# POTENTIALLY EXPLOSIVE ATMOSPHERES EU DIRECTIVE 1999/92/EC

**Doc 134/21**

Revision of Doc 134/12


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**Amendments to 134/12**

| Section | Change |
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| | Editorial to align style with EIGA style manual |
| 1, 2 | Update to reflect updated EU directive |
| 3 | Updated to definitions following updated directive and standards |
| 5 | Update for new directive |
| 6 | Update to references |
| 7 | Updated section structure, and revised wording |
| 12 | Updated guidance on storage and references |
| 13 | New section |
| | |

NOTE Technical changes from the previous edition are underlined

## 1 Introduction

Directive 1999/92/EC, *on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres*, also known as ATEX 137, defines the minimum requirements to protect workers from potentially explosive atmospheres [1].[1] This publication has been issued to facilitate and harmonise the interpretation and implementation among EIGA members of the required risk assessments and specifically the classification of areas where an explosive atmosphere can occur according to the directive and related standards.

The three key principles for prevention and protection against explosions taken from Directive 1999/92/EC are given in Article 6(2), in order of priority [1]:

1. The prevention of the formation of explosive atmospheres, or where the nature of the activity does not allow that.

2. The avoidance of the ignition of explosive atmospheres.

3. The mitigation of the detrimental effects of an explosion so as to ensure the health and safety of workers.

## 2 Scope and purpose

The scope includes handling and storage of flammable gases and liquids where an explosive atmosphere with air under atmospheric conditions might arise at industrial gases company's plants. The publication does not apply to the use of flammable medical gases or the risk arising in piping systems, cylinders and vessels with increased pressure. Directive 1999/92/EC also applies to potentially explosive atmospheres involving dust [1]. This publication does not provide guidance on dust explosions, however members may have potentially explosive atmospheres involving dust that require assessment, for example painting facilities.

This publication covers potentially explosive atmospheres that form in the open air, it does not cover potentially flammable or explosive mixtures within a process, for example flammable gas cylinder mixtures.

This publication also provides guidance on the storage of flammable gas cylinders in open air.

The classification of hazardous areas according to this publication and EC Directive 1999/92 can also be used for the selection of Ex-classified equipment and systems as required by Directive 2014/34/EU *concerning equipment and protection systems intended for use in potentially explosives atmospheres*, (also known as ATEX 100a) [1, 2].

## 3 Definitions

For the purpose of this publication, the following definitions apply.

### 3.1 Publication terminology

#### 3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

#### 3.1.2 Should

Indicates that a procedure is recommended.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

#### 3.1.3 May

Indicates that the procedure is optional.

#### 3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

#### 3.1.5 Can

Indicates a possibility or ability.

### 3.2 Technical definitions

#### 3.2.1 Explosive atmosphere

A mixture with air, under atmospheric conditions of flammable substances in the form of gases, vapours, dust, fibres, or flyings, in which, after ignition permits self-sustaining flame propagation.

NOTE The definition is taken from IEC 60079-0, *Explosive atmospheres - Part 0: Equipment - General requirements* [3].

#### 3.2.2 Explosive limit, lower (LEL)

Concentration of flammable gas or vapour in air, below which the gas atmosphere is not explosive.

#### 3.2.3 Explosive limit, upper (UEL)

Concentration of flammable gas or vapour in air, above which the gas atmosphere is not explosive.

#### 3.2.4 Hazardous area

An area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment.

NOTE The definition is taken from IEC 60079-0 [3].

#### 3.2.5 Ignition temperature

The lowest temperature of a heated surface at which, under specified conditions, the ignition of a flammable substance in the form of a gas or vapour mixture with air will occur.

#### 3.2.6 Open air storage

A storage area with at least 25% of the sides open to atmosphere and without a roof.

#### 3.2.7 Temperature class

Equipment is classified by temperature class according to its maximum surface temperature.

#### 3.2.8 Zone 0

A place in which an explosive atmosphere consisting of a mixture with air of flammable gas, vapour or mist is present continuously or for long periods or frequently.

NOTE Generally accepted guidance for Zone 0 is where explosive atmospheres are present for more than 1000 hours per year.

### 3.2.9 Zone 1

A place in which an explosive atmosphere consisting of a mixture with air of flammable gas, vapour or mist is likely to occur in normal operation occasionally.

NOTE Generally accepted guidance for Zone 1 is where explosive atmospheres are present for more than 10 but less than 1000 hours per year.

### 3.2.10 Zone 2

A place in which an explosive atmosphere consisting of a mixture with air of flammable gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

NOTE Generally accepted guidance for Zone 2 is where explosive atmospheres are present for less than 10 hours per year.

NOTE Zone 20, 21 and 22 are only valid for dusts and are not defined here.

## 4 EU Directive 1999/92/EC (ATEX 137) [1]

The directive specifies the minimum requirements for the protection of workers potentially at risk from explosive atmospheres. It requires the employer to carry out an explosion risk assessment including a classification of the areas and take necessary measures to not endanger the safety and health of workers. It includes organisational measures such as training of workers, work permit system, the need for work instructions, and the use of warning signs as well as the responsibility to coordinate work of employees belonging to different employers. Furthermore, the directive details some specific requirements on the work equipment and workplaces where explosive atmosphere can arise.

The actions required shall be described in an explosion protection document, (refer to Section 14).

## 5 EU Directive 2014/34 (ATEX 100a) [2]

This publication is issued to harmonise the interpretation of EU Directive 1999/92 [1]. However, it is necessary to review the content of Directive 2014/34 due to its high importance for work in areas with a risk for explosive atmosphere [2]. Directive 2014/34 concerning mechanical and electrical equipment and protective systems intended for use in potentially explosive areas is valid when the equipment has an own source of ignition of any kind [2]. It also applies to safety, regulating and controlling devices not placed in explosive atmospheres but forming an integral part of those protective devices.

NOTE The directive applies to equipment and systems that are placed on the market after 26th February 2014. It replaced directive 94/9/EC which applied to equipment placed on the market after 1st July 2003 [4].

Equipment and devices included in the scope shall:

- bear CE as well as Ex proof marking and additional marking according to the directive and be accompanied by a declaration of conformity;
- be accompanied at delivery with comprehensive and detailed instructions (user manual); and
- be classified in Group I or II, where Group I is intended for use in mines and Group II is for other applications.

  NOTE Only Group II equipment is in the scope of this publication.

Equipment / devices shall be classified in a Category (1, 2 or 3), as described in 5.1 to 5.4. The category selected will then allow the use of the equipment in the corresponding area where the risk of explosive atmosphere has been defined.

### 5.1 Category 1 equipment

Category 1 equipment shall have a very high level of protection even for rare equipment failures and it can be used in zone 0 areas. In the conformity assessment there is a requirement that the:

- equipment is CE and Ex marked against ATEX Directive 2014/34 [2];
- equipment has passed an EC-type certification by a notified body; and
- manufacturer of the equipment has an approved quality assurance system for the production, inspection and testing of the equipment

### 5.2 Electrical equipment in category 2

Category 2 equipment can be used in zone 1 areas. There is a requirement that the:

- equipment is CE and Ex marked against ATEX Directive 2014/34 [2];
- equipment has passed an EC-type certification by a notified body; and
- manufacturer shall have an approved quality assurance system for the production, inspection and testing of the equipment.

