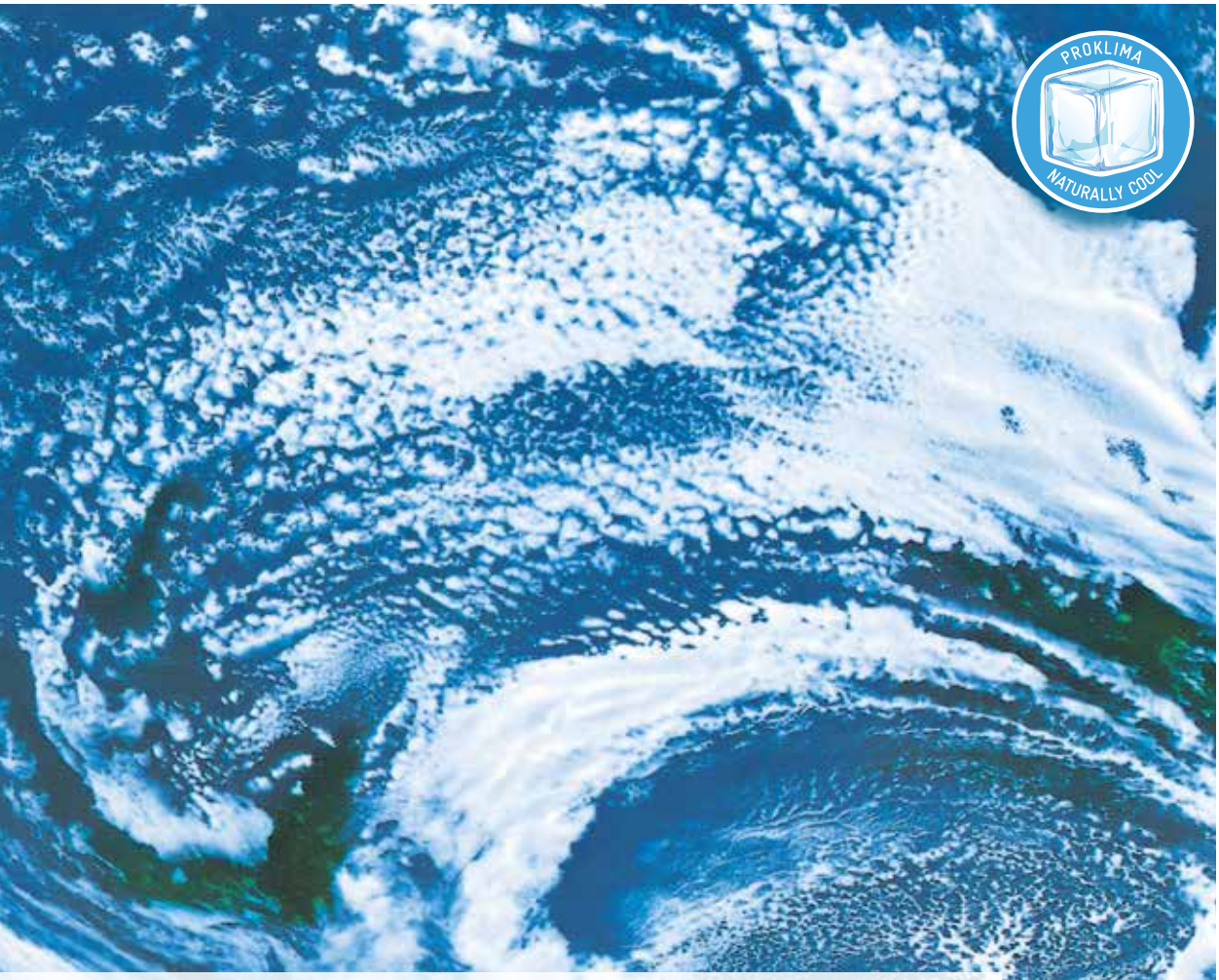

GUIDELINES FOR THE SAFE USE OF FLAMMABLE BLOWING AGENTS IN THE PRODUCTION OF EXTRUDED POLYSTYRENE BOARDS (XPS)

A handbook for engineers, technicians, trainers and policy-makers -
For a climate-friendly cooling / insulation

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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On behalf of

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

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Proklima is a programme of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Since 2008 Proklima has been working successfully on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under its International Climate Initiative (ICI) to disseminate ozone-and climate-friendly technologies.

