where a direct assessment of minimum ignition energy is necessary, a value for the MIE should be determined from physical characteristics.

Other sources of information are Technical Data on Fuel, J.W. Rose and J. R. Cooper, and Flammability Characteristics of Combustible Gases and Vapors, M. Zabetakis). The MIE for the gases in Table A5 lies between about 0.02 mJ for the Group IIC gases and 0.3 mJ for Group IIA gases. The three sub-divisions reflect the different MIEs, but these sub-divisions apply only to some protection concepts where ignition energy is relevant. There is no simple link between ignition sensitivity and ignition temperature; for example, hydrogen is extremely sensitive to ignition by sparks but has a high ignition temperature; however, there may be an empirical correlation between MIC and MIE. The determined MIC of several gases and vapors is given in IEC 60079-20, and a selection is given in Table A6.

Table A6. *Properties of a selection of flammable gases.*

Gas subdivision	Gas name	Flash point	AIT	AIT/ MIC	Flammability % with air		Relative density (AIR = 1)	Use with apparatus groups Type 'i', 'd' and 'p'	'T' class of suitable apparatus
II C	Hydrogen	-	560	21	4.0	77	0.07	IIC	T1
	Acetylene	-	305	24	2.3	100	0.9	IIC	T2
	Carbon disulfide	-30	95	-	0.6	60	2.64	IIC	T6
II B	Dibutyl ether	25	198	-	0.9	8.5	4.48	IIB	T4
	Ethylene	-	425	45	2.7	34	0.97	IIB	T2
	Cyclopropane	-	498	-	2.4	10.4	1.45	IIA	T1
	Hydrogen sulfide	-	270	-	4.0	45.5	1.19	IIB	T2
	Coke oven gas	-	-	-	-	-	-	IIB-IIC	-
II A	Acetone	<-20	535	-	2.5	13	2	IIA	T1
	Ammonia	-	630	-	15	33.6	0.59	IIA	T1
	Benzene	-11	560	-	1.2	8.6	2.7	IIA	T1
	Butane	372	80	1,4	9.3	2.05	IIA	T2	
	Carbon Monoxide	-	605	-	10.9	74	0.97	IIB	T1
	Cyclohexane	-18	259	-	1.2	8.3	2.9	IIA	T3
	Ethane	-	515	70	2.5	15.5	1.04	IIA	T1
	Ethanol	12	363	75	3.1	19.0	1.59	IIA	T2
	Hexane	<-20	240	75	1.2	7.4	2.79	IIA	T3
	Kerosene	38	210	-	0.7	5	-	IIA	T3
	Methane	-	537	85	4.4	17	0.55	I	T1
	Methane (Industrial)	-21	537	85	4.4	17	0.55	IIA	T1
	Methanol	11	386	70	5.5	36	1.11	IIA	T1
	Propane	<-20	470	70	1.7	10.9	1.56	IIA	T1
	Pentane	-40	258	73	1.4	7.8	2.48	IIA	T3
	Petroleum	<-20	560	-	1.2	8	2.8	IIA	T1
	Toluene	4	535	-	1.1	7.8	3.2	IIA	T1
	Xylenes	30	464	-	1.0	7.6	3.66	IIA	T1
	Acetone	<-20	535	-	2.5	13	2	IIA	T1

Notes:

1. The above list is a small selection compiled from the tables of gases in sub-divisions IIA, IIB, and IIC, from IEC 60079-20.
2. Gases are subdivided into A, B, or C as determined either by MESG tests, typically for evaluation of flameproof equipment or by their MIC for use with intrinsically safe equipment.
3. Abel closed cup test method IP 170, equivalent to EN ISO 13736.
4. Apparatus with types of protection 'e' and 'n' is suitable for all gases unless designed for a specific gas.
5. Indicates that the equipment class differs from the gas classification in this case.
6. Coke oven gas is a mixture of hydrogen, carbon monoxide, and methane. If the total concentration (vol %) of hydrogen and carbon monoxide is less than 75 % of the total, the flameproof apparatus of Group IIB is recommended. Otherwise, the apparatus of Group IIC.
7. Methane (or firedamp) may be found underground in mines. It is the only gas for which Group I apparatus is required.

4. Suitability for Environmental Conditions

Apparatus and parts should be designed to guard against specific environmental conditions and to protect persons against contact with internal live or moving parts, as detailed in the following subsections.

4.1. Ingress of water and solid material

The ingress protection rating describes the degree of protection against solid material and water. In some applications, e.g., on ships' decks, apparatus to ingress protection IP66 might provide better protection against waves that flood over the deck than IP67 (temporary immersion in water).

4.2. Corrosion

Water, particularly salt water, will cause corrosion of most metal enclosures and apparatus. Painting may offer suitable protection, and other appropriate protection, such as silicone grease and tape, should be applied. In the case of Ex 'd' apparatus, care should be taken not to obstruct or reduce the flame path by other substances such as paint.

(a) Effects of corrosion on special types of Ex electrical equipment (suffix X)

Some Ex electrical equipment is certified with special measures, indicated by a suffix X on the certificate. Such equipment may include electric heaters where the element may be inserted inside a vessel. The application may rely upon the heater always being immersed in liquid or within a gas that is not flammable, or a liquid-level detector located within the vapor space of a storage tank. The certification of such Ex electrical equipment may depend on the electrical circuit being completely enclosed within a metallic sheath and considered outside the potentially hazardous area. Such concepts can be highly dependent on the mechanical integrity of the metallic outer sheath not being damaged or suffering from corrosion and will therefore require routine inspection.

(b) Effects of corrosion on metallic supporting structures

Metallic supporting structures on aging installations have been found to produce excessive rust, which results in the expansion of the structure causing plastic Ex enclosure supports to fracture. This normally occurs at the fixing points of the plastic enclosure.

4.3. Use of plastic enclosures

Many common plastic materials are subject to embrittlement and failure due to exposure to high temperatures, ultra-violet light, and general aging. Therefore, enclosures used in hazardous areas should have proven stability and long-term resistance, and the advice of the manufacturer as to the service life expectancy of plastic enclosures should be sought. In addition, there should be no possibility of ignition due to charge or discharge of electrostatic energy during normal use and cleaning conditions.

5. Other Requirements

All apparatus should be installed, used, and maintained within its rating, including fault rating. For example, electrical ratings include power, voltage, current, frequency, etc., and other general factors, e.g., earthing, that might affect the safety of the installation. Electrical protection standards against such factors as overload or overcurrent are outside the scope of this model code. Other standards of a general nature and all statutory instruments should be followed.

5.1. Enclosures of light metals and their alloys

There is a risk of ignition from impact or frictional sparking when light metals are brought into contact with iron or steel, particularly where the iron or steel has a coating of metallic oxide, such as rust; this is called a thermite reaction. To reduce this risk, alloy content should meet the following criteria:

- Group II, category 1: not more than 10 % in total aluminium, magnesium, titanium, and zirconium and not more than 7,5 % in total magnesium, titanium, and zirconium.
- Group II, category 2: not more than 7,5 % of magnesium.
- Group II, category 3: no special requirements.

In addition, in a hazardous area, consideration should be given to the location of light metal enclosures, aluminium ladders, and similar access equipment.

5.2. Accumulations of dust

The accumulation of dust on explosion-protected electrical apparatus should be avoided since, due to the thermal insulating properties of dust, this could lead to an excessive temperature rise on the enclosure and on the internal parts to which an external flammable gas might have access, e.g., in types 'e' and 'n' apparatus. Deterioration of electrical insulation properties could also occur.

5.3. Solvent attack

Where exposure to solvents cannot be avoided, particularly in underground cable installations, additional protection against direct contact or vapor attack should be provided, e.g., by lead or other appropriate sheathings. Precautions should also be considered wherever plastic materials are employed, e.g., cable boxes, cable gland shrouds, and gaskets. Note that Ex certification tests address the effects of gases and vapors on elastomeric seals but do not address the effects of hydrocarbon liquids on such materials – where hydrocarbon liquids can wet elastomeric seals, seals may lose performance, leading to a detrimental effect on IP rating. Elastomeric seals can also lose performance as they age, and advice on the manufacturer replacement strategy should be sought.

6. Apparatus with an Internal Source of Release

It is important to note in selecting explosion-protected apparatus that consideration should be given to whether there may be a possible internal release of flammable material within the equipment itself, which could require a different allocation of what zone may be applicable for this selection, and, if so, whether a difference in composition as compared to the external atmosphere could affect the selection of apparatus sub-division and 'T' class.

6.1. In the first instance, the advice of the manufacturer or supplier should always be ascertained. The following notes, while not exhaustive, should also be considered:

a. Where a flammable substance is of necessity introduced into the enclosure of an Ex-apparatus, for example, in the case of a process analyzer or in certain instruments used for measurement and control where there is a connection with the process fluid, an internal source of release of flammable gas or vapor may occur, either in the course of normal operation or in abnormal circumstances, e.g., due to failure of the containment system. For some instruments, protection by pressurization or continuous dilution by either air or an inert gas such as nitrogen may be provided, as in a type of protection 'p' under EN 60079-2 Explosive atmospheres Equipment protection by pressurized enclosure 'p.'

b. It should be noted that an enclosure may be of any size and may range from a small instrument case to a structure such as an analyzer house or control room containing multiple apparatus. The enclosure may serve solely as mechanical protection or constitute an integral part of the type of explosion protection. The following notes apply to a release within a single apparatus enclosure. Still, it should be borne in mind that there may be ‘nested' enclosures when one or more enclosures are placed within another. In such a case, it is necessary to assess the probability of a flammable material of potentially explosive force being present between each successive enclosure boundary before proceeding to determine the type of protection for the apparatus inside each. In placing one or more enclosures within one another, the atmosphere of the inner enclosures may prove more significant in determining the types of protection for apparatus inside than the hazardous area classification in the zone of application.

c. The nature of an internal hazard within the enclosure (casing) of a single apparatus will depend, as in general classification, upon several circumstances, such as the integrity of construction and in-service maintenance, whether an internal release occurs in normal or abnormal conditions, and whether when, for example, the protection of the apparatus is pressurization or dilution with air, the release is 'restricted' or 'unrestricted.'

6.2. The following notes should be considered providing such apparatus is correctly installed, tested, and maintained:

a. A 'restricted' release is one in which any release of flammable material within the apparatus is limited to an extent within the containment or diluent capacity of a protective gas system. An 'unrestricted' release is one in which this can be exceeded. It is not just equipment performance when new; the effect of long-term aging and deterioration should also be considered. Where an internal release could be significant, there will be a need for adequate means of relieving this to the exterior by special breather or similar provision, which will not affect the type of protection. With a flammable release, such devices should include flame arrester provision, as in the case of the flameproof enclosure of Ex 'd' apparatus.
b. Assessment of an internal release. The assessment should recognize that the consequences of an internal release of flammable gas or vapor within an apparatus may be more severe than an external release since, in the former, in the absence of a dilution protective system, it can remain and accumulate. Thus, a release that could be undetectable in the open due to diffusion can slowly raise the level within such an enclosure to the point that it comes within the flammable range. While individual judgment must always apply, the broad types of release potential that can arise with various forms of apparatus can be considered.
c. 'No normal' release. This recognizes that for certain equipment, there is minimal risk of a release within its enclosure throughout its in-service duration between inspection and maintenance intervals. While it is not possible to be specific, it is normally assigned to equipment in which there is an enclosure in metallic piping, tubing, and elements such as Bourdon gauges, bellows, or spirals operated within their established ratings and with joints with threads welding, metallic compression fittings, etc., which could similarly be considered as having 'no normal' release. Such a criterion is based on materials and construction that withstand time and service and do not age or degrade; normally, it would exclude window assemblies in casings, moving seals, elastomeric seal materials, and non-metallic flexible tubing unless operational experience demonstrates the contrary. Since seals, rotating or sliding, flanged joints and flexible non-metallic tubing can be assumed often to leak minutely after a period in service, the lower categorization of 'limited normal' release may be considered against the possibility that degradation with age could give rise to release above that expected for new equipment.
d. 'No abnormal' release. Apparatus may be considered in this category if, under any foreseeable abnormal conditions, there is no possibility that an internal release could occur. An example would be a Bourdon tube with a mechanical strength such that any foreseeable overpressure would not cause the failure of the tube. Conversely, when under foreseeable abnormal conditions, an internal release could occur, e.g., a thin-

walled metal diaphragm or bellows, which could mechanically fail due to repeated flexing or application outside the intended range of operation, the apparatus should be considered as having an abnormal release potential. Evaluation of internal release hazard relative to the external hazard zoning. It will be seen from the preceding review that the internal hazard will, in some cases, override the external classification and be the factor that determines the type of protection. In other cases, when the same equipment is to be installed in a more severe external hazard zoning, these external hazards will determine the actual type of protection to be applied.