### 5.3 Category 2 non-electrical equipment

Category 2 equipment can be used in zone 1 areas. There is a requirement that the:

- Equipment is CE and Ex marked against ATEX Directive 2014/34 [2];
- manufacturer has checked and verified that the equipment conforms to the essential health and safety requirement in the Directive [2];
- manufacturer shall have an approved quality assurance system for the production, inspection and testing of the equipment; and
- manufacturer shall provide a technical file to a notified body and the production process shall ensure compliance of the manufactured equipment with the technical documentation.

### 5.4 Category 3 equipment

Category 3 equipment is allowed only in Zone 2 areas. There is a requirement that the:

- equipment is CE and Ex marked against ATEX Directive 2014/34 [2];
- manufacturer has checked and verified that the equipment conforms to the essential health and safety requirement in the Directive [2];
- manufacturer shall have an approved quality assurance system for the production, inspection and testing of the equipment; and
- manufacturer shall provide a technical file to a notified body and the production process shall ensure compliance of the manufactured equipment with the technical documentation.

For all equipment there is also an alternative to send each single equipment item to a notified body and have it inspected, tested and categorised.

NOTE Category 2 non-electrical equipment and Category 3 equipment do not require type approval by a notified according to the directive, however it is common in the industry for manufacturers to have a type approval under the IEC Ex system [5].

## 6 Data for the assessment of explosion risks

### 6.1 General

The risk assessment process should assess the likelihood that an explosive atmosphere will occur and the likelihood that ignition sources are present. It shall include normal operations, start up, shut down and dismantling of the process / equipment, inspection, maintenance and repair activities, cleaning of facilities, common malfunctions and failures as well as foreseeable misuse. The assessment shall also include the risk of flammable atmosphere spreading to neighbouring areas through openings, ventilation ducts, etc. Equipment, devices and components installed in classified areas before 1st July 2003 do not need to comply with EU Directive 2014/34, but a separate risk assessment of the design may be required [2].

NOTE All changes of procedures, equipment and facilities in hazardous areas shall be risk assessed – the management of change is essential, see EIGA Doc 51, *Management of Change* [6].

Emergency scenarios such as rupture of pipe lines and vessels followed by a release of flammable gases, sudden rupture of a gas cylinder at use, filling or handling and release of the content, etc. should be handled in the site emergency plans, see EIGA Doc 233, *Emergency Response Planning*, or other dedicated documents, for example Seveso documentation, see EIGA Doc 60, *Seveso Documents - Guidance on Applicability, Assessment and Legal Documents for Demonstrating Compliance of Industrial Gases Facilities with Seveso Directive(s)* [7, 8]. These scenarios are not considered as expected failures or malfunctions and the consequence should not be a basis for the risk assessment and classification of hazardous areas according to this publication and the ATEX directives.

### 6.2 Ignition energy

The energy needed to ignite gases and vapours commonly found in the gas industry can be found in Table 2. A general assumption is that ignition of a flammable gas / air mixture requires an ignition source with an energy less than 1 mJ, and vapour from many solvents requires 0.1 – 3 mJ. The ignition energy given refers to the stoichiometric mixture, closer to the upper and lower explosion limits the required energy can be up to a hundred times greater.

The energy needed to ignite a mixture should be compared to the possible energy generated by some common sources, some examples are given in Table 1.

It is very clear that all these sources are fully capable of igniting a gas mixture and the same applies to mobile phones, calculators, PC's and many other electrical devices without any explosion protection. However, the use of ordinary wristwatches, hearing aids and remote-control key fobs powered by primary button cells (non-rechargeable) in Zone 1 and 2 can be allowed due to the fact the possibly generated ignition energy is very low and gas penetration into the device is very slow, for more information see *Safety notice: Electrical/electronic devices energised by button cells in hazardous areas (potentially explosive atmospheres)* from the Energy Institute [9].

**Table 1 – Example ignition sources**

| Description | Energy |
|---|---|
| Electrostatically charged person | 10-100 mJ |
| Dropped mobile phone | 10-20 mJ |

### 6.3 Properties of involved substances

Physical data of some substances commonly used by EIGA member companies is shown in Table 2.

NOTE The values of the minimum ignition energy in air differs significantly in the literature.

**Table 2 – Ignition energies**

| Substance | Density relative to air 1) | LEL in air1) % vol/vol | UEL in air1) % vol/vol | Auto Ignition temp.1) °C | Temp class1) | Explosion group 1) | Flash point1) °C | Min. ign. energy in air3) mJ |
|---|---|---|---|---|---|---|---|---|
| Acetylene | 0.90 | 2.3 | 82.0 2) | 305 | T2 | IIC | | 0.019 |
| Acetone | 2.0 | 2.5 | 13.0 | 535 | T1 | IIA | <20 | 1.15 |
| Ammonia | 0.59 | 15.0 | 33.6 | 630 | T1 | IIA | | 680 |
| Butane | 2.05 | 1.4 | 9.3 | 372 | T2 | IIA | | 0.25 |
| Carbon monoxide | 0.97 | 10.9 | 74.0 | 605 | T1 | IIB | | 0.3 |
| Hydrogen | 0.07 | 4.0 | 77.0 | 560 | T1 | IIC | | 0.019 |
| Methane | 0.55 | 4.4 | 17.0 | 537 | T1 | IIA | | 0.28 |
| Propane | 1.56 | 1.7 | 10.99 | 470 | T1 | IIA | -104 | 0.25 |

NOTE Some gases not classified as flammable gases, such as nitrous oxide, can decompose at elevated temperature. These gases are not considered in the ATEX directive [1].

1) Data is taken from IEC 60079-20, *Explosive atmospheres. Material characteristics for gas and vapour classification. Test methods and data* [10]

2) Pure acetylene can decompose when exposed to temperature above 350 °C and the decomposition can spread through piping systems at an acetylene pressure of 200 kPa or more. The contained decomposition causes a large pressure increase. Therefore, the UEL for acetylene is sometimes stated as 100%

3) Data taken from *Richtlinien für die Vermeidung von Zündgefahren infolge elektrostatischer Aufladungen – Richtlinien „Statische Elektrizität“*, GUV 19.7 [11].

NOTE The properties in Table 2 are related to the conditions assumed in the Directive, that is air and atmospheric pressure [1]. At elevated pressure or in oxygen enrichment, most of the parameters are significantly changed, for example ignition energies can be reduced in high oxygen atmospheres.