Proklima has been providing technical and financial support for developing countries since 1996, commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) to implement the provisions of the Montreal Protocol on Substances that Deplete the Ozone Layer.

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Contents

Abbreviations 9
List of figures 10
List of tables 11

1. INTRODUCTION 12

1.1 Definition of flammable 14

1.2 Classification of Flammable Substances according to regulation EC 1272/2008 15

1.3 ATEX standards 16

1.4 Directives applied to work sites with explosion risk 17

1.5 Protection for workers against explosion 20

1.6 Safety measures against explosions 22

1.7 Organisational measures against explosions 23

1.8 Conformity of equipment by applying Directive 2014/34/EU 30

2. SUBSTANCES IN USE 36

2.1 Introduction 36

2.2 Behaviour of liquid and gaseous products 37

2.3 Fire triangle 41

2.4 Explosion limits 41

3. ATEX AREA 45

3.1 Hazardous areas 45

3.2 Identification methods for hazardous areas 47

3.3 Classification of zone 54

3.4 Examples of a standard installation classification 55

3.5 Gas detectors 59

4. ELECTRIC PLANTS: ELECTROSTATIC CHARGES AND ATMOSPHERIC DISCHARGES 63

4.1 Introduction 63

4.2 Construction temperature classification 64

4.3 Protection methods allowed by ATEX directive 65

4.4 Ingress protection - IP Code 67

4.5 Atmospheric discharge protection (lightning) 68

4.6 Grounding system – electrostatic discharge 69

4.7 Electrostatic charge 70

5. STORAGE PLANT AND BLOWING AGENT DISTRIBUTION 72

5.1 Storage systems 72

5.2 Pressurised tanks 73

5.3 Construction method for storage areas 73

5.4 Non pressurised tank storage (atmospheric pressure) 75

5.5 Pipe connection between low pressure pump to high pressure pump 77

6. PRODUCTION DEPARTMENT AND TEST CHAMBERS 78

6.1 Production process 82

6.2 Emission sources of blowing agent 83

6.3 Hot areas 86

6.4 Areas subjected to ATEX due to presence of powder / dust 87

6.5 High pressure pump room 87

6.6 Extruder 92

6.7 Cutting centre 96

7 SUMMARY IDENTIFICATION OF HAZARDOUS AREAS 97

7.1 Introduction 97

7.2 Quick guide to XPS blowing agent analysis 97

7.3 Quick guide to the identification of hazardous areas 99

7.4 Quick guide to the identification of a substance 100

APPENDICES 101

Appendix 1: Typical blowing agents used 101
Appendix 2: Influence of ventilation on type of Zone 101
Appendix 3: List of standards / references 102

Abbreviations

ATEX	AtmosphereExplosive
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMZ	Federal Ministry for Economic Cooperation and Development
DME	Dimethylether
EN	EuropeanNorm
ES	Emission Sources
EU	European Union
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPPS	General Purpose Polystyrene
HFC	Hydrofluorocarbon
HV	High ventilation
ICI	International Climate Initiative
LEL	Lower Explosive Limit
LFL	Lower Flammable Limit
LPS	Lightning Protection System
LV	Low ventilation
MSDS	Material Safety Data Sheet
MV	Medium Ventilation
NE	Negligible Extent
PED	Pressure Equipment Directive
SPD	Source Protective Device
UEL	Upper Explosive Limit
UFL	Upper Flammable Limit
XPS	Extruded Polystyrene

List of figures

Figure 1	Symbols for combustive and explosive substances	16
Figure 2	Application of Directives 99/92/CE and 2014/34/EU	17
Figure 3	Flow chart for minimum safety prescriptions	19
Figure 4	Symbol to indicate ATEX area	25
Figure 5	Logic for explosion risk assessment	28
Figure 6	Technical organisational protection measures	29
Figure 7	Typical EU-EC type ATEX labelling plate	32
Figure 8	EC-EU Type examination certificate	33
Figure 9	The fire triangle	41
Figure 10	Flashpoint, auto ignition temperature and concept of MIE	43
Figure 11	Schematic summary of aspects to consider for an XPS production line	48
Figure 12	Example of Type A opening	49
Figure 13	Example of Type B opening	50
Figure 14	Example of Type C opening	50
Figure 15	Example of Type D opening	50
Figure 16	Low ventilation	52
Figure 17	Medium ventilation	52
Figure 18	High ventilation	53
Figure 19	Procedure schematic for area classification	56
Figure 20	Layout of storage tank construction	73
Figure 21	Non-pressurised underground tank storage	75
Figure 22	Production line sample layout	80
Figure 23	Production line sample layout detail	81
Figure 24	Production line sample layout blowing agent storage detail	81
Figure 25	Example of double ventilator layout	91