6.3. The following generalized examples are illustrative of the approach that may be taken. However, more detailed guidance than is possible to detail in this model code will be required. The effect of the internal release composition on the apparatus sub-group and temperature class should always be considered.

a. When there is a normal internal release, the internal hazards are comparable to the hazards associated with an external Zone 0, and comparable types of protection limitations should be assumed, with consideration of the type of protection 'p' to protect against the release by continuous dilution with air to circa 25 % of the LFL.
b. Pressurization with an inert gas such as nitrogen may also be applied since the normal internal release cannot create a flammable atmosphere without oxygen. With the type of protection 'p,' the protection requirements against loss of protective gas input by alarm or shutdown should be observed.
c. Where dilution with air is applied in the case of a 'restricted normal' release, the internal hazards are reduced to a level comparable to those in an external non-hazardous area. This also applies in the event of an abnormal release, which would be considered 'restricted.' Were the abnormal release considered 'unrestricted' (as defined in 6.2 (a)), this would not be applicable, and the internal hazard would become comparable to the hazard associated with an external Zone 1.
d. When protective gases are used, as in these generalized examples, pre-purging by the passage through the enclosure and its associated ducting should be carried out before the energization of the system so that any flammable gas is first cleared from the enclosure.
e. In all other types of protection, provided there is no normal release, an abnormal release would be very infrequent and of relatively short duration. The internal hazards are comparable to those associated with an external release in Zone 2. Thus, if such apparatus is installed in an external non-hazardous or Zone 2 area, the internal hazards are the determining factor for Zone 2 type protection.
f. However, where the apparatus described in (e) is installed in an external Zone 1 or Zone 0, the latter external classification will determine the type of protection, not the internal conditions.

g. Again, with an apparatus in which the internal release hazards are assessed as comparable to that of an external Zone 1, installation of that apparatus in an external Zone 0 will result in the latter determining that the type of protection should also be for Zone 0.

7. Safeguards on Fired Process Heaters

It is not appropriate to classify the inside of a plant designed for controlled combustion as a hazardous area. However, if fuel is supplied to a combustion chamber with no flame or ignition, a flammable atmosphere can quickly form. Note also that fired heaters are a source of potential ignition and should normally be sited in a non-hazardous area. With fired heaters, dangerous conditions may occur:

- While the plant is shut down if fuel can leak past a control valve or valves.
- During start-up, if too much fuel is supplied before a source of ignition is provided.
- During normal running, if the flame fails for any reason, e.g., because of flame instability, a brief interruption to the fuel supply, or sudden surge of combustion air or shut down if the combustion air supply is shut before the fuel supply.

Detailed technical specifications for burner control systems have been developed for many applications. The requirements depend on the designed heat input and whether the plant runs intermittently for long periods. Fired process heaters should normally follow the requirements for similar heaters. Precautions can be grouped under the headings: flame failure safeguards, safety shutoff valves for fuel lines, ignition sequences, operating procedures, shutdown sequences, additional safety monitors, and explosion relief.

7.1. Flame failure safeguards

These are required on all burners operating below 750 °C and higher temperature burners that operate intermittently. Ionizing detectors (particularly flame rectification) or radiation detectors are preferred. Burners operating for long periods above 750 °C may not be fitted with flame failure protection. They may have manually operated valves in the fuel supply to individual burners or a group of burners. In this case, control systems are required to prevent fuel supply to a burner when no pilot flame or other ignition source is present.

7.2. Safety shut-off valves

Information on types and monitoring systems are given in the:

- EN 161 Automatic shut-off valves for gas burners and gas appliances.
- EN 676 Automatic forced draught burners for gaseous fuels.
- EN 1643 Valve proving systems for auto shutoff valves for gas burners & appliances.
- BS EN 5885 Automatic gas burners.

7.3 Ignition sequences

These should preferably be fully automatic with timed sequences, incorporating:

- Prepare checks on the safety system.
- Pre-ignition purge, typically five times the combustion chamber volume of air.
- Ignition, with fuel supply before ignition controlled so that the maximum energy release is limited to 53 KJ/m3 of combustion chamber volume.
- Flame proving, with post purge, if the ignition is not established.

7.4. Operating procedures

These should be available in a clear, unambiguous form, with concise instructions for emergency shutdown.

7.5. Shut down sequences

Air supplies should be maintained until all pilot/main fuel valves have been closed and continue for a period to purge residual combustion products. The safety shutdown system should be closed when the plant is shut down.

7.6. Additional safety monitors

These may be appropriate, e.g., flow and pressure sensors on fuel and air supplies or exhaust and recirculation fans.

7.7. Explosion relief

The design should consider the possible risk of explosions and, if necessary, incorporate explosion relief system.

A.3. Certification of Apparatus

In the European Union, The ATEX 95 Directive forms the EU-wide basis of relevant national legislation applicable to equipment, protective systems, components intended for use in potentially explosive atmospheres, and related controlling devices intended for use in non-hazardous areas. The ATEX 137 Directive forms the EU-wide basis for national legislation applicable to the health and safety of workers in potentially explosive atmospheres. The relevant regulations, such as EPSR and DSEAR. Note that these Directives, EPSR and DSEAR, extend requirements to non-electrical apparatuses, internal combustion engines, and electrical apparatus.

EPSR requires a conformity assessment process to be carried out on hazardous area products, whether equipment, protective system, device, or component as defined, and whether electrical or non-electrical. Except for components, once conformity of the apparatus has been established, a Declaration of Conformity is issued by the responsible person, and the apparatus is CE marked. Components are subject to parallel conformity assessment procedures, according to equipment group and category, but do not have CE marking; they are accompanied by a written attestation that declares conformity and states the characteristics of the component (which is invariably combined with other products to make a functional whole). This conformity assessment process, CE marking, and certification give a presumption of conformity with the legislation's relevant standards and the essential health and safety requirements. Thus, it should be presumed that all possible ignition mechanisms of the apparatus have been considered. However, users should be aware that they should address any special conditions of use in their applications and any requirements when incorporating these products into systems that combine two or more products. Note that additional 'secondary' or 'voluntary' Ex certification is not recommended beyond that required by EPSR.

In exceptional circumstances, e.g., in research, development, pilot plant, and some new project work, suitably certified apparatus may not be available. In such cases, uncertified apparatus may be used if the risk assessment required by DSEAR Regulation 5 finds that certified apparatus is not necessary. However, users of such apparatus should address the essential health and safety requirements defined in EPSR Schedule 3 to satisfy themselves that explosion risks are as low as is reasonably practicable and should, if necessary, involve specialist advice from a competent person such as a Notified Body; this process should be documented. Countries outside the EU may certify to their national or IEC standards for the apparatus used.

A.4. Marking of Apparatus

The internationally agreed symbol to identify explosion-protected apparatus is (Ex). The IEC Ex scheme aims to facilitate international trade in electrical equipment for use in hazardous areas by eliminating the need for multiple national certifications. The scheme has two objectives in its approach:

- To accommodate national needs and safety concerns through a defined and practical transition period.
- To provide a route to using one international certificate (mark) in all participating countries.

In the European Union, EPSR requires explosion-protected apparatus to be marked with the CE mark, the symbol for explosion protection, and certain other details defined in the various standards. The marking requirements for compliance with the relevant EU harmonized standards are outlined below. They should be applied in a visible position and should be legible, durable, and have protection against corrosion. These requirements may be added to those required by the ATEX 95 Directive (see Annex B).

- Symbol CE to indicate compliance with relevant European Standards.

- Symbol Ex to indicate that this apparatus is explosion-protected
- The symbol for the type of protection.
- Group symbol I or II.
- Temperature class.
- Symbol 'X' if special conditions of use apply.
- Symbol 'G' when certified for flammable gas or 'D' for use in combustible dust.
- Any markings normally required, such as voltage, current, power, frequency, short circuit rating, IP rating, etc.

A.5. General Installation Recommendations

1. General requirements

EN 60079-0 outlines the general requirements for constructing, testing, marking, and installing apparatus for use in explosive gas atmosphere applications. These requirements are generally in addition to those detailed in the IEC 60364 series of standards and BS 7671.

1.1 Earthing and bonding

The requirements for earthing and bonding of installations in hazardous areas are outlined in EN 60079-14, EN 60079-11 (for intrinsically safe installations), and BS 7430 Code of practice for earthing.

1.2 Mechanical protection

All apparatus should be installed with due regard to the possibility of mechanical damage affecting the integrity of the type of protection of the apparatus. EN 60079-0 specifies impact and mechanical strength tests and tests for resistance to some chemicals. Nonetheless, installers should locate apparatus and cabling that is not vulnerable to damage.

Electrical equipment used inside process atmospheric tanks might consist of electric heaters (e.g., frost protection heaters), high-level liquid detectors (e.g., reed switches), or submersible electric pumps (including the supply cable). These are likely to depend on the mechanical integrity of, e.g., the electric heater outer sheath, the reed switches outer sheath, or the supply cable outer sheath. This mechanical protection may be relevant to any potentially explosive atmosphere in the vapor space within the tank, which may be classified as a hazardous area. It is the user’s responsibility to ensure that the mechanical integrity of this equipment is appropriately inspected and maintained.

1.3 Cabling and glanding

The requirements for wiring and cabling are included in EN 60079-14. Cable glands used on new installations must be certified against the appropriate EN Standards as Ex 'e' or Ex 'de.'1

Some types of equipment may have specific cabling and glanding requirements detailed in their certification. All cable glands should fully engage with, grip, and seal the cable by compression seal or sealing compound to meet Ex certification requirements and the IP rating. However, gland seals should not be overtightened, as this may damage the cable. Incorrect cable glanding can be a major issue owing to poor design, e.g., cables undersized for a type of gland. Problems include over-tightening compression glands (which damages the inner seal), incorrect application of ingress protection washers, etc. To maintain the ingress protection rating, conduit entries should be sealed. Cable glands will require an external ingress protection seal washer unless the length of the engaged thread is greater than 6 mm (normally five full threads); glands should be Ex 'e' certified. Note that some types of cables, especially 'low smoke' or 'fire resistant' types, employ materials that exhibit significant cold flow characteristics at ambient temperature, and this could have adverse effects on the protection of the apparatus; in this situation, cable glands which employ compression seals which act on part(s) of the cable having the cold flow characteristics should not be used. A more suitable cable entry device should be used. For high-integrity circuits such as emergency shutdown or fire alarm circuits, consideration should be given to the protection of cables and conduits against fire or fire-resistant cables. For offshore or indoor manned operations, using cables with low smoke and low acid emission is recommended on the grounds of both safety of persons and the risk of damage to equipment when subjected to fire.

Cables should be run where mechanical or fire damage risk is low. If this is not practicable, the cables should be given additional protection and supported throughout their length, e.g., on cable trays or through protective troughs or conduits. This is important in the case of cables associated with fire and gas detection and public address systems, where their survivability/availability is required. Such systems should consider dual systems, i.e., redundancy and separate cable routes.

Attention should be paid to the electrical continuity and jointing of conductive cable trays and conduits, which may carry stray currents whose interruption may cause an incentive spark.

Cables for extension leads for portable tools, hand lamps, and associated portable transformers are to be either heat, oil, and flame-retardant (HOFR) or 'SY' steel braided cables. 'SY' cables were introduced following issues with flexibility when used on tools such as grinders etc. An 'SY' cable is not flame-retardant but is used extensively in offshore and onshore industries. Systems would be either Extra Low Voltage or Centre Tapped to Earth on 110 V a.c. Transformers with ELCB protection. Where higher voltages (240 V a.c.), RCD is required.