## 6.4 Ignition sources

EN 1127-1, *Explosive atmospheres. Explosion prevention and protection. Basic concepts and methodology* identifies thirteen different ignition sources, which are listed below and separated in two groups [12]. The ignition source most relevant for industrial gases operations are given in 6.4.1 and then a group for the remaining sources are given in 6.4.2. EN 1127-1 gives more detailed information concerning protective requirements for equipment in different zones [12]. In general, there should be a safety margin between the ignition source and the actual situation in which it will be effective. The likelihood of a malfunction is also essential for the risk assessment.

### 6.4.1 Relevant ignition sources

**Hot surfaces**: An explosive atmosphere can be ignited by a hot surface when the temperature exceeds the auto-ignition temperature of the gas. These surfaces can include hot pipes, radiators, drying cabinets, brakes and clutches while operated, etc. Malfunctions can generate heat by friction due to loss of lubrication, foreign bodies in moving parts, belts slipping, etc. There shall be a safety margin between the ignition temperature and the surface temperature depending on the zone where the equipment is located.

**Flames, hot gases and hot particles**: Flames are an inherent ignition source and are present during cutting and welding, and in burners for air heating, etc. Naked flames shall not be allowed in a classified zone and the enclosure of equipment containing flames shall conform to the relevant equipment group / zoning.

**Mechanically generated sparks**: Sparks can be generated at grinding or as a result of impact or friction. The ingress of foreign material, for example grit in equipment can be a cause of sparking. Equipment which can produce mechanically generated sparks shall not be used in any zone where a potential explosive atmosphere contains explosion group IIC substances acetylene, hydrogen, carbon disulphide, hydrogen sulphide or ethylene oxide according to EN 1127-1 section 6.4.4 [12]. However, steel tools which can generate only a single spark such as screwdrivers, spanners, etc. may be used in zone 2 – explosion group IIC substances.

Additional protective measures apply depending on the zone.

**Electrical apparatus**: Electrical equipment can ignite an explosive atmosphere when, for example closing or opening electrical circuits or by loose connections. The equipment used in classified areas shall be certified for the applicable zone, gas group and temperature classification of the gas. The equipment shall be installed and maintained as per manufacturer's recommendations and type approval certificate.

**Static electricity**: Insulated conductive parts and non-conductive materials (solid, liquid or gaseous phase) can be charged to such a high level that the static discharge can ignite a flammable atmosphere. The risk is present in most areas and the bonding and earthing of all equipment is essential in all classified zones. Since manual work is carried out in the classified zones, semi-conductive footwear and floorings as well as approved working clothes should be used according to risk assessment see Section 9. Additional precautions apply for non-conductive parts and depend on the classification of the zone.

**Lightning**: If lightning strikes in an explosive atmosphere, an ignition will always occur. Furthermore, the lightning can cause currents and sparks at a distance from the actual point of strike. The thunderstorm itself has the potential to create high intensity induced voltages in equipment and systems. If the risk assessment demonstrates a hazard due to lightning, protective measures shall be taken which can include lightning conductors, over-voltage protection as well as bonding and earthing of equipment.

**Adiabatic compression**: A dangerous adiabatic compression can occur when, for example, a high-pressure gas suddenly is released into a piping system by a quick opening valve. The gas will be heated and the high temperature can spread to the external surface of piping and equipment causing a temperature exceeding the auto-ignition temperature of the flammable atmosphere. This shall be avoided in normal operations as well as failure cases as required by the zone classification.

NOTE Other hazards are associated with adiabatic compression, for example for oxidising gases and acetylene, which are covered by the design of those systems but are not relevant for explosion protection.

**Exothermic reaction**: Many chemical reactions are exothermic and can act as an ignition source when the rate of heat generation exceeds the heat loss to the surroundings. Catalysts, for example platinum for oxygen reduction in hydrogen production system, can cause a high temperature. Some combinations of construction materials and chemicals, for example copper and acetylene can cause reactions which can ignite an explosive atmosphere.

### 6.4.2 Other ignition sources

**Stray electric currents, cathodic corrosion protection**: Stray currents can become an ignition source by heating up the current path equipment or by sparks when the stray current is disconnected.

**Radio frequency electromagnetic waves**: Radio frequency equipment can be used for heating, drying, welding, radio transmitters, etc. In powerful fields, conductive parts can pick up energy and cause connected thin parts (wires) to glow or sparks can be generated.

**High frequency electromagnetic waves**. Electromagnetic waves of high frequency can be absorbed by the explosive atmosphere itself or by other materials causing an ignition. Sun light, focused through a lens/bottle can cause high temperatures as well as a laser beam used for distance measurement, fire protection, etc.

**Ionising radiation**: Ionising radiation from X-ray tubes or radioactive materials can act as an ignition source by the radiation:

- material itself is heating up;
- being absorbed and the absorption material, especially dust particles, heating up; or
- causing chemical reactions or decompositions.

**Ultrasonic**: When using ultrasonic equipment, the sound waves can, in extreme cases, be absorbed by solid or liquid material resulting in heating up of the material.

## 7 Assessment of risk for explosive atmospheres

### 7.1 Inventory

The first step of the assessment is to make an inventory of which flammable substances are used, where and for which purpose. At this stage, consideration should be given to determine if the flammable substances can be replaced by non-flammable ones. Before such a replacement is carried out the risk of explosion shall be assessed together with other safety / health / environmental properties as well as technical and economic factors.

### 7.2 Evaluation

The second step is to evaluate if the substance can evaporate/disperse in sufficient quantity to create an explosive atmosphere, this is usually the case for gases. But even if there is an explosive atmosphere present, it may not be regarded as a hazardous (explosive) atmosphere. In some cases, a zone of negligible extent (NE) may arise and may be treated as non-hazardous. Such a zone implies that an explosion, if it takes place, will have negligible consequences. The zone NE concept can be applied irrespective of any other adjustments for risk assessment to determine equipment protection level [3]. For example, small amounts of explosive atmosphere, can, depending on local circumstances, be regarded as non-hazardous under the condition that the room volume exceeds ten thousand times the volume of explosive atmosphere. When only a non-hazardous explosive atmosphere is present, which can be the case when handling very small quantities of a flammable substance, no further actions are needed.

### 7.3 Mitigation

The third step before the hazardous areas are classified in zones, (see definition), is to prevent, by technical measures, the occurrence of an explosive atmosphere. One method rarely used in industrial gas operations is the inerting of the atmosphere. Another more common method is to dilute the concentration of the flammable substance in the air by ventilation. IEC 60079-10-1, *Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres*, gives a detailed description on how the effects of local and general ventilation can be calculated to arrive at the correct zone classification [13]. With reliable and efficient ventilation, a room with flammable gas release sources can be classified as non-hazardous. But in the example in the Appendix (an acetylene plant) there are several possible leak sources and rates to explain why increased ventilation would not allow reduction of the zone 2 area to only a section of the room. Whatever method is chosen, it shall ensure that it offers an efficient and reliable protection against an explosive atmosphere. Usually, the concentration of flammable substance should be less than 25% of the LEL under all possible conditions; start up, shut down, operation, maintenance, etc. before an area is considered as non-hazardous.

Additional mitigation measures such as gas detection with alarms, automatic shutdown or initiating start of additional ventilation can be used.