List of Tables

Table 1	Overview of different risk labels	15
Table 2	An example of a work authorisation form used by Italian firms	27
Table 3	Examples of blowing agents used in XPS	36
Table 4	Classification of Minimum Ignition Energy (MIE) for surface applications Group II and Group III and reference values of MIE	44
Table 5	Summary of openings and classification	51
Table 6	Equipment temperature class rating group II electrical apparatus (IEC 60079-11)	64
Table 7	Specific equipment codes	65
Table 8	Main features of the protection methods	66
Table 9	Ingress protection numerals	67
Table 10	Individual positions of emissions	83

1. INTRODUCTION

This document will examine the technical, safety and administrative problems related to the use of flammable blowing agents in the production of extruded polystyrene boards (XPS).

The document focuses on production of XPS rather than the design and certification of the XPS boards itself. The explanations, descriptions and examples are specifically focused on safety elements required for a proper production. The producer of XPS should always be aware of the product quality and on the basis of this knowledge eventually increase the safety system.

The industrial use of flammable blowing agents, throughout the document also named gas, within the European Union (EU) is regulated by two directives approved by each member state.

The directives are[1]:

- Directive 99/92/CE[2] on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres
- Directive 2014/34/EU applicable since 20th of April 2016 replaced Directive 94/9/CE on equipment and protective systems intended for use in explosive atmospheres with major amendments regard the legislative framework. It is now harmonised throughout the EU.
  - Responsibilities for importers and distributors are included. When risks from non-electrical equipment are recognised according to this directive, EN 1127-1 will apply. For this standard the hazard analysis has been changed to risk analysis and reference is made to EN 15198 "Methodology for the risk assessment of non-electrical equipment and components for intended use in potentially explosive atmospheres. This involves in the assessment ignition sources from:
    Hot surfaces
    - Flames and hot gases
    - Mechanically generated sparks
    - Electrical apparatus
    - Stray electric currents, cathodic corrosion protection
    - Static electricity
    - Lightning
    - Radio frequency (RF) electromagnetic waves from 104 Hz to 3 x

1 The directives 99/92/CE are generally called "ATEX directives" from "Explosive Atmospheres
2 The denotation of the Directive 99/92/CE is 1999/92/CE

  - Electromagnetic waves from 3 x 1011 Hz to 3. x 1015 Hz
  - Ionising radiation
  - Ultrasonics
  - Adiabatic compression and shock waves
  - Exothermic reactions, including self-ignition of dusts
- Further changes are with regard to the notified bodies which need to reapply for accreditation
- ATEX marking must include the ID of the notified body
- Changes to CE certificates
- Existing equipment under use of directive 94/9/CE remains valid. However, in case of replacement the new directive will apply.

Basically ATEX is created from these two directives.
Additionally, any gases under pressure – such as blowing agents or refrigerants – are EU regulated by: Directive 2014/68/EU which has replaced Directive 97/23/CE PED since 19th of July 2016 regarding pressure equipment.

Always keep in mind that the products in use are flammable and pressurised and no safety system can prevent accidents caused by negligence.

This guideline describes in the chapters 1 to 3 the general aspects which have to be taken into account for installing a production line. Chapters 4 to 7 go into detail describing the activities to be taken according to a sample layout. This sample layout helps to give a better understanding of all the aspects.

This notwithstanding a safety risk analysis has to be conducted for each installation. This guideline shall in now way be considered as replacing this.

1.1 Definition of flammable[3]

The term "flammable" means "substance with the capacity to develop an exothermic oxidation reaction", whilst within the ATEX directives, the definition of explosive atmosphere (which is specifically to what the directives apply) is: a "mixture with air, under atmospheric conditions, of flammable substances in the form of gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture".