1.4. Isolation

All electrical circuits should be provided with an effective means of isolation (as opposed to simply switching off), as required by EAW Regulation 12(1)(b). Isolation facilities should be adequately labelled to ensure foolproof and rapid identification. A master isolator may be provided to allow large plant areas to be disconnected in a severe emergency. Devices used to isolate equipment in hazardous areas should isolate all circuit conductors, including the neutral, using disconnection and separation of the electrical equipment from every source of electrical energy so that this disconnection and separation is secure.

1.5. Fault protection

All electrical apparatus must be provided with an automatic means of disconnection in the event of fault current and overload conditions. Ex electrical equipment certification does not assess the requirement of fault levels, e.g., an Ex 'e' motor or junction box rated at 6 600 V and 200 A will not generally have a fault level rating specified by the manufacturer. It is the user's responsibility to ensure that all electrical equipment is fit for purpose, is adequately protected, and that its Ex-certification conditions will not be violated and lead to a source of potential ignition. When three-phase apparatus may be subjected to single-phase operation, which could result in danger, e.g., motor applications, single-phasing protection should be fitted. The following functionality should also be provided:

- Earth fault protection on all high voltage systems and low voltage systems as required.
- Backup protection for high-voltage equipment and possibly for low-voltage explosion-protected equipment.
- A means of testing protective devices.

1.6. Luminaires

Luminaires should be located such that maintenance access is provided. It is necessary to ensure that only the correct type and rating of replacement lamps are fitted. Lamps of higher wattage or lower voltage than that for which a fitting is certified should not be fitted. Low-pressure sodium lamps (SOX) embodying free metallic sodium should not be installed or used in or above hazardous areas. (For guidance on lighting levels for safe working, see the national labor law). Attention is drawn to the fact that fluorescent lamps age and their temperature increases towards the end of lamp life, or if not kept free from dust accumulation, can potentially violate the 'T' class. Periodic scheduled re-lamping may be a solution, and the advice of the lamp manufacturer as to an appropriate periodicity should be sought. Another solution is a stop circuit in the electronic ballast, which prevents the lamp from igniting when it has reached the end-of-life condition (For more information, see EN 60079-7 Explosive atmospheres).

Equipment protection by increased safety 'e'). Users should risk assessing their fluorescent lamps and associated control equipment (e.g., electronic ballasts) and the effects of lamp aging. Some electronic ballasts can detect lamp aging and automatically switch the luminaire off. However, other types have no protection, and lamp aging might result in abnormal temperatures over 800 °C at the cathode. EN 60079-15 Electrical apparatus for explosive atmospheres. Construction tests and marking of type of protection 'n' electrical apparatus provide information on cut-out device tests and life tests (failed lamps).

1.7. Trace heating

Electric trace heating on, e.g., process pipework presents an ignition risk and should be installed only where necessary. When installed, it must be appropriately protected from electrical and mechanical failures. Electrical protection can be achieved by installing the correct fuse, MCB, and RCD to the supply source. The RCD protection provides both personnel shock protection and earth fault protection. Pipework insulation (lagging) provides mechanical protection of the trace heating tape and allows effective heat transfer to the pipework. EN 60079-30-1 Explosive atmospheres. Electrical resistance trace heating. General and testing requirements provide information on the circuit protection requirements for trace heating circuits. EN 60079-30-2 Explosive atmospheres. Electrical resistance trace heating. Application guide for design, installation, and maintenance provides information on the maintenance requirements for electric trace heating systems; it also provides information on methods of fault location using an induction instrument operating at approximately 1,000 Hz, which can be used to inject a signal followed by an audible signal. Suppose the pipework insulation (lagging) is removed. In that case, the exposed trace heating tape may present a greater ignition risk (e.g., the lagging might have prevented the heating tape from vibrating or abrasion). A risk assessment should be conducted to determine whether the electric trace heating must be isolated.

1.8. Field bus

Requirements for field bus intrinsically safe and field bus non-incentive systems (used for transmitting control and instrument data) are given in EN 60079-27.

2. Installation Requirements

The installation requirements for particular types of protection are given in EN 60079-14. The following sections detail the principal requirements for particular types of protection and, where necessary, provide further information.

2.1. Electrical apparatus with type of protection 'p.'

EN 60079-2 Explosive atmospheres. Equipment protection by pressurized enclosure 'p' details the construction and testing of pressurized apparatus. This apparatus relies on pressurization of the apparatus with a protective gas to exclude the ingress of any flammable gas from the wider hazardous area and ventilation to dilute and flush any flammable gas from the interior to ensure that gas concentration within the apparatus enclosure is below LFL before and during operation, and while internal temperatures may exceed the 'T' class following shut down. EN 60079-2 provides information showing the use of the infallible containment system concept to simplify the purging and dilution requirements. Note the following:

a. Ventilation EI 15 defines ventilation as “a general term to indicate air movement and replacement by fresh air.” Ventilation may be natural or artificial. Artificial ventilation refers to the ventilation of enclosures by mechanical means, such as fans blowing into or extracting air from the enclosure.
b. Pressurization This is a means whereby sources of ignition within apparatus installed in hazardous areas may be isolated from any surrounding explosive atmosphere. The pressure within the enclosure is maintained above that of the external atmosphere, thereby preventing the ingress of the external atmosphere. A pressure differential of 5 mm water gauge or approximately 0,5 m bar is adequate for this purpose.
c. Purging Where there is no internal release source within the apparatus enclosure, it is only necessary to provide sufficient ventilation after the pre-purge to maintain the pressure differential.
d. Continuous dilution Where there is an internal source of release, it is necessary to purge the atmosphere inside the apparatus enclosure with air drawn from a non-hazardous area. The released flammable material should be diluted such that it is maintained well below its LFL. For reassurance, the exhaust air should be ducted away from potential ignition sources.
e. Pre-purging Where there is a possibility that a flammable gas may have entered a machine/ apparatus while de-energized, it is necessary to purge the machine/ apparatus enclosure with air drawn from a non-hazardous area or with an inert gas such as nitrogen before any new power connection. Pre-purging with inert gas reduces the combustible gas concentration and reduces the oxygen concentration; note that inert gas may create an asphyxiation hazard. The amount of pre-purging required may be stated on the certification documents but should not be less than five times that of the internal free volume.
f. Actions on ventilation failure EI 15 guides the principals in determining actions in the event of loss of ventilation in hazardous areas. While the overriding priority is to restore ventilation in all cases of ventilation loss, the principles may be summarized as follows:

   With no internal source of release:

   The action should be determined based on local site conditions. However, where ventilated enclosures are in a Zone 1 area, the action following ventilation loss should be to:

   i. Operate an audio and visual alarm and arrange for urgent restoration of the ventilation.

ii. De-energize all ignition sources if a flammable gas is detected in the enclosure or ducting either during a ventilation failure or during a normal operation where ventilation is working. (Note that there may be instances where it is impossible to remove ignition sources, e.g., hot surfaces. These instances should be treated as special circumstances when determining a safe working practice.)

With an internal source of release:

iii. On loss of dilution ventilation, the development of a flammable atmosphere could be rapid, and the enclosure volume could become hazardous, dependent upon the grade of release. In these conditions, all ignition apparatus within the enclosure should be disconnected immediately by external isolation. In addition, an audiovisual alarm should be raised. Note that where hot surfaces may exist within the enclosure, the risk of ignition cannot easily be removed. Either the hot surface needs to be controlled, or the heat source needs to be tripped, and an emergency powered ventilation system provided.

iv. Where there is apparatus within the enclosure that is not capable of causing an ignition because it has a type of protection suitable (e.g., for use in Zone2) for the gas and a Zone 2 classification and does not require ventilation, the apparatus within the enclosure may be allowed to continue in operation.

v. Where the release of flammable gas from a primary source of release is small, it can be considered that the area will revert to a Zone 2, and apparatus suitable for Zone 2 use may be allowed to continue operation.

Because the Ex 'p' apparatus is predicated on sufficient dilution flow and pressurization, and for these to be maintained for set times before start-up and beyond shutdown, these protective functions should have quantified performance requirements. The facilities which provide these functions (e.g., purge timer, pressure sensor, trips to the motor starter, etc.) should be proof tested as part of the planned maintenance regime.

2.2. Other ventilated and pressurized systems

There are examples of ventilated and pressurized enclosures that use the same general concepts as the Ex 'p' apparatus but without being intended to comply fully with EN 60079-2(and hence not certified as Ex 'p'). Gas turbine enclosures are typical examples of enclosures that are provided with ventilation. These are invariably located within non-hazardous areas but may have internal sources of release. Where possible, gas detection on the cooling/ventilation air outlet should be provided. Consideration should be given to installing gas detection at the combustion air intake of the packages to satisfy a perceived situation not catered for by normal approaches to the risk of ignition. Actions following gas detection should be determined for the project-specific circumstance.

Note that the AIT of diesel mists and lubricating oil mists is relatively low (approximately 240 °C), so ignition of pressurized leaks of diesel or lubricating oil in gas turbines is likely; therefore, the installation of oil mist detection devices should be considered. Another example is a ventilated cabin (whether transportable or not) used for temporary applications. These cabins are generally used to house uncertified electrical apparatus. The cabin is pressurized and ventilated with air drawn from a non-hazardous area. To ensure that no stagnant areas remain before energization, adequate ventilation should be provided. Active protective functions should be provided to uncertified trip apparatus should pressurization or ventilation flow fail, e.g., if a door is left open.

2.3. Electrical apparatus with type of protection 'd'

EN 60079-1 Explosive atmosphere. Equipment protection by flameproof enclosures d' details the requirements for the construction and testing of flameproof apparatus. These are such as to ensure that the component or enclosure will withstand an internal explosion of the gas mixture for which it is certified and that the hot combustion products of any such explosion which might pass through specified flange and other gaps will be cooled sufficiently to avoid ignition of any external flammable atmosphere. The following points should also be considered:

- Unused cable entries are plugged with certified plugs.
- Cable connections are via certified glands.
- Conduit connections are via filled stopper (sealing) boxes at the point of entry.
- Bolts must have adequate tensile strength and be tightened to the torque specified by the equipment manufacturer.

Ingress protection is required to provide environmental protection and thereby prevent corrosion, particularly of the flame paths. To minimize corrosion and to ease assembly and disassembly, non-hardening grease-approved anti-corrosive agents and silicone-based greases (the latter not to be used on gas detection units) may be applied to the surfaces of flame paths and the fixing bolts.

Seals and gap faces should not be painted as this may open the flame path beyond the specified maximum. Aluminium paints should not be used on exterior surfaces, as an aluminium powder, in combination with rust, is a potential ignition source.

Flanges for Group IIA apparatus may have a single wrap of non-hardening grease-bearing textile tape to minimize any ingress of moisture and dirt. No tape should be used for Group IIB apparatus without first seeking the appropriate advice, and tape should not be used for Group IIC apparatus under any circumstances. If the tape is removed, the new tape should be re-applied upon re-assembly, comprising one layer only, with a slight overlap of 25 mm. The exterior of the enclosure and the outer flange edges may be painted after assembly to prevent corrosion. Still, care should be taken to prevent paint, grease, or corrosion products from opening the flame path.

Flange gaps are not to be obstructed by solid objects such as walls or machinery. The minimum clearances required are 40, 30, and 10 mm for gas sub-divisions IIC, IIB, and IIA, respectively.

Apparatus installed within a certified Ex 'd' enclosure should be as specified in the certification for that enclosure.

There should be no drilling or modification of the enclosure other than that shown on the certification details.

Entries into flameproof enclosures may be direct or indirect. Direct entry terminals are within the enclosure, and glands certified as either Ex 'd' or Ex 'de' should be used. Where the enclosure contains a source of ignition, barrier glands will be required if the internal free volume exceeds 2 dm^3 (two liters). For indirect entry, connections are brought from the enclosure through factory-installed bushings certified as part of the enclosure into a terminal chamber where Ex 'e' terminals and glands may be used.

Where protection is inherent in a component, the enclosure is only required to provide the degree of protection needed for environmental purposes.