### 7.4 Potential release identification

When determining the extent of the hazardous zones, the following factors shall be assessed:

- The release type (continuous or intermittent release, accidental release, leakage).
- The release rate, which depends on:
  - the geometry of the release source;
  - release velocity;
  - concentration of the flammable substance in the released mixture;

  - volatility of a flammable liquid; and

  - preventive measures (such as leak control according procedures and tightness criteria).

- Type of ventilation – Natural or forced ventilation depending on whether location is indoors or outdoors, continuous or intermittent.

The assessment should cover all operational conditions at the plant such as normal operation, maintenance, commissioning and decommissioning and reasonably foreseeable malfunctions.

***WARNING*** *It is very important that operations other than normal are assessed. Experience of accidents in the industry involving explosive atmospheres indicates that they normally occur during maintenance, start up, shut down and process upset conditions. Operations outside of normal operating conditions should be assessed and controlled for example under a safety work permit system, see EIGA Doc 40, Work Permit Systems, for more information [14].*

The release identification is key to determining extent of hazardous zone and the study should be done by a competent person. The study should document assumptions and provide references in order to choose the adequate release rate (function of normal leak, sealing, design). The dilution rate also is key (depending on local reference), see IEC 60079-10-1 Annex B [13].

Once all the relevant information has been obtained, the extent of the flammable zone can be calculated using dispersion modelling. Several software packages such as DNV GL PHAST and QUADVENT are available to do this modelling.

Examples of evaluation of potential release are given in Appendix C.

## 8 Hazardous area classification

After the extent of the flammable zone is calculated, it is possible to determine the hazardous area classification as per the definitions in Section 3.

Appendices A and B show examples of the area classification of two typical industrial gas operations, an acetylene plant and a storage of gas cylinders.

NOTE The actual area classification consists of the columns “Area and activity”, “Zone” and “Release mechanism” while the other columns include ignition risk, comments, etc.

Other common industrial gas operations where a flammable atmosphere might be present are:

- hydrogen plants including filling of high pressure or liquefied hydrogen;

- specialty gas plants handling flammable gases;

- laboratory analysing flammable gases or gas mixtures;

- sites filling LPG;

- sites filling industrial or medical gas mixtures containing flammable components;

- CO plants including any filling activity;

- customer stations for acetylene, hydrogen, etc. for cylinder manifold systems; and

- customer stations for bulk gaseous or liquid hydrogen.

## 9 Assessment of risk for ignition of hazardous explosive atmosphere

In the classified areas protective measures shall be taken to avoid the ignition of potentially flammable atmospheres. These measures depend on the potential for an explosive atmosphere as defined in the zones below and shall comply with the relevant rules in Table 3.

**Table 3 – Zone description**

| Zone | Ignition sources (see 6.4) shall be avoided: |
|---|---|
| Zone 0 | In normal operation, in foreseeable cases of malfunctions and in rare malfunctions |
| Zone 1 | In normal operation and in foreseeable cases of malfunctions |
| Zone 2 | In normal operation |

The measures to prevent an ignition can be of a technical or an organisational nature. In the example in Appendix A and B, the risk assessment is based on the following precautionary measures.

NOTE These are only examples and each operational unit shall list the measures taken at the relevant site:

**Organisational:**

- The workers (including any contracted worker) are trained in the risks from explosive atmospheres. The company keeps records of training.
- Visitors in areas with risk of an explosive hazardous atmosphere shall always be accompanied by an employee. The person responsible for the visitor shall also ensure that the visitors conform to the specified safety and emergency procedures.
- It is not permitted to bring portable electrical equipment, such as mobile phones, calculators, cameras, etc. into Ex-hazardous areas. Electrical wristwatches and hearing aids are permitted.
- There is a work permit system implemented for all non-standard work (repair, maintenance, etc.) and all work carried out by contractors in the classified hazardous area. This includes when any uncertified equipment is to be brought into an Ex-hazardous area.
- Work instructions are issued and implemented which include maintenance, purging operations and cleaning.
- Emergency instructions are issued and implemented that include correct behaviour in the event of fire, gas releases, spill of dangerous material, etc. The emergency routines shall be practiced periodically.

**Technical:**

- All electrical equipment used in classified areas is certified for the actual zone according to Directive 2014/34/EU or previous international or national standards [2]. This applies also to mechanical equipment such as fans, compressors, turbines, pumps, valve actuators, flame arrestors, etc.
- Ex-labels / signs are in place at the entrances to hazardous classified areas.
- Only spark free tools are available and used in hazardous classified areas, zone 1 and 2. If other tools are to be used a written work permit is required.
- Fixed equipment items in hazardous classified areas are electrically bonded to each other and an earthing system. The efficiency of this bonding should be periodically checked in accordance with national standards.
- All workers at the site shall wear working clothes made of material, which will not create electrostatic sparks.

- All workers at the site shall wear semi-conductive shoes and the floor shall have semi-conductive properties. Concrete floors usually have semi-conductive properties, but a surface treatment of the floor can destroy the conductivity.

In the example of a risk assessment, additional precautionary measures can be found related to certain identified risks.

The above mentioned technical and organisational measures also make it highly unlikely that any person by mistake may bring a potential ignition source into an area classified as hazardous explosive atmosphere.

## 10 Assessment of risk for ignition of hazardous explosive atmosphere – mechanical equipment

An example of mechanical equipment frequently used in classified areas is the forklift truck. Self-propelled industrial trucks as well as pedestrian controlled ones can be used in hazardous areas classified as zone 1 or zone 2 under the condition that they conform to the EN 1755, *Industrial Trucks. Safety requirements and verification. Supplementary requirements for operation in potentially explosive atmospheres* [15]. EN 1755 is issued to complete the requirements of the Machinery Directive and related EN standards when a truck is used in hazardous classified areas where an explosive atmosphere can be present [15, 16]. For forklift trucks not complying with EN 1755, the operator shall demonstrate that it is safe to use, this requirement may demand significant resources [15]. An alternative which allows the use of the forklift truck in areas classified as zone 2 is to equip the truck or hazardous areas with a flammable atmosphere warning system that gives warning before any dangerous concentration of flammable gas is reached. It is recommended to set the alarm at less than 25% of the LEL. The driver shall also be instructed to stop the truck when the alarm is activated. The gas alarm is an essential element for the safe operation of the plant and shall comply with the requirements of Directive 2014/34/EU, which ensures its suitability for the intended use [2].

For older equipment placed on the market before the implementation of Directive 2014/34/EU, it shall be demonstrated that the equipment is designed, constructed, assembled, operated and maintained to minimise the risk of an explosion. This risk assessment should be a part of the explosion protection document.

## 11 Mitigation measures of an explosion

The preferred method to protect workers potentially at risk from explosive atmosphere are to reduce the risk of having a hazardous explosive atmosphere and an ignition source to an acceptably low level. However, there may be cases when the risk of an explosion is not negligible and mitigation measures shall be taken. These measures can include:

- The construction of vessels, pipes and other equipment so they are able to withstand an explosion without rupturing. In most cases with air and a flammable gas, the explosion overpressure can reach 10 times the original pressure, but exceptionally even higher-pressure increases may occur.