The flammable substances are classified by the regulation EC 1272/2008 which repealed Directive 67/548/CEE (and the following modifications) and can be identified by the obligatory label placed on the liquid or gas container (see Table 1) and described hereafter.

Thus, each time, a product or substance identified as flammable, enters the production cycle, the ATEX directives must be considered. In many cases, the ATEX directives can be met through application of the various European standards that have been harmonised to them.

It does not matter whether a product or substance is "more or less flammable" or only a small percentage of the substance is used or if it is mixed with other substances. The ATEX must always be followed.

3 In atmospheric pressure

1.2 Classification of Flammable Substances according to regulation EC 1272/2008

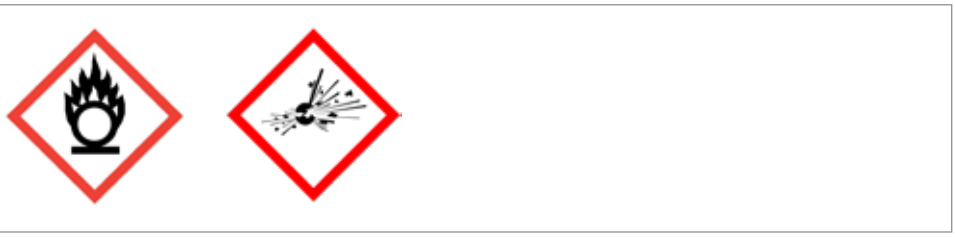
The following table shows the classification of a substance with the relevant risk labels and the meaning of the risk labels. Every substance delivered should carry a label on which the symbol is shown as well as the risk labels. This information is indicated also on the MSDS (Material Safety Data Sheets).

Table 1: Overview of different risk labels

Hazard statement		Description	GHS Pictogram
H224	Extremely flammable liquid and vapour, hazard category 1	If flashpoint <23°C and initial boiling point <= 35°C	
H225	Highly flammable liquid and vapour, hazard category 2	If flashpoint <23°C and initial boiling point > 35°C	
H226	Flammable liquid and vapour, hazard category 3	If flashpoint >= 23°C	
H220	Extremely flammable gas, hazard category 1	gases which at 20°C and a standard pressure of 101,3 KPA; (a) are ignitable when in a mixture of 13% or less by volume in air; or (b) have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit	
H221	Flammable gas, hazard category 2	Gases other than category 1, which at 20°C and a standard pressure of 101,3 KPa have a flammable range while mixed in air.	

The following two labels are for reference only and indicate explosive material; in this case no further symbols like F, F+ are required. The O (Oxidizing) symbol indicates that the material acts as combustible without the need of oxygen and needs to be kept separate from flammable substances.

Figure 1: Symbols for combustive and explosive substances



Although these labels are not applicable for our scope, they are of importance when substances are used for other processes and e.g. are stored together with other substances.

1.3 ATEX standards

ATEX applies to situations where flammable materials exist or are in use, specifically:

- Equipment
- Plant
- **Behaviour**

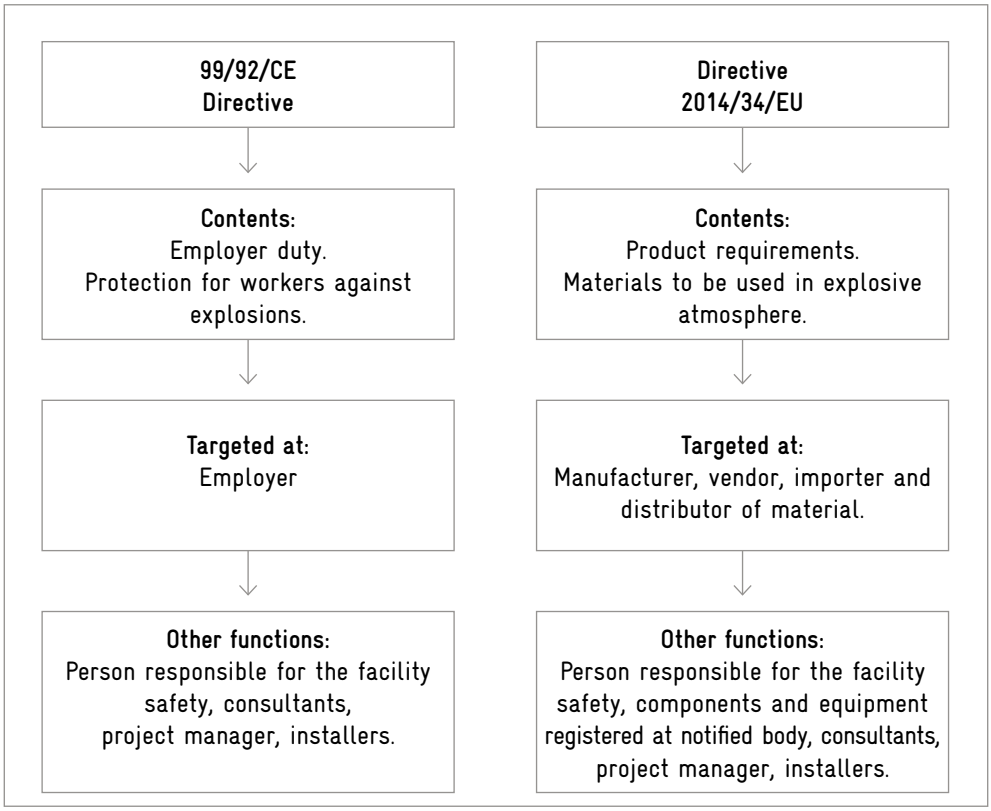
The word "ATEX"has been composed by two words: "**AT**mosphere**EX**plosive". On a work site, in the open or in a closed space, where flammable substances in large or small quantity are present, ATEX must be followed.

It is important to emphasise that ATEX does not necessarily regard the construction of equipment or specialised plants. ATEX is a way to understand if we find ourselves in a hazardous area and if it is necessary to apply appropriate behaviour and/or use designated equipment constructed according to ATEX.

This guideline will also look into sites with flammable substances where the features of the site, for example ventilation, make the risk non-considerable. The equipment and machinery could therefore require less specific protection.

1.4 Directives applied to work sites with explosion risk

Figure 2: Application of Directives 99/92/CE and 2014/34/EU



Introduction to ATEX directives

ATEX regards all work sites where flammable substances are present, kept and/or handled. The **99/92/CE Directive** is designed for the protection of the worker whereas the **94/9/CE Directive** concerns material designed for use in potentially explosive atmospheres. It is necessary to emphasise that once the choice of a flammable substance for the production cycle has been done (in this case the apparatus for manufacturing XPS), the first thing to do is to evaluate where and in which way hazardous areas will appear. This is done by applying the Directive 99/92/CE, described in the next section.

The ATEX directives are basically subdivided as follows:

Classification of hazardous areas by Directive 99/92/CE

The Directive 99/92/CE is applicable in the following way:

a. Identifying the flammable substances used in the process
b. Applying the Standard EN 60079-10-1 for explosive atmospheres
c. Issuing a document in which the hazardous areas are indicated by the function of:
   c1. The physical state of the substance
   c2. Frequency and duration of the presence of an explosive atmosphere
   c3. The type and rate of ventilation

Generally the document consists of a report edited by an expert in the field accompanied by a lay-out indicating the areas defined as hazardous.

The hazardous areas are classified by the type of flammable gas[4], for example presence of vapour and/or mist.

The areas are divided into the following three classes (zone 0-high risk, zone 1-medium risk, zone 2-low risk):

Zone 0 Area in which a consistent explosive atmosphere is present for long periods of time or frequently in a mixture of air and flammable substance in the form of gas, vapour or mist. (Frequency of an anomaly >10-1 days and period of occurrence >1000 h).*

Zone 1 Area in which the formation of a consistent explosive atmosphere in a mixture of air and flammable substance in the form of gas, vapour or mist is likely to occur occasionally. (Frequency of an anomaly 10-1 > P >10-3 days and period of occurrence 1000 > h > 10).*

Zone 2 Area in which, during normal activity, a formation of a consistent explosive atmosphere in a mixture of air and flammable substance in the form of gas, vapour or mist will not occur. If it does, for example due to malfunction or damage, the duration is for a short period of time only

Information in parentheses ( ) is only meant as guidance on defining the zones
Once the hazardous areas have been identified, the explosion risk must be evaluated.