Painting of Ex 'd' enclosures

The protection concept of Ex‘d equipment depends on machined mating flanges (the flame gap) with no deliberate gap, a defined maximum gap, and a defined path length across the flange. The principle is that any ignited products within the enclosure will be cooled by their passage between the flange faces and will be incapable of causing ignition of a potentially flammable atmosphere outside the enclosure.

Over-painting of Ex 'd' equipment should not present a problem, other than where a paint build-up can cause thermal problems. However, paint within the flame path may cause a problem in that:

- Any dried paint (or any other obstruction, e.g., rust) in the gap can prevent the flange from seating properly when it is next removed and reassembled.
- Any obstruction at the flame path outer edge, whether dried paint or adjacent equipment, can affect the way combustion products flow through the gap and create conditions for which the equipment has not been certified as suitable.

On some types of Ex equipment, e.g., motors, it can be challenging not to paint over the flange edges. EN 60079-14 allows painting of the Ex-enclosure after complete assembly. Therefore, there needs to be a practical balance between the benefits of painting versus the adverse effects of corrosion on the integrity of Ex 'd' equipment. The painting should be carried out with care using a minimal amount of paint of a type specified by the original equipment manufacturer (OEM).

2.4. Electrical apparatus with type of protection 'e.'

EN 60079-7 Explosive atmospheres. Equipment protection by increased safety 'e' details the requirements for the construction, testing, and marking of increased safety apparatus. The design ensures that arcs or sparks are not produced during normal operation and that temperatures are maintained below the maximum 'T' class, even during starting and under specified overload conditions. Protection against impact is also a specific requirement. Motor thermal protection devices require attention to be given to the settings used. These settings will determine the time allowed during starting to ensure that the maximum allowable temperature of internal surfaces to which a flammable atmosphere has access is not exceeded. The cumulative heating effect should be considered when automatic repeat starts are envisaged, including the requirement for re-start inhibition.

Environmental considerations may determine the need for enhanced ingress protection. The IP rating should be at least IP 54. Where a suitable location, e.g., deluge, cannot achieve essential mechanical and environmental protection, additional guards and canopies may be required. Care should be taken to ensure that such measures do not impair the integrity of the inherent protection features, for example, by restricting cooling airflow.

To maintain the ingress protection rating, conduit entries should be sealed. Cable glands will require an external ingress protection seal washer unless the length of the engaged thread is greater than 6 mm (normally five full threads); cable glands should be Ex 'e' certified. The following points are also relevant:

- Unused cable entries should be plugged in to maintain IP54.
- Glands should maintain IP54 to enclosure and cable. Top entries should be avoided outdoors.
- Equipment should be located so that enclosures and gaskets are not liable to mechanical damage or the effect of chemicals and their vapors. Materials are generally assessed by exposure to vapors, including acetone, benzene, hexane, methanol, carbon disulfide, and ethyl acetate. However, where the apparatus is located where there is a possibility of exposure to petroleum products, for example, top-loading gantries, written confirmation should be obtained from the manufacturer that the enclosure and gaskets are suitable.
- The concept of protection type Ex 'e' is fully reliant upon the requirement that arcing and hot surfaces (e.g., loose connections) will not occur. This concept, therefore, relies on a high degree of component integrity coupled with manufacturing quality

assurance. Installation should receive similar attention to quality and integrity, which should be reflected in an appropriate inspection and maintenance regime.

- Ex 'e' enclosures are not fault-rated as part of their Ex-certification. Therefore, users should determine if the enclosure is suitable for the fault level at the circuit where it is used. Ex 'e' terminations need to be tightened to the correct torque settings, and detailed inspections should check the torque as a potentially high-risk issue.

2.5. Electrical apparatus and systems with the type of protection 'i'

Intrinsically safe protection relies upon stored energy being limited to a level below that which could cause ignition, and power is limited to a level below that which could cause an incentive hot surface. EN 60079-11 Explosive atmospheres. Equipment protection by intrinsic safety 'i' specifies the construction and testing of intrinsically safe apparatus; EN 60079-25 Electrical apparatus for explosive gas atmospheres. Intrinsically safe systems extend guidance to intrinsically safe systems. Intrinsically safe equipment is categorized as either 'ia,' 'ib,' or 'ic.' Category 'ia' has the highest integrity and is the only type of intrinsically safe protection which may be used in Zone 0.

Energy and power limitations are achieved by 'Zener' barriers or other electronic power-limiting devices. These are usually in a non-hazardous area but may be located in a hazardous area, for example, protected within an Ex 'd' enclosure. Further safeguards are provided by design such that, even with a prescribed number of internal faults, safety should still be assured for Ex 'ia' and Ex 'ib' systems. Ex 'ic' systems have no fault tolerance, and the concept of infallible components and assemblies (used in Ex 'ia' and Ex 'ib' systems) does not apply to Ex 'ic' systems.

Stored energy depends on the capacitance and inductance of connecting cables, which are the user's responsibility. The design should be documented to confirm that the Ex 'i' system meets the requirements of the standards; when the operatorship of an installation changes hands, this documentation should be handed over so that the safety of this Ex 'i' system can continue to be managed correctly. Where Ex 'i' apparatus becomes obsolete, its replacement with a new type requires the whole system design, including cable properties, to be re-assessed. This may present particular difficulties where several items of Ex 'i' equipment are connected on one loop. EN 60079-14 describes the requirements for verification documents (drawings, schedules, maintenance manuals, etc.) to be prepared by the system designer, in which the items of electrical equipment and the electrical parameters of the system, including those of inter-connecting wiring, are specified. Any specific installation requirements will be detailed in the certification documents and the details supplied by the manufacturer or vendor. Installation requirements are detailed in EN 60079-14 and include the following:

- Screened or unscreened cables may be specified depending on the installation and possible interference from other circuits. The preferred arrangement for the earthing of instrument cable conducting screens, which are to be earthed at the non-hazardous area, i.e., the supply point, is shown.

- It is recommended that the cable outer sheath color should be light blue.
- The mixed use of intrinsically safe circuits and non-intrinsically safe circuits in the same multicore cable is not allowed.
- Intrinsically safe and non-intrinsically safe cables may be run on the same cable tray provided that: (a) a visible space separates them, and they are protected against mechanical damage, or (b) either the intrinsically safe or non-intrinsically safe cables are armored, metal sheathed or screened, and this protection is earthed.
- Where both intrinsically safe and non-intrinsically safe circuits are terminated in the same enclosure, it is essential to segregate (by a separating panel or a gap of 50 mm) and mark the intrinsically safe circuits and their wiring. Separate terminal rails for intrinsically safe circuits and non-intrinsically safe circuits should enhance safety. This potentially high-risk area should be checked as part of detailed inspections.
- Where earth connections are essential to preserving the system integrity (such as for diode barrier earth, barrier relay frame earth, associated transformer screen earth, or other intrinsically safe earth requirements), they should only be made to a dedicated intrinsically safe earthing bar mounted on insulators.
- For 'Zener' barriers, the earth impedance from the intrinsically safe earthing point to the main power system neutral earth point should not exceed 1,0 Ω. The minimum protective conductor size should take into consideration the risk of mechanical damage and should consist of two separate insulated conductors, each of a minimum cross-sectional area of 1,5 mm2 copper, each having an impedance of less than 1,0 Ω, thereby enabling continuity of the protective conductor to be tested without total disconnection. This is a potentially high-risk area and should be installed to ensure that the barrier protection will function and the earth resistance tested as part of detailed inspections.
- More than one earth connection is permitted on a circuit, provided it is galvanically separated into subcircuits, each of which has only one earth point.

2.6. Electrical apparatus with type of protection 'n.'

EN 60079-15 Electrical apparatus for explosive atmospheres. Construction test and marking of type of protection ‘n’ electrical apparatus details requirements for the construction, testing, and marking of apparatus with type of protection 'n.' Type 'n' apparatus is restricted in Zone 2 and non-hazardous areas.

The specification for type 'n' apparatus is derived from commercial apparatus by paying particular attention to bearings, clearances, and impact resistance of items such as fan casings and covers. Certified cable glands should be used, and an ingress protection rating of not less than IP54 should be maintained.

Apparatus sub-grouping does not normally apply to type 'n' apparatus. In special cases, the apparatus can be designed for a particular gas sub-group or gas. Details in associated documentation provided by the manufacturer must be complied with. Sub-divisions of protection type 'n' are included in EN 60079-15. These include:

- nA, non-sparking apparatus.
- nC, sparking apparatus in which the contacts are suitably protected other than by restricted breathing enclosures, energy limitation, or n- pressurization.
- nL, energy limited apparatus.
- nR, restricted breathing enclosures where the entry of the external atmosphere is restricted. Restricted breathing enclosures may contain infrequently operated contacts. Where conduit or ductwork is used, cable entries must be sealed close to the enclosure.
- nZ (or nP for Cenelec), An enclosure with n-pressurization (For more information, see EN 60079-2).

2.7. Electrical apparatus with certification type '1G.'

Type of protection '1G' enables apparatus to be specially designed and certified for a particular application and zone of use, including Zone 0 (For more information, see EN 60079-26 Explosive atmospheres). Equipment with equipment protection level (EPL) Ga). The special details concerning installation and use given in the certification documents and manufacturer's literature should be complied with.

2.8. Moveable apparatus

Where moveable apparatus is transported from one location to another, it must not be used unless it is suitable for the zone of operation, i.e., it must have the necessary type of protection, apparatus group, and temperature classification. Permits-to-work and other special measures, such as gas-freeing during decommissioning, movement, and subsequent re-use, are likely to be required. Cable terminations and associated ancillary equipment must also be suitable for the zone of use. Moveable apparatus designed and constructed to explosion protection standards is not generally suitable for all zones and every possible flammable atmosphere. Therefore, zone 2 moveable apparatus is not recommended since the boundary between Zone 2 and Zone 1 is not necessarily obvious on the plant (whereas Zone 0 can be easier to identify). Moveable apparatus should be specified for the most demanding gas group on the plant. Plug and socket connections should be certified as suitable for the particular zone. They should have mechanical/electrical interlocking to prevent danger during the insertion or removal of the plug.

Mobile apparatus may include electrically propelled or electrically powered apparatus and apparatus that itself generates electricity. In the latter case, consideration should be given to the mode of use and type of protection adopted for the prime mover and the electrical generator.

Personal apparatus certified to an appropriate standard may be taken into a hazardous area, e.g., certified torches or certified mobile phones. Uncertified apparatus may be used in certified gas-free conditions under the control of a Permit-to-Work. Uncertified apparatus such as watches, and hearing aids may be approved by site management for use in hazardous areas due to the very low power of such apparatus. Still, other personal apparatus should be assessed for use in the hazardous area or be allowed into the hazardous area only under gas-free conditions.

Where moveable apparatus is connected to the installation power supply or other utilities, consideration should be given to the security of supply required for safe operation, e.g., where this apparatus provides a life support function (such as supplying breathable air to divers). Consideration should be given to any safety shutdown, e.g., a gas release occurs.

2.9. Electrical apparatus with other types of protection

Other types of protection include (Type 'o' - Oil immersion Zones 1 and 2, Type 'q' - Sand filled Zones 1&2, and Type 'm' - Encapsulation Zones 1 and 2)

Their application and use are detailed in EN 60079-6 Explosive atmospheres. Equipment protected by oil immersion 'o', EN 60079-5 Explosive atmospheres. Equipment protection by powder filling 'q' and EN 60079-18 Electrical apparatus for explosive atmospheres. Construction test and marking of type of protection encapsulation 'm' electrical apparatus.

2.10. High voltage motors

The standards for protection type Ex 'n' and Ex 'e' have developed significantly in light of high voltage (HV) motors incidents. The changes largely reflect an increased understanding of two sources of potential ignition: rotor sparking and stator sparking. Rotor sparking is caused by the interruption of stray currents flowing through the rotor core material rather than the conductor bars. It occurs only on startup due to the increased forces on the bars. The standards require a risk assessment, either a typing test to prove that incentive sparking does not occur or special precautions (which are the responsibility of the user); an X indicates these special precautions on the certificate.