- The design of equipment or buildings to release the explosion pressure in a safe direction (pressure relief devices). The devices shall be designed to ensure correct functioning and shall comply with the Directive 2014/34/EU [2]. A common industrial practice at acetylene plants is to have a pressure release area equal to 10% of the volume of the protected room. Additionally, the roof of acetylene plants can be designed with a weight of less than 100 kg/m². Note that explosion of, for example, an air / hydrogen atmosphere in a room will result in an extremely fast pressure increase, which may reduce the mitigation effects of pressure relief windows or light walls.

- Prevention of explosion propagation. For example, a commonly used device in the acetylene plants' piping systems is the flame / flashback arrester.

Additional mitigation measures exist but since they are of less relevance for the industrial gas industry they are not commented on here. Furthermore, the more traditional firefighting measures may reduce the consequences of the fire that may follow after an explosion. These methods include the construction of the building, the availability of emergency exits, fixed and mobile firefighting equipment, etc.

## 12 Storage of flammable gas cylinders

It is important that the operator of a site distinguishes between the storage and the use of flammable cylinders. When stored cylinders are not connected to a process, they are considered unlikely to leak as the valve is closed and checked for leaks when storing the cylinder. When they are in use then the cylinder valve may be open and there may be a connection which has the potential for leaking. That connection has a significantly greater risk of leaking than a closed valve and therefore is a potential source of release, creating a hazardous area.

With the correct safeguards, the outdoor storage (not use) of cylinders containing flammable products does not create classified hazardous zoned areas as defined by ATEX 137. It is for this reason that outdoor storage of flammable gases in cylinders is generally preferred to indoor storage.

For open air storage with a roof, at least 50% of the sides shall be open to atmosphere. Open sides may have chain link fencing for security purposes, but this shall provide at least 90% open area for free movement of air.

If indoor storage is used, preventative measures such as ventilation, leak test, room size and gas detection shall be considered, and a risk assessment shall be conducted to determine hazardous area classification.

### 12.1 Restriction of ignition sources

All storage areas shall have systems (fences, gates etc.) that restrict access to only authorised, trained personnel. No smoking, mobile phones or other personal equipment liable to cause ignition of a flammable gas dispersion shall be allowed into the restricted area. All fixed electrical equipment within the restricted area shall be rated to the appropriate ATEX zone if applicable. All transitory equipment used in the restricted area shall be approved by the operator by specific risk assessment.

### 12.2 Liquefiable hydrocarbon gases

The risk assessment for liquefiable hydrocarbon gases (for example propane, butane and LPG) is similar to that for the shorter chain permanent gas hydrocarbons. However, the heavier than air nature of these liquefiable gases mean that the facility shall take into account the potential for a small release rate to be directed in a low-lying confined space for example a pit, drain or underground room. The dispersion of these heavier than air gases can go surprisingly long distances if channelled in ducts or pipes. As a guide no openings to low lying confined areas shall be allowed within 10m of the storage of heavier than air flammable gases.

Guidance on the storage of LPG is available from other authorities – such as the WLPG (The World Liquefied Petroleum Gas Technical Association).

### 12.3 Hydrogen

The physical properties of hydrogen and the high pressure at which it is contained in cylinders make the length of the dispersion (and the potential jet flame) from a small hole greater than that for other gases.

***WARNING*** *Jet flames from hydrogen are virtually invisible to the naked eye and produce low radiant heat. If there is suspicion of a hydrogen jet flame, care shall be taken in approaching the area.*

For more information on gaseous hydrogen installations see EIGA Doc 15, *Gaseous Hydrogen Stations* [17].

### 12.4 Acetylene

Acetylene is stored as a dissolved gas within a solvent that is flammable. The risk assessment of the storage shall consider both the release of the gas and the release of the solvent. The solvent can only be released if the cylinder is laid on its side, which is not permitted practice. As long as the operator of the facility ensures that all acetylene cylinders are stored vertically then there is no hazardous zone area created from potential solvent release.

### 12.5 Pyrophoric gases (Arsine etc.)

Pyrophoric gases present a dual risk if released. Immediate ignition means that the release represents a potential source of ignition. Delayed ignition means the release represents a potential explosive atmosphere. The causes of release are similar to the risk assessment for methane, ethane, propane, however the consequence means that there is a greater requirement for safeguards. Pyrophoric gases shall be stored separated from flammable gases because they present a potential source of ignition i.e. they shall be outside any zone area created by other sources of release. Storage of pyrophoric gases require a specific risk assessment by a competent person to establish whether ATEX zones are required. See EIGA Doc 160, *Code of Practice – Silane Phosphine and Arsine*, for more information [18].

## 13 Maintenance

Where ATEX zones have been defined, the permit to work system shall consider any risks of the work related to flammable gases and potential ignition (for example hot work permits). The technicians shall be competent to work on ATEX equipment and work in ATEX zones. ATEX zones shall be clearly identified such that personnel are aware.

Maintenance activities can create additional flammable/explosive atmospheres. A specific risk assessment shall be performed to assess creation of any temporary ATEX zones related to the maintenance activity.

See EIGA Doc 40 and Lock Out / Tag Out systems (LOTO) for more information [14].

Repair and replacement of equipment shall follow a management of change system that addresses the risks associated with flammable / explosive atmospheres. The approver of any MOC related to ATEX equipment shall be competent in ATEX.

## 14 Explosion protection documentation

The explosion protection documentation can be a separate document including all essential information or partly consist of references to previous documentation. Although there is no formal style required, the documentation shall be able to be read and understood by all persons concerned and the document shall be up to date. The directive does not specifically require that the explosion protection document shall be a standalone document. To facilitate updates and minimise the administrative efforts in the operating company, it is recommended that the explosion protection document refer to other existing documents containing the required information. According to Directive 1999/92/EC, the explosion protection document shall demonstrate (Article 8, text copied from the Directive is in *Italic*) [1]:

- *That the explosion risks have been determined and assessed;*
- *That adequate measures will be taken to attain the aims of the Directive* (i.e. how the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres are implemented);
- *Those places which have been classified in zones*;
- *Those places where the minimum requirements set out apply (*this includes the areas classified in zones as well as equipment in non-hazardous areas which contributes to the safety in hazardous areas);

- *References to procedures for work permits, training of employees, contractors and visitors and control of work in explosion hazard areas*;

- *That the work place and work equipment, including warning devices, are designed, operated and maintained safely*; and

- *That arrangements have been made for the safe use of work equipment as set out in Directive 89/655/EEC concerning the minimum safety and health requirements for the use of work equipment by workers at work.*

  NOTE Directive 89/655/EEC has been replaced by Directive 2009/104/EC.

The explosion protection documentation and related risk assessments shall include not only normal operations but also maintenance, start up and shut down, dismantling, cleaning of equipment and plant as well as possible failures and malfunctions. The documentation should include:

- Name of establishment, plant manager, etc.