It is important to emphasise that the European Standards regard only explosive atmosphere in air under normal conditions: 0.8 bar – 1.1 bar and at temperature between –20°C and +60°C. The reason for these limits is that they are most frequently present.

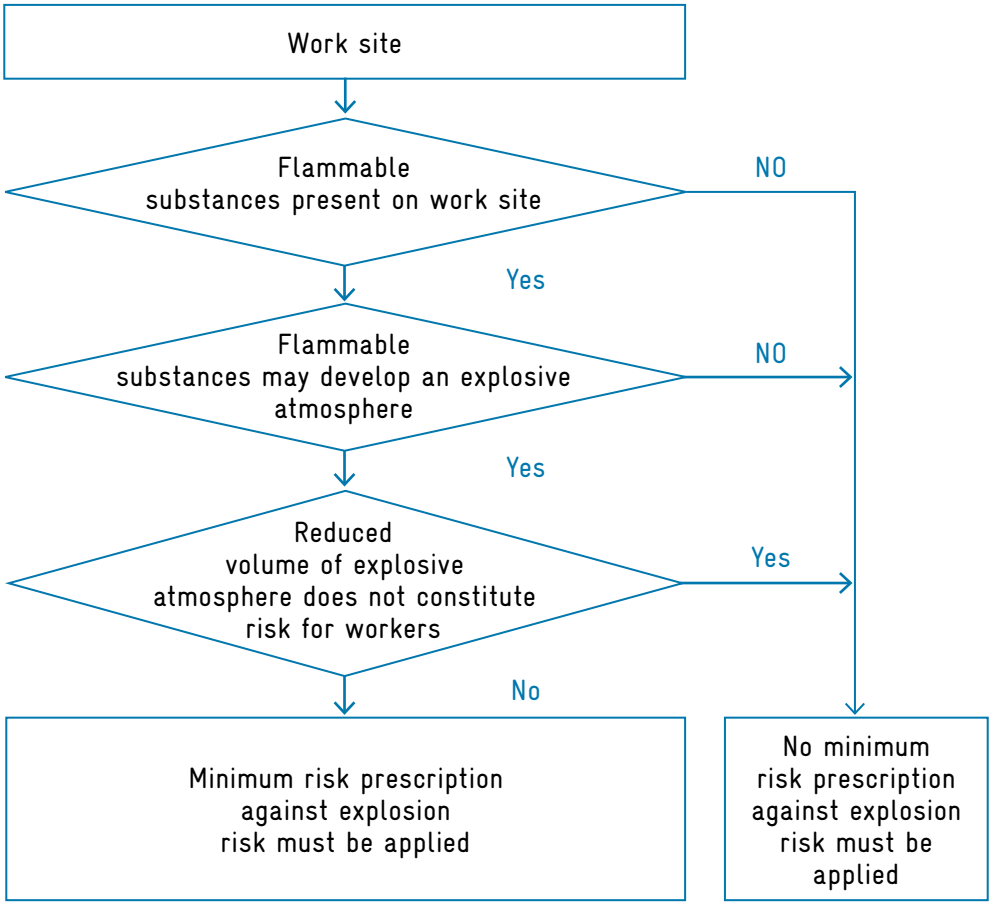
4 In this document gas refers to vapor or mist.

Normally, explosion risks can be excluded when:

a. No flammable substances are present
b. Flammable substances are present but cannot develop explosive atmosphere. For example, if the temperature of the flammable substances remains constantly under flash-point, or if they are not in contact with air[5]
c. Explosive atmosphere can develop, but in reduced volume, which does not constitute any risk for the personnel present

Figure 3 illustrates a flow chart of the application of minimum safety measures at a work site.

Figure 3: Flow chart for minimum safety prescriptions



5 For flammable conditions see the following paragraph

This flow chart could induce to quickly select the option "No minimum risk prescription against explosion risk must be applied". It must be considered that a specific analysis is required, preferably by an experienced and certified expert. A good example where measures have to be applied is e.g. that a supplier indicates that one container of a substance does not pose a risk, but the reality in the factory is that many more containers of that substance are used and that the sum of all DOES pose a risk.