A stator-type test is required for stator sparking in Ex 'e' machines. For Ex 'n' machines, a stator risk assessment is undertaken; when required, a typing test is conducted, or special precautions should be employed by the user (indicated by an X on the certificate). HV motors certified to current standards (EN 60079-15 for Ex ‘n’, and EN 60079-7 for Ex 'e') should incorporate these developments. For motors certified to older standards (including Ex 'N' motors), these tests and special measures were not necessarily part of the certification process. Users should therefore assess the risks associated with such HV motors and, where appropriate, follow the special measures recommended by the current standards, i.e., pressurization, pre-start purge, or gas detection within the motor enclosure. There are other issues associated with HV motors, including:

- Type Ex 'n', Ex 'e,' and Ex 'N' motors should not be used where the probability of a flammable gas release cannot be disassociated with the start sequence as an independent event, e.g., the oil seal systems of gas compressors are known to produce such releases during starting and should be subject to assessment. Consequently, sealing, or lubricating oil systems shared between a motor, and its driven compressor is not recommended.
- A non-sinusoidal supply may increase the running temperature of the machine so that some derating may be appropriate.
- An overtemperature alarm/trip function should be provided to protect against overheating, e.g., caused by cooling loss, which might result in the 'T' class rating being exceeded or the machine being damaged.
- Some large HV motors depend on an active protection function, such as protection relays, to ensure that the 'T' class rating is not exceeded. This protective function should be managed, and proof tested.
- Where a motor drives a high inertia load and torsional resonance is possible, or auto restarts result in out-of-phase starting, the risks associated with additional heating and an extended rotor sparking should be assessed.
- Stator sparking might be present at all times, i.e., not just during start-up. Consideration should be given to identify whether current control measures, e.g., pre-start purging are appropriate, and if not appropriate, consider additional control measures, e.g., pressurization.

2.11. Variable speed Ex motors

Special conditions apply to the use of variable speed drives supplying Ex motors that have to be considered to reduce the risk of the motor exceeding its 'T' class rating or causing a failure resulting in a source of ignition:

- Variable speed operation will alter the rate of cooling air to the motor stator and rotor at a lower speed than its full-speed rated design, which may cause an increase in temperature. This should be accounted for in matching the variable speed drive and motor rating to the load torque/speed relationship or fitting separately driven ventilation fans.

- Motor stator windings should have embedded temperature protection (alarm and trip) fitted with testing provisions.
- Reduced voltage operation will cause higher current and, therefore, an increase in motor temperature, e.g., if the voltage/frequency ratio of the variable speed drive is not adequately matched to the motor characteristics or does not take account of voltage drop due to variable speed drive output harmonic filters.
- Motor heating due to harmonic content in the variable speed drive output supply may require derating the motor.
- Stress on the stator winding insulation system due to short waveform rise times and voltage overshoots in the variable speed drive output may require waveform filtering or up rating of the stator winding insulation system.
- Bearing currents due to magnetic asymmetry, electrostatic build-up, or high-frequency voltages that can be mitigated by specifying insulated motor bearings.

Consideration should also be given to the effects of harmonics produced by variable speed drives (and thyristor-controlled heaters) on the connected motor and other electrical equipment connected to the electrical system.

Non-linear loads such as variable speed drives create harmonic currents and voltages, which can adversely affect the quality of the electrical supply system. This may cause the operating temperature of equipment to increase and adversely affect other electrical equipment. Design reviews, power systems analysis, and appropriate systems testing should be conducted to determine whether the electrical supply is within acceptable limits. This potential problem may be more prevalent on offshore installations due to the high numbers of large non-linear loads, such as downhole pumps, and the high power demand concentration.

2.12. Non-electrical apparatus with type of protection 'fr.'

EN 13463-2 Non-electrical equipment for use in potentially explosive atmospheres. Protection by flow-restricting enclosure details requirements for constructing and testing non-electrical flow-restricting apparatus. These ensure that an explosive atmosphere surrounding the enclosure cannot penetrate it, whether through ventilation, diffusion, or by equalization of pressure differences (i.e., breathing, such as can be caused by temperature changes). These enclosures can prevent a surrounding flammable atmosphere from reaching any internal ignition sources with adequate probability if that surrounding atmosphere becomes flammable only rarely and for short durations. This type of protection is suitable for Zone 2 only. Attention should be paid to the following points:

- Power dissipation within the enclosure should be limited to ensure a limited temperature increase and a limited rate of temperature change. Anti-frost and anti-condensation heaters should be considered.
- Heating by solar radiation and cooling by rain should be considered.
- Failure of gaskets could allow higher breathing rates, so the manufacturer's recommendations on the type of gasket and replacement frequency should be followed.

2.13. Non-electrical apparatus with type of protection 'd.'

EN 13463-3 Non-electrical equipment for use in potentially explosive atmospheres. Protection by flame-proof enclosure 'd' details requirements for constructing and testing non-electrical flameproof apparatus. These are similar to the requirements for electrical apparatus with Ex 'd' type protection. Still, attention should be paid to the difference regarding pipe entries to the enclosure should be treated similarly to cable glands or conduit entries.

2.14. Non-electrical apparatus with type of protection 'c.'

EN 13463-5 Non-electrical equipment for use in potentially explosive atmospheres. Protection by constructional safety 'c' details the requirements for constructing and testing non-electrical apparatus protected by constructional safety. These are to ensure that measures are applied to protect against the possibility of ignition from hot surfaces, sparks, and adiabatic compression generated by moving parts. Therefore, this type of apparatus contains no ignition source in normal operation. In addition, good engineering practice is applied so that the risk of mechanical failure, which could result in incentive temperatures or sparks, is reduced to a low level. Consideration should be given to the following points:

- Moving parts could fail prematurely and result in high vibration, reduced clearances, impact, or friction.
- Moving parts may depend on lubrication to prevent an excessive temperature rise.
- Bearings may require attention to fit, alignment, and protection against water or solids ingress and may require periodic replacement.
- Belt drives/conveyors should be non-combustible and anti-static. Correct tension and alignment should be maintained. This condition should be detected where the belt can exceed the maximum allowable temperature when stalled.
- Hydrostatic/hydrokinetic/pneumatic apparatus should employ non-combustible fluid, and the maximum temperature of any fluid which can be released should not exceed the maximum surface temperature of the apparatus.

- Clutches and couplings create frictional heating and sparks; these should be limited by attention to slippage and engaging time. This apparatus can also create electrostatic discharge.
- Brakes should be able to dissipate the maximum kinetic energy without exceeding the maximum surface temperature or generating incentive sparks.

2.15. Non-electrical apparatus with type of protection 'b.'

EN 13463-6 Non-electrical equipment for use in potentially explosive atmospheres Protection by control of ignition sources 'b' details the requirements for constructing and testing non-electrical apparatus protected by ignition sources. The apparatus incorporates sensors that detect an impending operation likely to cause ignition of any surrounding atmosphere and initiates automatic or manual ignition control measures to prevent a potential ignition source from becoming an effective ignition source. Critical to the success of this technique is the following:

- The speed of change of the potential ignition source becomes an effective source of ignition (e.g., the rate of temperature rises and the difference between normal and critical temperatures).
- The response time of the sensor.
- The response time of the ignition prevention system.
- The probability of correct operation of the protective function, i.e., the Ignition Prevention Level (IPL) of the ignition prevention system.

Note: A control panel intended for installation in a non-hazardous area that interprets the sensor signal(s) and provides controlling output signal(s) may be a 'device' as defined by EPSR, and if so, should be CE marked. Note also that the IPL is a similar concept to SIL and should attract similar management. It is considered that IPL 1 is broadly equivalent to SIL 1 and that IPL 2 is broadly equivalent to SIL 2.

2.16. Non-electrical apparatus with type of protection 'k.'

EN 13463-8 Non-electrical equipment for use in potentially explosive atmospheres. Protection by liquid immersion 'k' details the requirements for constructing and testing non-electrical apparatus protected by liquid immersion. This type of apparatus renders potential ignition sources ineffective by submersing them in a protective liquid or coating them in a flowing film of protective liquid. This liquid may have other functions, e.g., as a lubricant, coolant, hydraulic power transmission medium, or the process liquid itself. Examples are immersed brakes, submersible pumps, hydraulic pumps, oil-filled gearboxes, etc. This standard differs from EN 60079-6 in those conductive liquids, and flammable liquids are allowed. Users should pay attention to the maintenance of the liquid level between the maximum and minimum levels specified, the maximum working angle, the use of the correct liquid, and its periodic replacement or replenishment.

A.6. Inspection, Maintenance, and Testing

1. General

To minimize the risk of ignition in hazardous areas, a high standard of inspection and maintenance of Ex equipment and systems is essential. This should be undertaken by experienced and competent personnel. The technical person should manage ex-inspections with executive function (TPEF).

Inspection and maintenance ensure that equipment remains fit for purpose throughout its lifetime in service. It remains functional and retains all of its Ex-design features. General recommendations for inspection and maintenance of electrical installations are given in EN 60079-17 Explosive atmospheres. Electrical installations inspection and maintenance.

2. Inspection Strategies

To help future maintenance and to help demonstrate that ignition hazards are being appropriately managed, an Ex-strategy should be in place, which sets out the strategy for the management of ignition risks. This should include the following requirements:

- An Ex-register (inventory) of all Ex-certified apparatus: this should be updated when required to record changes in apparatus. For each Ex-certified apparatus, the Ex-register should include the identification number (tag), location, type of protection temperature class, and subgroup (where relevant).
- An area classification drawing that includes details of the properties of the flammable fluid(s) expected to be present in different parts of the installation; relevant details include a boiling point or vapor pressure at ambient temperature, ignition temperature, flash point, flammable limits, and relative density. This applies to normal atmospheric conditions, including normal variations in temperature and atmospheric pressure; where these cannot be assumed or where a raised oxygen content of the atmosphere is possible, specialist advice should be sought. Some types of explosion-protected apparatus contain flammable fluids within the enclosure. This should have been considered when the apparatus was certified, but it may impact the overall area classification; this should be checked in case the internal release source affects zoning around that apparatus.
- An Ex-inspection and maintenance strategy covers the complete life cycle of the Ex-apparatus from design, installation, commissioning, Ex initial, periodic, and sampling inspections through to decommissioning. EN 60079-17 defines three grades of inspection of Ex electrical equipment, visual, close, and detailed, and requires periodic visual or close inspections, normally at three-yearly intervals, but allows flexibility in the inspection grade without any recognition of the different ignition risks which may

apply. EN 60079-17 allows a sampling approach to be applied to all three grades of Ex inspection but does not provide guidance on how this might be achieved. This approach should not be considered ALARP since neither risk nor cost is considered explicitly. Because EN 60079-17 provides some flexibility over grades of inspection and how much apparatus is inspected, a wide range of approaches has been developed, which users may not be able to justify.

This guideline for managing the inspection of Ex electrical equipment ignition risk in support of IEC 60079-17 advocates an RBI approach that recognizes that all the Ex electrical equipment installed will not present the same ignition risk. Ignition risk is dependent upon the hazardous area classification, i.e., with Zone 0 presenting higher ignition risks than Zones 1 and 2, and the level of Ex protection, i.e., Ex 'e' equipment presenting a higher ignition risk than Ex 'I' equipment (as intrinsically safe equipment should not produce an incentive spark). This RBI approach may consider many other factors, e.g., the possibility of mechanical damage (e.g., around the drill floor area). Adopting this RBI approach will result in high-risk equipment being inspected more rigorously than low-risk equipment, which is considered ALARP.

The Ex-strategy should include a strong emphasis on Ex inspection history, Ex failure codes, and trend analysis (to highlight generic Ex failures, etc.) together with the importance of audit and review of this inspection data to ensure that the Ex-strategy is appropriate, targeted, and using all resources (e.g., electrical technicians) in the most effective manner. Any deficiencies highlighted should be recorded, and changes to the Ex-strategy should be implemented as required. This approach may also be applied to non-electrical equipment.

3. Inspection of Apparatus

The level of inspections may be defined as one of three grades: visual, close, or detailed, as determined by the TPEF.