- Summarised description of the process and number of employees in areas at risk from explosive atmosphere. Process parameters relevant to the risk of explosive atmosphere, for example pressure in equipment with flammable gas, should be stated.

- An inventory of flammable substances present and its relevant properties, see 6.3.

- As a result of the risk assessment, the areas where a hazardous explosive atmosphere may occur and the classification in zones. Usually, it is appropriate to present the result of the zoning on two types of drawing, the layout of the plant and sections of each building.

- The measures (technical and organisational) taken to protect against explosion, arising from the risk assessment.

- A list of relevant procedures and work instructions including emergency routines.

- A list of the electrical and mechanical equipment and their classification for use in hazardous areas.

- Manufacturer certificates, EU declarations of conformity, risk assessment of existing mechanical equipment and other relevant documents.

The explosion protection documentation shall be reviewed and updated periodically, and after any modification or incident.

## 15 References

Unless otherwise specified, the latest edition shall apply.


[1] Directive 1999/92/EC, *on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres*, www.europa.eu.

[2] Directive 2014/34/EU *concerning equipment and protection systems intended for use in potentially explosives atmospheres*, www.europa.eu.

[3] IEC 60079-0, *Explosive atmospheres - Part 0: Equipment - General requirements*, www.iecex.com.

[4] Directive 94/9/EC *concerning equipment and protective systems intended for use in potentially explosive atmospheres*, www.europa.eu.

[5] International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres (IECEx System), www.iecex.com.

[6] EIGA Doc 51, *Management of Change*, www.eiga.eu.

[7] EIGA Doc 233, *Emergency Response Planning*, www.eiga,eu.

[8] EIGA Doc 60, *Seveso Documents - Guidance on Applicability, Assessment and Legal Documents for Demonstrating Compliance of Industrial Gases Facilities with Seveso Directive(s)*, www.eiga.eu.

[9] *Safety notice: Electrical/electronic devices energised by button cells in hazardous areas (potentially explosive atmospheres)*, www.energyinst.org.

[10] IEC 60079-20, *Explosive atmospheres. Material characteristics for gas and vapour classification. Test methods and data*, www.iecex.com.

[11] GUV 19.7, *Richtlinien für die Vermeidung von Zündgefahren infolge elektrostatischer Aufladungen – Richtlinien „Statische Elektrizität“*, www.kleinwaechtergmbh.de.

[12] EN 1127-1, *Explosive atmospheres. Explosion prevention and protection. Basic concepts and methodology*, www.cen.org.

[13] IEC 60079-10-1, *Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres*, www.iecex.com.

[14] EIGA Doc 40, *Work Permit Systems*, www.eiga.eu.

[15] EN 1755, *Industrial Trucks. Safety requirements and verification. Supplementary requirements for operation in potentially explosive atmospheres*, www.cen.org.

[16] Directive 2006/42/EC *on machinery* (Machinery Directive), www.europa.eu.

[17] EIGA Doc 15, *Gaseous Hydrogen Stations*, www.eiga.eu.

[18] EIGA Doc 160, *Code of Practice – Silane Phosphine and Arsine*, www.eiga.eu.

[19] EN 1593, *Non-destructive testing. Leak testing. Bubble emission techniques*, www.cen.org.

**Appendix A – Example risk assessment and classification of hazardous areas – Acetylene plant**

The table below is an example risk assessment, local conditions shall be considered for specific site risk assessments and zones.

| Item | Area and/or activity | Initial Zone | Release mechanism | Ignition risk and consequence | Comments and references |
|---|---|---|---|---|---|
| **1** | **Carbide storage and handling areas** | | | | |
| 1.1 | Storage of carbide Turnbin containers, outdoors and indoors area | None | The Turnbin container has only one valve in the bottom and is tight. No risk of water ingress and acetylene generation. The container is purged with nitrogen at the filling of carbide | - | Ordinary, non Ex-proof equipment can be used at handling |
| 1.2 | Outdoors transport of containers | None | The design of Turnbin will not allow any water ingress | - | Ordinary, non Ex-proof equipment can be used |
| 1.3 | Generic in carbide handling room | 2 | The carbide area is open to generator room. A major accidental release in the generator room will therefore spread to carbide room | Very low ignition risk, see general precautions. An ignition can cause a room explosion and considerable damage. Also injury if operator in the room | Water is not allowed in the carbide room and the entrance is marked correspondingly |
| 1.4 | Transport/handling of containers in carbide handling room | None | No release of flammable gas | An accidental drop of steel container against concrete floor might cause a spark possible to ignite a cloud according to 1.3. Extremely low risk | Pneumatic crane or manual lifter for Ex areas is used. Maintenance schedule of crane and equipment is implemented. |
| 1.5 | Purging of Turnbin | None | The purge gas nitrogen is vented above roof including any residual acetylene in the Turnbin | - | The vented gas is not flammable why there is no hazardous zone around the outlet above roof |
| 1.5 | Cleaning of indoors carbide handling area | None | No water available or must be brought into the area. Only brushes (spark free) used for cleaning | Very low ignition risk due to spark free brushes, see general precautions. An ignition caused by acetylene generated by carbide residuals on the floor can only cause minor fire without any | The area is not hazardous since the possible flammable gas volume occupies < one ten thousands of room volume |

| Item | Area and/or activity | Initial Zone | Release mechanism | Ignition risk and consequence | Comments and references |
|---|---|---|---|---|---|
| | | | | serious consequence | |
| **2** | **Acetylene generation area (low pressure area)** | | | | |
| 2.1 | Generic | 2 | A single failure of valves, water seal at generator, blockage in the generator, etc. might cause a release of acetylene in the room | No ignition sources available in the room. Only low pressure acetylene | The release will be noticed by the operator and the process stopped immediately. Natural ventilation by low and high openings |
| 2.2 | Valves, pipe connections, water seal, etc. | 2 | Small insignificant leakage from the low pressure system can occur and persist during normal operation | See 2.1 | Natural ventilation in the room. The very small possible leakage will not cause any zone 1 area |
| **3** | **Lime bin** | | | | |
| 3.1 | Lime bin | 1<br><br>2 | The residual lime is piped from generator to the bin and contains dissolved acetylene and maybe non-reacted carbide residue. A post-generation of acetylene might occur in the bin and temperature variation will release the dissolved acetylene Zone 1 only 0.1 m above the surface of the lime sludge<br><br>Accidentally a significant amount of non-reacted carbide might be dumped in the bins Zone 2, from the top of the bin walls down to the zone 1 level | The lime bin is in the open air, that is good ventilation. No ignition source available | |
| 3.2 | Outlet of lime sludge pipe from generator | 1 | See 3.1. Zone 1 0.1 m around pipe outlet and jet of liquid | | |
| **4** | **Gas holder – indoors** | | | | |
| 4.1 | Generic | 2 | Acetylene escaping at emergency emptying or internal water seal failure is piped above roof. The external water seal might fail and release acetylene | There is no ignition source available in the room. Natural ventilation by low and high openings | |
| 4.2 | Valves, water seal | 1 | Minor evaporation of acetylene from water seal. | No ignition source | No significant leakage from the low pressure system can |