The responsibility to verify whether or not the minimum prescription against explosion needs to be applied lies solely in the hands of the user and NOT the raw material supplier!

1.5 Protection for workers against explosion

The first thing to do when evaluating explosion risk is to exclude, if possible, the presence of an explosive atmosphere.
If this is not possible, then an evaluation of explosion risk must be carried out. The evaluation procedure begins with the consideration of the work process and/or production process under three conditions:

- Under normal production activity
- During start-up, technical test, etc.
- During malfunction and predictable malfunction

Furthermore, the following must be considered:

- Probability and duration of explosive atmosphere
- Presence of ignition source
- Predictable effect of an explosion

Analysing each consideration of explosive atmosphere

1. Probability of presence of an explosive atmosphere
Work-sites with explosive risk must be divided into specific areas, according to the grade of the presence of explosive atmosphere, applying the standard EN 60079-10-17[6]. The procedure for dividing the work-site into areas must be named "Classification of Areas (zones) with Explosion Risk"[7]. When the procedure is terminated the work-site will be divided into hazardous areas as follows:

6 It is not obligatory to apply the standard; other regulations can be taken into consideration. However, the EN 60079-10-1 Standard permits the justification of any changes from controlling authorities.
7 From here on the term EXPLOSIVE ATMOSPHERE means HAZARDOUS EXPLOSIVE ATMOSPHERE

- Zone type 0
- Zone type 1
- Zone type 2

For Zones 0, 1 and 2 protection measures must be provided. For higher risk, more effective protection measures are required.

NOTE: The use of ATEX directives does not necessary mean the automatic installation of particular plants.

ATEX sometimes allows classification of some areas as non-hazardous areas, where explosive atmosphere exists, but the volume of the atmosphere is limited such that it does not present any potential risk and is termed, zone of "negligible extent" (NE).

This means that if an explosion occurs, the damage caused is likely to be minimal. An example is a cigarette lighter: Once you operate, the flammable gas will exit and with the spark a flame is lit. This is not particularly dangerous when used in the proper way. Many airlines prohibit lighters inside the airplane, as with many passengers the amount of lighter and flammable gas would become a potential danger.

2. Presence of Ignition Source

In the context of risk evaluation, the presence of ignition sources that are able to ignite an explosive atmosphere must be identified. The types of ignition sources are listed in the standard EN 1127-1. Furthermore, as mentioned in the introduction, mechanical, moving parts able to create a potential ignition from either hot surfaces or through sparks caused by friction are also included in the risk assessment.

3. The predictable effect of an explosion

There are mathematical methods to evaluate the damage of an explosion and the probability that an explosion will occur. However, this document considers the damage of an explosion and the safety measures aimed to prevent explosion.

In certain cases it is even more important to prevent explosion:

- Where there is a risk of chain explosions,
- where there is a risk that an explosion releases toxic substances, and
- where the explosion site is near a residential area (here, much greater effort must be exerted into reducing the explosion risk.)

It is necessary to intensify the safety measures to avoid explosion and its consequences.

1.6 Safety measures against explosions

Safety measures against explosions must ***always*** be provided for if there are explosive atmospheres and ignition sources present.

The measures may be of the following types:

A. Technical
B. Organisational

The technical measures against explosions can be divided into:

A1. Technical measures to prevent explosions
A2. Technical measures to protect from explosions

In the EU it is obligatory for employers to adopt safety measures ***preventing*** the formation of hazardous explosive atmospheres. These safety measures are first priority before other measures.

This means that when workers are protected by barriers, e.g. a concrete wall, this protection does not substitute the safety measures. The safety measures have to be applied in any case and the barrier is an additional safety precaution but does not substitute the measures!

Technical measures to prevent explosions

Prevention measures help to avoid the formation of explosive atmospheres. The formation can be avoided by the following rules:

- replacing flammable substances with other substances
- keeping flammable substances below lower explosion limit (LEL)
- keeping flammable substances below their flash-point temperature
- limiting the areas where substances may be in contact with air (oxygen)

Safety measures to avoid ignition sources

To avoid the ignition of an explosive atmosphere, it is necessary to identify the ignition sources present and to adapt the necessary protection measures to such an extent that no ignition can occur. The use of materials allowed by the Directive 2014/34/EU, which means materials adequate for the type of hazardous zone in which they are installed, will guarantee that such material does not contain ignition sources.