3.1. Grades of inspection

The following grades of inspection are based on the definitions in EN 60079-17:

- ***Visual*** - An inspection that identifies defects without using access equipment or tools. At a minimum, this will be visual. Binoculars and remote heat-detecting equipment may be useful in some situations. (Note: Ex-visual inspections play a vital role in ensuring that the Ex-apparatus is externally inspected and is fit for purpose since this does not require any intrusive work.)
- ***Close*** - An inspection that encompasses those aspects covered by visual inspection and identifies those defects (e.g., loose bolts) that will be apparent only by using access equipment (e.g., scaffolding) and tools. Close inspections do not normally require the enclosure to be opened or the equipment to be de-energized.

- ***Detailed*** - An inspection that encompasses those aspects covered by close inspection and, in addition, identifies those defects (e.g., loose terminations and ingress of water), which will only be apparent by opening the enclosure and using tools and test equipment.

3.2. Types of inspection

Following an 'initial' inspection, either 'periodic' inspection or 'continuous supervision' may be employed. Sample inspection techniques may be applied to both the latter approaches.

Initial inspections are inspections of all apparatus, systems, and installations before they are brought into service to check that the selected type of protection and its installation is appropriate. Initial inspections will be detailed, as referred to in EN 60079-17. Results should be recorded. The installation is likely to be successful only if competent personnel and Quality Assurance (QA) checks are employed. Full inspection records should be created, and these should be audited and reviewed by the installation Duty Holder. Achieving a robust initial inspection and associated records cannot be over-emphasized in controlling Ex ignition risks throughout their life cycle. The level of future inspections may be one of three visual, close, or detailed grades as determined by the TPEF.

- ***Periodic inspections*** - Periodic inspections are inspections of all apparatus carried out routinely after being put into service. They may be visual or close. A visual or close periodic inspection may lead to the need for a detailed inspection. The interval between periodic inspections should not normally exceed three years without expert advice. Inspection results should be recorded. Due to environmental or increased safety requirements, equipment with a more onerous duty of use may require more frequent inspection. A risk assessment should determine this. An inspection record should be kept for each Ex-apparatus, which should record all defects found. Such inspection records provide suitable evidence of completing the inspections and that the Ex-strategy is appropriate.

- ***Sample inspections*** - Sample inspections are inspections of a proportion of the installed apparatus. They may be visual, close, or detailed; however, it is recommended that sampling is not applied to visual inspections. The size and composition of the samples should be determined concerning the purpose of the inspection by the TPEF. Sampling should not be applied to close and detailed inspections until the user has robust information (i.e., the Ex-inspection history), which gives the user appropriate confidence and knowledge in the status of the Ex-apparatus being fit for purpose.

- ***Continuous supervision*** - This takes advantage of the fact that skilled personnel, familiar with the fabric of the electrical installation and with explosion protection, are constantly aware of the installation and its state of maintenance and repair. This activity should be supervised by a scheme manager, i.e., the TPEF. It requires formal training in the concept and an ability to be audited to prove effectiveness. This approach uses the same grades of inspection available for periodic inspection, and the appropriate grade is selected by the skilled person involved in the inspection together with the TPEF. An inspection record should be kept, and this should record all defects. Such inspection records provide evidence of completing the inspections and that the Ex-strategy is appropriate.

4. Model Sampling Methodology

The following section summarizes the sampling methodology detailed in EI Guidelines for managing the inspection of Ex electrical equipment ignition risk in support of IEC 60079-17. For inspections where sampling techniques are employed, equipment is grouped into lots of similar types of Ex equipment. For each lot, an appropriate inspection grade is defined, informed by previous inspection work. The grades of inspection and the periodicity should be refined over time as the results of inspection work, previous experience, and knowledge of performance, along with records of faults and their trends, become available. The size of the sample to be taken is defined. It depends on the lot size, the commonly assumed failure rate for that equipment, the inspection and acceptance safety level (ASL) category, and a derived rejection criterion. The sample should be a random representative sample taken from the Ex-register and not selected by the technician carrying out the inspection. The inspection frequency depends on equipment criticality, lot size, ASL, confidence in historical records, and other constraints. The inspection is carried out on a random sample of the Ex-equipment in that lot. The total number of faulty equipment (weighted according to the probability of ignition) is calculated, and if the number of faulty apparatuses is above the rejection criterion, rules are used for dealing with the remainder of that lot; this may involve inspection of a further random sample, increasing the level of inspection, etc., according to the findings. Faults are scrutinized for common mode mechanisms; where a generic fault is suspected, another sample may be inspected, and in other cases, the entire lot is inspected. Faulty equipment may require to be removed from service awaiting repair. This approach can be used for certified equipment.

As the results of inspections become available, the sampling and inspection regime can be optimized to provide a cost-effective and safe solution. Full details of all these processes are given in the EI Guidelines for managing the inspection of Ex electrical equipment ignition risk in support of IEC 60079-17, which will need to be consulted to draw up an inspection scheme of this kind. A standard Safety Management System (SMS) is recommended to manage this approach, and a methodology for organizations to carry out a gap analysis to compare their current practices with those in EI Guidelines for managing the inspection of Ex electrical equipment ignition risk in support of IEC 60079-17 and show that they are demonstrably ALARP.

For offshore installations, certified Ex equipment is recognized as an ignition risk and is regarded as a Safety Critical Element (SCE) requiring a higher level of inspection and maintenance and the examination scheme to be subject to independent verification.

5. Inspections Involving Electrical Testing

For electric cables and associated apparatus, the following items require testing:

- Insulation resistance.
- Earth electrode resistance.
- Earth loop impedance test.
- Continuity of protective and bonding conductors.
- Operation and setting of protective devices.

The testing frequency should depend upon the type of equipment or system and its age, environment, and duty of use. Comparisons should be made with the results of previous tests. For continuously operating plants, it is considered appropriate to carry out periodic tests on a sample basis. These inspections can be effectively carried out during Ex initial and detailed inspections, which require the electrical equipment to be isolated. The possibility of stored energy in the complete circuit under test should be verified. Unless this is shown to be incapable of producing incentive sparking, the area should be tested and proven gas-free before testing commences.

5.1. Insulation resistance testing

If test instruments are to be used in a hazardous area, they should be certified as intrinsically safe for use in hazardous areas. When an insulation resistance tester applies 500 V DC. to conductors, a charge will be stored within the cable due to capacitance. This charge could remain after the tester has been disconnected or prove an incentive if the charged cable discharges via a fault. Most modern insulation resistance test instruments have a built-in discharge facility which is always operational except when the test button is depressed. Where this facility is unavailable, the cable should be discharged from within the non-hazardous area. Note: the intrinsically safe certification of Ex 'i' test instruments applies only to the instrument itself; when used on any circuit that could store electrical energy, the act of testing is not necessarily intrinsically safe. Care should be exercised when testing for insulation resistance to ensure that the test voltage does not damage sensitive electronic circuits.

5.2. Earth loop impedance testing

Earth loop impedance testing might generate high values of test current in the region of 30 – 200 A to be imposed on the electrical system. Suppose this testing is carried out on electrical systems located in hazardous areas or locations where such test currents are likely to stray into hazardous areas. In that case, such test currents will present an ignition risk. Therefore, earth loop impedance tests should be carried out on all electrical systems before hydrocarbons are present, e.g., during the Ex initial inspection phase (i.e., during the commissioning of the new plant). Such test results can then be used as a datum to be referred to during the installation's life cycle.

Where possible routine earth loop impedance testing should be carried out during plant shutdowns when the area has been classified as being gas-free, however, care needs to be exercised where stray test currents might migrate back to the source of supply via a hazardous area that still contains hydrocarbons, i.e., is not classified as gas-free.

Having established the initial electrical systems' earth loop impedance values, it is prudent to consider a method to verify that this remains suitable during its life cycle and a method that is safe to be carried out with electrical systems present within a flammable area. One method of achieving this is to use a high current conductivity test. Ideally, this should be carried out at the same time as the initial earth loop impedance tests to provide a datum for reference and verify future test results.

It is recommended that this testing is carried out during an Ex detailed inspection of the field device, e.g., Ex motor, Ex light fitting, etc., and can be carried out as part of a random sample (as per Ex detailed inspection requirements). This random high-level conductivity test should be compared to the previous reading, and a judgment should be made on whether this is satisfactory. Where readings are significantly different from previous readings, this should be investigated. Further tests should be carried out on similar electrical equipment in the same location to determine the scale of any degradation in the earthing/bonding of electrical equipment. An example method of using a conductivity meter to verify the life cycle integrity of protective conductors as part of earth loop impedance tests.

Associated electrical equipment will need to be appropriately risk assessed, electrically isolated, and a Permit-to-Work issued to carry out the following work/testing:

- Using a high current conductor tester at the field device, e.g., Ex motor, Ex light fitting, etc., will require a gas-free certificate and constant gas testing during test periods.
- At the source of supply, carry out a conductivity test from the supply switchboard to the main incoming earth bar to get R (main)
- At the field device end, e.g., Ex motor, Ex light fitting, etc., remove any two-phase conductors and connect them to an insulated connector.
- Replace the field device with Ex enclosure covers to retain Ex integrity.
- At the source of supply, e.g., the motor starter connects the high current conductor and tests between the two-phase conductors: divide the reading by 2 to get R (conductor).

- At the field, the device end connects the high current conductor between the field device outer enclosure and the local earthing point to get R (remote)
- The total high current conductivity test is $R_{(total)} = R_{(main)} + R_{(conductor)} + R_{(remote)}$.

$R_{(total)}$ should be compared with the initial or datum high current conductivity test to determine whether there have been any significant changes.

5.3. Earth electrode resistance

Earth electrodes should be tested individually. The plant should not be unearthed during testing unless it has been electrically isolated. Knowledge of earthing arrangements for the entire installation is required. Current injection (heavy current) testing should be performed as part of the Ex-initial inspection and, in the operational phase, may be undertaken subject to risk assessment. (Heavy current testing may cause localized heating effects or sparking, and so should be carried out only under gas-free conditions.)

5.4. Continuity of protective and bonding conductors

This should preferably be tested using a significant current to detect better bad joints and any serious localized earthing conductor corrosion. Before commissioning, continuity tests should be carried out using the substantial current method and a low current instrument that has been certified for use in intrinsically safe circuits. Note that heavy current testing may cause localized heating effects or sparking and should be carried out only under gas-free conditions. Also, note that the capacitance and inductance of the circuit under test may invalidate the certification requirements of an Ex 'i' test instrument. Provided that the results compare favourably, a meter certified for use in intrinsically safe circuits may be used for future purposes when intrinsically safe testing is carried out.

5.5. Operation and setting of protective devices

Routine trip testing of protective devices is required for all electrical systems and apparatus. However, owing to the potential ignition risk for Ex electrical equipment, this testing is more pertinent to ensure that its 'T' class (e.g., T3 (200°C)) is not exceeded. Motor protection relay settings should be checked, and tripping capability should be verified. Where current injection techniques are used, this should be under skilled supervision. Any other inspection activity during testing likely to affect the integrity of any explosion-protected apparatus, such as opening covers, should only be undertaken in a controlled, gas-free atmosphere. Where secondary injection testing cannot be carried out, as a minimum, molded case and other circuit breakers should be operated on and off to confirm functionality. Active protection should have defined performance requirements, and periodic proof tests are required to ensure these requirements continue to be met.

6. Competencies for Inspection and Maintenance Personnel

Competent personnel should only carry out inspection and maintenance work within a hazardous area. Personnel should have completed an assessed training course covering the core principles of the knowledge and practical elements required for this work. Personnel with a certificate of core competence (or equivalent) should, before being considered competent, have completed a period of work under the close supervision of a more senior competent person.

The core competencies should cover hazardous areas, types of explosion protection, selection of apparatus, and general installation practices. Within the UK, a vocational qualification incorporating a Comp-Ex certificate of core competency is one method of demonstrating that the named person is sufficiently competent to avoid danger and has knowledge relevant to these topics. Similarly, such competency schemes may be used for personnel involved with non-electrical equipment.

Within the UK, any person carrying out work on or near electrical equipment must have the competence to satisfy EAW Regulation 16 'No person shall be engaged in any work activity where technical knowledge or experience is necessary to prevent danger or, where appropriate, injury, unless he possesses such knowledge or experience, or is under such degree of supervision as may be appropriate having regard to the nature of the work.' EN 60079-14 and EN 60079-17 provide information on responsible persons and designers' knowledge, skills, and competencies. It is recommended that refresher training be given regularly, such as every three to five years. Core competency certification is invalid after five years if not refreshed.