| Item | Area and/or activity | Initial Zone | Release mechanism | Ignition risk and consequence | Comments and references |
|---|---|---|---|---|---|
| | | | Zone 1, 0.2 m above water seal surface | Natural ventilation by low and high openings | occur and persist during normal operation |
| **5** | **High pressure area – compressors and driers** | | | | |
| 5.1 | Generic | 2 | Valve failure, leaking joints, and other accidental scenarios might cause a release of acetylene in the room | The release will be noticed by the operator, the process will be emergency stopped and all persons will leave the room. No ignition sources available in the room. Natural ventilation by low and high openings | The acetylene pressure in piping system and cylinders is < 25 bar. The room has a mechanical ventilation with >4 air changes/hour |
| 5.2 | Valves, pipe connections, etc. | 1 | Small leakage from the high pressure system can occur and persist during normal operation Zone 1 or Zone 2, 0.1 m around valves and connections | See 5.1 | See section 8 above. Zone 1 or Zone 2 depends on the risk of release |
| 5.3 | Emptying of cylinders | 1 | See 5.2 | See 5.2 | |
| 5.4 | Safety valve release, emergency emptying of system | - | All these release sources are piped outdoors, see below | - | |
| 5.5 | Emptying of water separator | 1 | The water from the compressor contains some dissolved acetylene and the valve is manually shut off when the water ends. Small amounts of acetylene of atmospheric pressure can be released occasionally | The water separator is open to the atmosphere through a piping above roof | |
| **6** | **Cylinder filling room** | | | | |
| 6.1 | Generic | 2 | Valve failure, ruptured flexible hose if cylinder falls, bad connection to cylinder valve and other accidental scenarios might cause a release of acetylene in the room | No ignition sources available in the room. Natural ventilation by low and high openings. Low risk that the gas stream will be ignited due to electrostatic | The release will be noticed by the trained operator, who will initiate an emergency action by stopping the process and evacuating the room |

| Item | Area and/or activity | Initial Zone | Release mechanism | Ignition risk and consequence | Comments and references |
|---|---|---|---|---|---|
| | | | | discharge due to gas velocity | |
| 6.2 | Valves, pipe connections, etc. | 1 | Small leakage from the high pressure system can occur and persist during normal operation Zone 1 or Zone 2, 0.1 m around valves and connections | See 6.1 | Zone 1 or Zone 2 depends on the risk of release |
| 6.3 | Air ingress in hoses before connection to cylinder | - | If air has entered the hose an adiabatic compression of the air/acetylene mixture at start of filling can cause an ignition | The hose might rupture releasing acetylene | The hoses are equipped with check valve at cylinder connector. Valves are opened before the pressure is increased |
| 6.4 | Acetylene release at disconnection | 1 | The 25 bar acetylene between cylinder valve and check valve will be released at disconnection of hose | The escaped acetylene will cause a zone 1 < 0.1 m | |
| 6.5 | Acetoning of cylinders | 1 | A minor leakage, 0.5 g/s can occur during acetone filling, that is 30 g can be released and wetting the cylinder and valve. At immediate vaporizing, this can cause a LEL zone1 0.5 m around the cylinder from the top down to the floor | The acetoning is done manually and there is an acetone supply emergency stop at the work place. Very low ignition risk | See 8 |
| 6.6 | Emptying of cylinders | 1 | See 6.2 | - | |
| 6.7 | Safety valve release, emergency emptying of system | - | All these outlets are piped above roof | | See outdoors area |
| **7** | **Acetone storage / pump room** | | | | |
| 7.1 | Pneumatic pump | 1 | The whole room is classified as zone 1 since a small leakage might cause an explosive atmosphere in the small room with rather poor ventilation | Low ignition risk. When changing acetone drums non Ex-proof hand driven pallet lifter can be used after shut off of pump and check of atmosphere (Acetone content < 25% of LEL) | The acetone drum and a pneumatic pump is located in a separate room, 30 m$^3$, with natural ventilation. The pneumatic pump is risk assessed as mechanical equipment and no possible ignition source has been identified. (This risk assessment is not |

| Item | Area and/or activity | Initial Zone | Release mechanism | Ignition risk and consequence | Comments and references |
|---|---|---|---|---|---|
| | | | | | included in this document) |
| **8** | **Storage of acetylene cylinders outdoors but under roof at the building's dock** | | | | |
| 8.1 | Cylinder storage and handling at outside dock area with roof | 2 | Several openings to the acetylene cylinder filling room. Any major release in the room will spread to the dock area | Low risk of ignition. At a major release inside the building, all persons will leave the area and activate emergency stops | |
| **9** | **Outside of doors, ventilation openings and other openings to high and low pressure buildings and other classified indoors areas** | | | | |
| 9.1 | Doors and other openings in the building | 2 | See above for possible major releases<br>Zone 2 1 m around door and window openings if no roof above (see 8.1) | No ignition source in the area. At a major release inside the building, all persons will leave the area and activate emergency stops | According to informative annex, EN 60079-10 ND.6.2.2.4.2 [13] |
| 9.2 | Ventilation duct opening | 2 | See above for possible major releases<br>Zone 2 1 m around door and window openings if no roof above (see 8.1) | Low risk of ignition. | According to informative annex, EN 60079-10, ND.6.2.2.4.2 [13] |
| **10** | **Outdoors release points from vents, safety valves, etc.** | | | | |
| 10.1 | Outlets from safety valves | 1<br><br>2 | Zone 1, 1 m around pipe outlet, diam. of safety valve 6 mm, pressure <25 bar.<br>Zone 2, 3 m around pipe outlet | - | According to informative annex, EN 60079-10, ND.6.2.2.4.2 [13] |
| 10.2 | Emergency emptying of gas holder | 2 | Zone 2, 5 m around pipe outlet | | For calculation, see note 10.2 below |
| 10.3 | Emergency emptying of high pressure (25 bars) system | 2 | Zone 2, 6 m around pipe outlet | | For calculation, see note 10.3 below |
| 10.4 | Residual emptying of acetylene cylinders | 1<br>2 | Zone 1, 0.5 m around pipe outlet<br>Zone 2, 1.5 m around outlet | No ignition sources around vent outlet at roof | Cylinders are emptied to gas holder. Only residual pressure (300 mmWG or 0.03 bar) in piping system above roof |
| 11 | **Shut down, start up and maintenance** | | | | |
| 11.1 | Shut down | - | None. The piping system or any equipment shall not be opened without purging. Work permit | None | At normal compressor stops the acetylene pressure will remain in the whole system. |

| Item | Area and/or activity | Initial Zone | Release mechanism | Ignition risk and consequence | Comments and references |
|---|---|---|---|---|---|
| | | | is issued for the opening and maintenance after check of purging etc. | | When the system or any part of it will be opened to the atmosphere, the system will be purged with nitrogen as a part of the shut down procedure |
| 11.2 | Start up | - | Accidental release might occur when equipment or pipes have been dismantled and connected again but since start up is done with nitrogen any release will be eliminated before the system is pressurised with acetylene | Failure of purging can cause an explosion of the acetylene / air mixture in the system. Low pressure part of the installation can rupture and injure operator | At normal compressor stops the acetylene pressure will remain in the whole system. When the system or any part of it has been opened to the atmosphere, the system will be purged with nitrogen as a part of the shut down /start up procedure. |
| 11.3 | Repair and maintenance | - | Accidental release when disconnecting pipes or equipment. Remaining flammable gas in equipment /pipes | Very low risk. If released acetylene is ignited, the operator can be injured | Job risk assessments and formal routines for maintenance and repair are implemented including purging and written work permits |

NOTE 10.2 Calculations using the PHAST model, Weather F Stability 0.6 m/s. Source a 50 mm vertical pipe with a weather protection hat ending 1 m above roof, acetylene pressure 0.03 bar, 15 °C. The hat will cause the gas to be released in all directions and the modelling assumes a release in four perpendicular directions, each ¼ of total flow.

NOTE 10.3. Release of 0.1 m³ gas, 25 bar. Pipe diameter 25 mm, valve opening corresponds to 6 mm diameter. The outlet is located 1 m above roof, directed downwards.

**Appendix B – Example risk assessment and classification of hazardous areas – Flammable gas cylinders storage in open air**

The table below is an example risk assessment, local conditions shall be considered for specific site risk assessments and zones.

| # | Area and/or activity | Initial Zone | Release mechanism and release size | Frequency of release occurrence | Ignition risk and consequence | Comments on safeguards |
|---|---|---|---|---|---|---|
| 1 | Leaking valve spindle or valve neck thread | None | Physical damage to the valve during storage<br>Very small release rate i.e. bubbles.<br>Less than 0.1litre of volume above LEL | Very low probability | Low risk of ignition<br><br>No immediate consequence | All valves are checked for leakage after filling. |
| 2 | Leaking valve outlet | None | Inadvertent small opening of the valve i.e. a small turn of the hand-wheel<br>Small release rate based upon barely audible leak<br>Less than 1litre of volume above LEL | Low probability | Low risk of ignition<br><br>No immediate consequence | All valves are checked for leakage after filling |
| 3 | Shell leakage caused by pit corrosion or weld defect | None | Failure of the shell would lead to sudden loss of containment, potential for significant release | Extremely low probability, orders of magnitude below that considered in ATEX | Medium ignition risk due to large size of release extending beyond the restricted access area.<br>Potential for conflagration by pool fire heating up other cylinders | Cylinders are inspected as per ADR frequency and requirements |
| 4 | Shell damaged by FLT fork | None | Failure of the shell would lead to sudden loss of containment, potential for significant release | Low probability | High probability of ignition – the FLT forks would cause sparks when pushed through the shell of the cylinder | Cylinders are contained within FLT pallets designed so as to not allow operator of FLT to damage cylinder<br><br>FLT drivers trained in accordance with law |
| 5 | Inadvertent opening of valve at handling | None | Operator will immediately close valve if release occurs<br><br>Less than 10litre release | Low probability | Low risk of ignition | Cylinder valve has cap/guard and sealing nut/shrink wrap cover<br>Moving cylinders by |

| # | Area and/or activity | Initial Zone | Release mechanism and release size | Frequency of release occurrence | Ignition risk and consequence | Comments on safeguards |
|---|---|---|---|---|---|---|
| | | | | | | rolling is not allowed when cylinders are not equipped with a cap/guard |
| 6 | Cylinder falls over causing valve damage | None | See #1 – leaking valve spindle | | | Valve/Cylinder conforms with EU legislation on design vs. fall.<br><br>Cylinder valve has cap/guard |
| 7 | Vehicle impact – other than FLT | None | See #4 shell damage by FLT | | | Traffic control system – cylinder storage is controlled so as to minimise risk of other vehicles impacting cylinders |
| 8 | Malicious damage | None | See requirements for restriction of access | | | The storage area is fenced and visitors are controlled |

## Appendix C – Evaluation of potential releases

| Scenario | 0.1 mbar.l/s (0.1 cm³/s) | 0.1 mbar.l/s (0.1 cm³/s) | 0.1 mbar.l/s (0.1 cm³/s) | 1 cm³/s | 1 cm³/s | 1 cm³/s | 0.025 mm² | 0.025 mm² | 0.025 mm² |
|---|---|---|---|---|---|---|---|---|---|
| **Comments** | Residual leak after a bubble test (see EN 1593) [19] | Residual leak after a bubble test (see EN 1593) [19] | Residual leak after a bubble test (see EN 1593) [19] | 10 times more than the bubble test | 10 times more than the bubble test | 10 times more than the bubble test | IEC60079-10-1 Table B1 [13] | IEC60079-10-1 Table B3 [13] | IEC60079-10-1 Table B4 [13] |
| **Models** | Italian code "dz high" | Explojet | Quadvent | Italian code "dz high" | Explojet | Quadvent | Italian code "dz high" | Explojet | Quadvent |
| **$H_2$ 200 bar** | 3.7 mm | 4.2 mm | 4.2 mm | 1.3 cm | 1.3 cm | | 80 cm | 76 cm | 81 cm |
| **$CH_4$ 200 bar** | 2.4 mm | 2.4 mm | 2.4 mm (5.6 10-8 kg/s) | 7.8 mm | 7.5 mm | 7.3 mm (5.7 10-7 kg/s) | 30 cm (7.3.10-4 kg/s) | 27 cm | 26 cm (7.3.10-4 kg/s) |
| **$C_2H_2$ 15 bar** | 4.7 mm ($1x10^{-7}$ kg/s) | 4.1 mm ($1x10^{-7}$ kg/s) | 4.3 mm ($1x10^{-7}$ kg/s) | 1.5 cm ($1x10^{-6}$ kg/s) | 1.3 cm ($1x10^{-6}$ kg/s) | 1.35 cm ($1x10^{-6}$ kg/s) | 12.7 cm ($7.8x10^{-5}$ kg/s) | 11.2 cm ($7.45x10^{-5}$ kg/s) | 11.6 cm ($7.8x10^{-5}$ kg/s) |
| **LPG 7.5 bar (50% $C_3H_8$ / 50% $C_4H_{10}$)** | | 5.4 mm ($1.9x10^{-7}$ kg/s) | 5.3 mm ($1.8x10^{-7}$ kg/s) | 1.9 cm ($1.8x10^{-6}$ kg/s) | 1.7 cm ($2x10^{-6}$ kg/s) | 1.7 cm ($1.8x10^{-6}$ kg/s) | 9.7 cm ($4.62x10^{-5}$ kg/s) | 8.7 cm ($5.1x10^{-5}$ kg/s) | 8.5 cm ($4.62x10^{-5}$ kg/s) |