An awareness of DSEAR should be developed, as these address user applications. Since EPSRs are relatively recent, non-electrical technicians may be less aware of the detailed requirements for apparatus explosion protection than an instrument or electrical technicians. This should be addressed in training.

7. Records

The Provision and Use of Work Equipment Regulations 1998 (PUWER) create a duty to keep inspection records. These records are a fundamental tool that enables the duty holder to manage the inspection arrangements for the Ex-apparatus. Record keeping is normally based on a computer-based maintenance management system. It is important to record the as-found condition of the apparatus, the nature of any faults, the date of inspection, remedial work, etc. Fault codes are a useful means of recording faults and facilitating the important safety management processes of the set of key performance indicators, monitoring, trend analysis, audit, and review.

Where maintenance is undertaken concurrently with inspection and test work, separate maintenance and inspection reports should be completed. The inspection and test report should be completed in a manner that provides sufficient detail to enable a subsequent audit. All records relating to inspection, testing, maintenance, and repair of apparatus and systems installed in hazardous areas should be stored securely. These records should be kept in electronic or paper form, together with a copy of the area classification drawing. They will serve as evidence in support of any decision to perform work at a greater or lesser frequency than that described in EN 60079-17.

A dossier should be created and retained in which copies of all equipment certification details are maintained, together with relevant information relating to types of protection where ownership/operatorship of the installation changes hands. These records and all technical documentation should be transferred to the new owner/operator, who should integrate this information into a safety management system.

8. Maintenance of Apparatus

EN 60079-19 Explosive atmospheres. Equipment repair, overhaul, and reclamation provide detail on repairs and overhaul. Where replacement parts or alterations are required, they should conform with any certification requirements and details from the manufacturer. Alterations that impact the explosion protection concept should not be made as this could compromise safety and invalidate the Declaration of Conformity. Any work other than the replacement of parts on a like-for-like basis, or alteration within the manufacturer's specification, should be treated as a change and subjected to a Management of Change (MoC) process.

Apparatus other than protection type Ex 'i' should not normally be opened in a hazardous area until it has been isolated from its source of power and measures have been taken to prevent it from being reconnected before reassembly. Attention should be given to apparatus which may remain live after isolation, e.g., while the rotating plant runs down to the stationary condition or with power capacitors. In circumstances where tests need to be conducted with live apparatus not fully assembled, this work should be undertaken under the control of a Permit-to-Work and certified gas-free conditions.

A.7. Electrical Isolation Procedures

Proper electrical isolations and proving dead are important for protecting personnel against electric shock and arc flash hazards. Electrical safety isolation procedures should be formalized in written procedures. A Permit-to-Work or equivalent system may form part of these procedures. The following information is provided to assist in the formation of such isolation procedures. Issues may include, for example, potential arcing hazards, the integrity of interlocks, earthing requirements, synchronization of generators, remote or local switching (which may require to be conducted with switchgear doors closed), isolation (as opposed to simply switching off), proving dead and appropriate test equipment. Isolations should be secured, as required by EAW Regulations 12(1) and 12(2), to ensure that they cannot be removed inadvertently. Before carrying out any work, an assessment for determining safe working practices should be completed, and this should typically cover the following:

- All equipment is to be adequately identified (labelled).
- Adequate information to be available, e.g., drawings, manufacturer's maintenance, testing procedures, etc.
- The personnel carrying out the tasks need to be suitably competent.
- The equipment should be surveyed before carrying out such tasks to check its suitability, e.g., with the isolator switched off, determine whether any back feeds are still live, live conductors are adequately screened, etc., and appropriate risk control measures should be put in place.

Personnel should use appropriate Personal Protective Equipment (PPE), but only as a final layer of protection against electric shock or arcing as determined by the risk assessment and not as the primary protection. This PPE may include arc-flash-proof coveralls, visors, and gloves and may be required during switching operations. PPE should generally be anti-static; where anti-static footwear is worn; this should have a high enough resistance to provide appropriate protection for electrical personnel against electric shock. The wider implications of the isolation in the operational context of the plant should be considered, e.g., the impact on electrically powered safety critical systems. Remote switching should be employed when switching HV circuits, particularly on older oil-filled equipment.

There may be instances where the switchgear is old and cannot be locked off conventionally. It may also not have clear markings indicating the 'off' position. Users should consider retrofitting locking-off mechanisms, and appropriate control measures should be put in place, as many incidents can occur on HV and LV switches, breakers, and fuses when racking in or out of the service position when the service conductors are live. On older types of electrical equipment, such as uninterruptible power supplies, variable speed drives, battery chargers, etc., the electronic tuning and troubleshooting diagnostics might be located adjacent to live conductors, which present an electric shock or arc flash hazard. In these cases, additional precautions will be necessary. Further information is available in HSG85 Electricity at work – Safe working practices.

Annex B - How to Read Markings of Electrical Equipment for Hazardous Areas

Figure 4 illustrates typical Ex markings used on nameplates of modern Ex instruments certified per the EU ATEX directive. The marking string can be divided into two parts because the first part is required by directive 2014/34/EU and only concerns devices with an ATEX certificate. ATEX is mandatory for all equipment sold in the EU. The second part is common to ATEX and IECEx-certified devices and is defined in 60079-0 standards, which specify general requirements for Ex apparatus. One nameplate can contain both ATEX / IECEx certifications, but a device may have its nameplate for ATEX and IECEx.

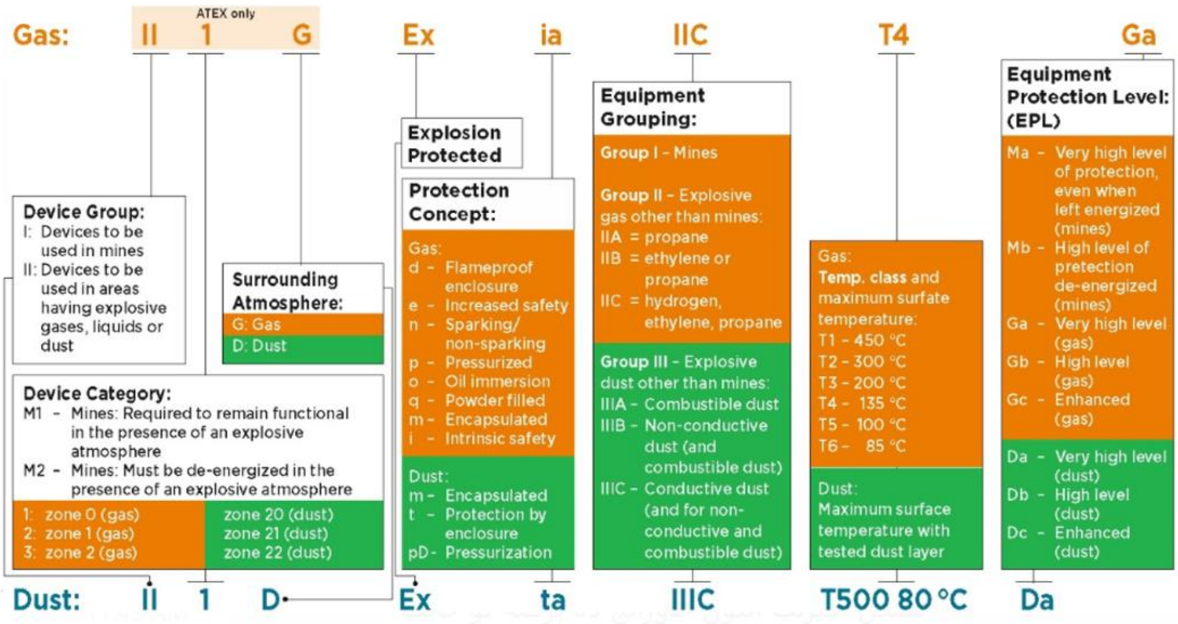

***Figure 4**. ATEX and IECEX marking.*

1. What is ATEX coding?

The ATEX code is an alphanumeric string that denotes the product's certification and the environment and conditions it is suitable for.

The code can be broken down into a prefix, for example, CE0518 Ex II 2 G, and a suffix, Ex d IIC T6 Gb. Products may carry more than one suffix for the same prefix, allowing the definition of applicability for different environments, for example, Gas hazards.

2. What does the ATEX prefix mean?

The prefix has five sections:

- The first part confirms that the product complies with the European Directive (CE) and the reference number for the notified body that produced the certification.
- The second part is the ATEX logo, shown as Ex within a hexagon, as shown in Figure 5.

***Figure 5**. ATEX logo.*

- The third section defines the Equipment Group, and there are only two options for this, I or II, where I relate to using in Mines where firedamp may be present and II becoming anywhere other than mines. Most labels in industrial applications are likely to be Equipment Group II.
- The fourth part of the coding is the Equipment Category, of which there are five variants, M1 & M2 for mine applications and 1, 2, or 3 for anything other than mining. As the number increases, the protection level falls such that the highest protection will always be 1 or M1. Some certifications can state more than one Equipment Category.
- The final part of the suffix refers to the Environment, which will be G for gases or vapors and D for combustible dust. Some devices may be dual-certified for both Gas and Dust environments, meaning there will be a separate suffix to define the certification reached.

3. What does the ATEX suffix mean?

The ATEX suffix details how the device is protected from causing an explosion when installed in a hazardous area and what those hazard conditions are. The ATEX suffix always starts with Ex to indicate explosion protection and is then followed by four more sections, whether for Gas or Dust applications. Many devices may show a separate suffix for Gas and one for Dust because they have achieved testing and certification for both hazards.

Types of protection include many different methods of preventing ignition in a hazardous environment, and Types of Protection define which has been used in a particular case. After the initial (Ex) will, follow either one or two letters to indicate the type of Protection. Some require a second character to stipulate the level of protection and, therefore, which hazardous area Zone or Category they apply to. The most common Types of Protection employed with valves and measuring instruments are d (Ex d), e (Ex e), m (Ex m), n (Ex n), and ia (Ex ia). Types d, e, and m are all suitable for Zones 1 or 2, Category 2 or 3 unless they have a second character of a, b, or c, further limiting this. Note that types of protection can be combined, and (de), (em), or (me) are all commonly seen. Ex d is commonly and incorrectly known as explosion-proof but is described as flameproof. The housing will contain a flame without allowing it to escape into the hazardous atmosphere. Ex e means increased safety, referring to the lack of arcs, sparks, or hot surfaces. Ex m is an encapsulation that prevents the atmosphere from reaching any potentially incentive parts. Ex n is similar to Ex m and means non-sparking, which limits it to Zone 2, and Category 3 environments. Ex ia or intrinsically safe is suitable for Zone 0 or 20, Category 1. This is achieved by limiting the energy of sparks and surface temperatures through very low power requirements.

4. Gas or dust?

The next section of the coding refers to the Gas Group or Dust Type of the hazardous environment for which compliance has been certified.

- (I) is solely for mining applications.
- (II) covers all gas hazards and is shown as IIA, IIB, or IIC, which relates to the potential gases that may be present.
- (III) indicates dust hazards and is split into IIIA, IIIB, and IIIC categories. IIA relates to combustible flying. IIIB is for non-conductive dust, and IIIC is for conductive dust.

In general, whether it is marked as II or III for the gas group, the C rating is always the safest as it relates to the biggest risk protection.

5. Temperature class?

The Temperature Class rating of T1, T2, T3, T4, T5, or T6 for gases, indicates the classification for the maximum surface temperature for the device and, therefore, the distance to the potential ignition temperature for a particular gas.

6. Equipment protection level?

The Equipment Protection Level is the last part of the coding for Gas or Dust and is similar to the Equipment Category in that Ma and Mb are only mining related. Ga, Gb, Gc or Da, Db, and Dc are the possible levels, with Ga or Da being the highest protection.

7. Which Zone or Category?

Understanding whether a particular product can be employed in a certain area requires information on how the area and the potential risk therein have been classified by the site or plant in question. The Zones are decided by the site based on a risk assessment of the likelihood of a potentially explosive atmosphere being present.

Zone 0 for gas, 20 for dust, or a Category 1 rating means the risk is continually present, and a very high Protection Level is required. In practice for valves and instrumentation, this would usually mean an (Ex-ia) Type of Protection would be the first choice. Where an explosive atmosphere is not continually present but is likely to occur in normal operation is rated Zone 1, Zone 21 (dust), or Category 2, the common choices for Types of Protection would be versions of Ex d, Ex e, or Ex m.

A place where an explosive atmosphere is not likely to occur in normal operation but could occur for short periods would be classified as Zone 2, Zone 22 (dust), or Category 3. Common choices for Types of Protection for this environment would be Ex m or Ex n.

Annex C - Classes, Groups, Divisions, and Zones Concepts

Area classification is the assessed division of a facility into hazardous areas and non-hazardous areas. The subdivision of the hazardous areas into zones according to the likelihood of the presence of the hazardous material in the atmosphere where zone 0 refers to that part of a hazardous area in which a flammable atmosphere is continuously present or present for long periods (typically more than 1000 hours per year), zone 1 refers to that part of a hazardous area in which a flammable atmosphere is likely to occur in normal operation (typically 10 to 1000 hours per year). Zone 2 refers to that part of a hazardous area in which a flammable atmosphere is not likely to occur in normal operation and, if it occurs, will exist only for a short period (typically less than 10 hours per year), as illustrated in Table C1. In other standards, the division concept is another alternative to the zone concept where (Division 1) in which ignitable concentrations of hazards exist under normal operating conditions and/or where a hazard is caused by frequent maintenance or repair work or frequent equipment failure, and (Division 2) in which ignitable concentrations of hazards are handled, processed or used, but which are normally in closed containers or closed systems from which they can only escape through accidental rupture or breakdown of such containers or systems , as illustrated in Table C2. The concept of a class of petroleum liquids refers to classifying them based on their flashpoints, as illustrated in Table C3.

The location class refers to the substance in the air in quantities sufficient to produce an explosive or ignitable mixture. In contrast, the class I location is where flammable gases or vapors may be present.

Gas Group refers to the explosive characteristics of the air mixtures of gases or vapors that vary with the specific material involved. Materials have been placed in groups based on ignition temperatures and explosion pressures. The Groups define substances by rating their flammable nature concerning other known substances. The gas group depends on the Minimum Igniting Current Ratio (MIC Ratio) and Maximum Experimental Safe Gap (MESG) of each gas group, as illustrated in Table C4. The material can be grouped into the following:

- Group A: Acetylene.
- Group B: Hydrogen.
- Group C: Ethylene, Cyclopropane, Ethyl Ether.
- Group D: Acetone, Butane, Propane, Hexane, Natural Gas, Fuel Oil.
- Group E: Dust of Combustible Metals.
- Group F: Dust of Carbonaceous Materials, Including Coal Dust.
- Group G: Non-Conductive Dust, e.g., Flour, Starch, Plastic.

The fluid category for each point source may be determined using Table C5 (For more information, see EI Model Code of Safe Practice - Part 15 - Annex A).

Table C1. *Zone classification* [4].

Zone	Probability of the presence of an explosive atmosphere in a year	Hours of presence
Zone 0	P>10-1	more than 1000 hrs per year
Zone 1	10-1>P>10-3	From 10 to 1000 Hrs per year
Zone 2	P<10-3	Less than 10 Hrs per year

Table C2. *Classes, groups, divisions, and zones concept in the area classification.*

Divisions / Zones				
Atmosphere	**Class***	**Division***	**Zone****	**Area Classification**
Gas	Class I	Div. 1	Zone 0	Continuous Hazard
			Zone 1	Intermitted Hazard
		Div. 2	Zone 2	Abnormal Conditions Hazard
Dust	Class II	Div. 1	Zone 20	Continuous Hazard
			Zone 21	Intermitted Hazard
		Div. 2	Zone 22	Abnormal Conditions Hazard
Fiber	Class III	Div. 1	Zone 20	Continuous Hazard
			Zone 21	Intermitted Hazard
		Div. 2	Zone 22	Abnormal Conditions Hazard
Groups				
Atmosphere	**Class***	**Group***	**Group ****	**Representative Element**
Gas	Class I	-	Group I	Methane
		Group D	Group IIA	Propane
		Group C	Group IIB	Ethelene
		Group B	Group IIC (Except Acetylene)	Hydrogen
		Group A	Group IIC	Acetylene
Dust	Class II	Group G	Group IIIB	Non-conductive dust
		Group F	Group IIIB	Carbonaceous dust
		Group E	Group IIIC	Metal dust
Fiber	Class III	-	Group IIIA	Fibers or flyings
*According to NEC/API 500		** According to EI 15, NEC/API 505		

Table C3. *The classification of petroleum liquids* [1].

Liquid	Class	Definition
Flammable Liquids (flash point < 100°F	IA	Liquids that have a flash point below 73°F (22.8°C) and a boiling point below 100°F (37.8°C).
	IB	Liquids that have a flash point below 73°F (22.8°C) and a boiling point at or above 100°F (37.8°C).
	IC	Liquids that have a flash point at or above 73°F (22.8°C) but below 100°F (37.8°C).
Flammable Liquids (flash point ≥ 100°F	II	Liquids that have a flash point at or above 100°F (37.8°C) and below 140°F (60°C).
	IIIA	Liquids that have a flash point at or above 140°F (60°C), but below 200°F (93°C)

Table C4. *Classes, groups, divisions, and zones concept in the area classification* [5].

Class	Division	Group	Flammable Material	MESG	MIC Ratio
Class I	Division 1&2	Group A	Acetylene	-	-
Class I	Division 1&2	Group B	Hydrogen, Butadiene, Ethylene Oxide, Propylene Oxide	≤0.4 mm	≤0.4
Class I	Division 1&2	Group C	Ethylene, Cyclopropane, Ethyl Ether	>0.45 mm ≤0.75 mm	>0.4 ≤0.8
Class I	Division 1&2	Group D	Propane, Acetone, Ammonia, Benzene, Butane, Ethanol, Gasoline, Methanol, Natural Gas	≥0.75 mm	>0.8

Table C5. *Fluid categories* [2].

Fluid Category	Description
A	A flammable liquid that, on release, would vaporize rapidly and substantially. This category includes: (a) Any liquefied petroleum gas or lighter flammable liquid. (b) Any flammable liquid at a temperature sufficient to produce, on release, more than about 40 % vol. vaporization with no heat input other than from the surroundings.
B	A flammable liquid, not in category A, but at a temperature sufficient for boiling to occur on release.
C	A flammable liquid, not in categories A or B, but which can, on release, be at a temperature above its flash point or form a flammable mist or spray.
G(i)	A typical methane-rich natural gas.
G(ii)	Refinery hydrogen.

Annex D - The Auto-Ignition Temperature (AIT) and the Temperature Class (T Class)

The auto-ignition temperature (AIT) of the hazardous material in a facility must be known to complete its area classification. To select equipment appropriate to the zone classification, the apparatus sub-group and T class should be determined during the area classification based on the flammable substances that can be released. This information should be added to the drawing and/or records. When applying this, the effect of abnormal operations, for example, start-up and shutdown, should be considered since such operations may affect the composition of any substances released and hence their flash points and/or auto-ignition temperatures. However, it may be reasonable to ignore any such abnormal composition if it is expected to exist within the plant for less than 10 hours per year and there is no continuous or primary grade release during this period. Secondary grade sources are not likely to release during such a period. The most restrictive apparatus sub-group and T class should be specified when a release is a mixture of substances. Suppose gases belonging to more than one electrical apparatus sub-group and T class are present in non-overlapping areas. In that case, it is acceptable to show different groups and classes, as illustrated in Table D1.

Table D1. *Temperature class in the hazardous area classification.*

Maximum Surface Temperature	T Class *	T Class **
450°C	T1	T1
300°C	T2	T2
280°C	T2A	
260°C	T2B	
230°C	T2C	
215°C	T2D	
200°C	T3	T3
180°C	T3A	
165°C	T3B	
160°C	T3C	
135°C	T4	T4
120°C	T4A	
100°C	T5	T5
85°C	T6	T6
*According to NEC/API 500	** According to IEC, EI 15, NEC/API 505	

Annex E - Zones Versus Grade of Release

As mentioned in the definitions, a source of release is a point from which a flammable gas, vapor, or liquid may be released into the atmosphere. Three grades of release are defined in terms of their likely frequency and duration:

- **Continuous grade release**: A continuous or nearly so or that frequently occurs and for short periods.
- **Primary grade release**: A release that is likely to occur periodically or occasionally in normal operation, i.e., a release which, in operating procedures, is anticipated to occur.
- **Secondary grade release**: A release that is unlikely to occur in normal operation and, in any event, will do so only infrequently and for short periods, for example, as might result from operator error or foreseeable equipment failures, such as a leak resulting from the failure of flange gasket, or seal on a pump or valve, etc.

The release grade is dependent solely on the frequency and duration of the release. It is completely independent of the rate and quantity of the release, the degree of ventilation, or the characteristics of the fluid, although these factors determine the extent of vapor travel and, in consequence, the dimensional limits of the hazardous area.

To assist in the understanding of the boundaries of the definitions of the different grades of release, the following quantities are suggested. A release should be regarded as a continuous grade if it is likely to be present for more than 1000 hours per year and a primary grade if it is likely to be present for between 10 and 1000 hours per year. A release that is not anticipated in normal operation, likely to be present for up to 10 hours per year and for short periods, should be regarded as the secondary grade. This assessment should take account of any likelihood of leaks remaining undetected. Where releases are likely to be present for up to 10 hours per year but are anticipated in normal operation (e.g., routine sampling points), they should be regarded as primary grade releases.

The time a leak may be present depends on the time taken to detect and isolate the leak. In facilities where operations personnel patrol the plant, the time to detect and isolate a leak may be taken to be, at most, the time interval between patrols (which is typically less than 10 hours). With the continuing trend for de-manning, the patrol interval may increase to greater than 10 hours. This will change the release grade unless other measures, such as gas detection and remote isolation, are provided to reduce the time to detect and isolate leaks.

Multiple secondary grade releases are not considered primary grade releases. This is based on the assessment of the grade of release and will require experienced engineering and operational judgment.

In most cases, under unrestricted 'open air' conditions, there is a direct relationship between the grade of release and the zone classification to which it gives rise. Therefore:

- Continuous grade normally leads to Zone 0.
- Primary grade normally leads to Zone 1.
- Secondary grade normally leads to Zone 2.

However, it should be noted that the terms 'grade of release' and 'zone' are not synonymous.

Although continuous, primary, and secondary grade releases will normally result in Zones 0, 1, and 2, respectively, this may not always be true. Table E1 illustrates the relationship between the release grade and zone for releases in open areas.

Table E1. *Relationship of grade of release to zone for an open area* [2].

Grade of release	Likely to occur in normal operation	Presence of flammable atmosphere hours/year in the open area	Zone
Continuous	Yes	Greater than 1 000	Zone 0
Primary	Yes	1000 – 10	Zone 1
Primary	Yes	Fewer than 10	Zone 2
Secondary	No	Greater than 10	Zone 1
Secondary	No	Fewer than 10	Zone 2

How to determine the grade of release?

In principle, the classification procedure entails the consideration of all actual and potential sources of flammable release. All continuous and primary grade release sources should be identified and assessed to determine the extent of the resulting Zone 0 and Zone 1 hazardous areas; wherever possible by design, they should be reduced in number and extent. The extent of vapor travel, and hence the hazard radii for each point source to be assessed, will be a function of the fluid characteristics and vapor-forming conditions during release. In assessing the grade of a release, the following points are pertinent:

a. In the case of operationally controlled releases, e.g., sampling and drain points, most (if not all) vents, filter cleaning, and pig receiving operations, no one grade of release is applicable since the operational frequency chosen will determine whether the equipment release should be graded as primary or continuous.

b. For releases that are not operationally controlled (e.g., accidental leakage from equipment), a secondary grade of release is applicable. An assessment of hole sizes from equipment (e.g., pumps, compressors, piping systems, etc.) has been undertaken (For more information, see EI 15 - Annex C Part 2, Table C13).

Note: As an alternative, equipment-specific hole sizes based on manufacturer, industry, or company-specific data may be used.