The ignition sources can be identified and eliminated by following the Standard EN 1127-1, further described in Chapters 6.3 and 6.4.

Technical measures preventing explosions

The technical measures for protection contain an explosion's effects to the extent that the it will no longer pose any danger. Protection measures can be synthesized as follows:

- Suffocating the explosion: By adequate actions, create an inert or oxygen free atmosphere.

- Discharging the explosion: By the use of specific equipment, the products of the combustion will be discharged in the open air. This action limits over-pressure to avoid stressing the structural limits, e.g. of a container.

1.7 Organisational measures against explosions

The organisational measures can be synthesized as follows:

- Qualification of the personnel
- Adequate training in explosion protection
- Operational instructions
- Work authorisation
- Caution during maintenance operations
- Signalling explosion risk areas
- Control and surveillance

Qualification of the personnel

Workers assigned to work in hazardous areas must have adequate training and experience in protection against explosions. This also applies to workers from subcontracted companies.

Training of personnel

Workers must take part in an appropriate training course with at least a minimum level of knowledge in the following:

- Information regarding explosion risks
- Description of work areas where explosion risks are present
- Applied preventive safety measures and the functioning of the safety measures
- Correct use of work equipment
- Information, instruction and knowledge to execute "in safety" the work in hazardous areas
- List of equipment
- Mobile protection equipment in hazardous areas
- Personal protection equipment to be used during work in hazardous areas

The training must also be provided to workers on certain occasions:

- New recruitments, before start working
- Transfer or assignment of different activity
- Introduction of new equipment (or modifications of the already existing equipment) or the introduction of new technology

Operational instructions

The term "Operational Instructions" in this context means procedures in written form established by the person in charge. The Operational Instructions must contain:

1. User instructions
2. Norms of behaviour

The Instructions must be written for the worker in a language that is widely used locally at the work place. Furthermore, the instructions must indicate:

- A list of equipment
- Mobile protection equipment in hazardous areas
- Personal protection equipment to be used during work in hazardous areas, e.g. anti-static garments

Specific caution during maintenance

Experience teaches that during maintenance operations the risk of accidents increases, especially those related to explosions. A particular attention during maintenance operations is therefore of extreme importance.

In situations where external companies are called in to perform maintenance operations, it becomes even more important to check the following parameters:

- No explosive atmospheres are present that can be ignited by maintenance work (for example, welding, cutting, etc.);
- When the maintenance work is finished, before starting up the machinery/ equipment, the reactivation of protection measures is done (protection measures are often deactivated during maintenance);
- The person in charge of the department must check that maintenance work has not damaged or caused any malfunctions to the safety measures. For example, re-establish functionality of e.g. gas detector and/or cleaning the gas detectors with solvent liquid if necessary.

Explosion risk area signalling

The explosion risk areas must be indicated by warning signs.

The warning signs must be accompanied by information such as:

- Type of flammable substance in use
- Type of hazardous area

Once the explosion risk area has been established, it is wise to mark the area limits on the floor by a broken line painted in yellow and black with the sign “EX”, as shown in Figure 4.

Figure 4: Symbol to indicate ATEX area

Work authorisation

Whenever extraordinary work such as maintenance must be performed, it is important to issue the necessary work authorisations. The most common work provoking accidents (fire or explosion) is welding.

It is therefore necessary to work out a system of work authorisations in written form. For example, a pre-printed form should be filled in by internal personnel or the external company performing the work. All personnel involved in the work must sign the form[8] (an example can be found in Table 2).

The following information must be included on the authorisation form, as a minimum:

- Identification of the areas where the work will take place
- Names of personnel performing the work and the person in charge of the areas where it will take place
- Work start and predicted finishing dates
- List of protective measures to adapt

Control and surveillance

It is important to check the equipment in the explosion risk areas:

- before starting-up
- in situations of malfunctioning
- scheduled regularly, the frequency depends on the safety measures adapted

For example, the control and maintenance of electrical equipment and plants in explosion risk areas can be done by checking the presence of gas/vapour/mist. See standard EN 60079-17.

Checking must be performed by technically trained personnel with experience in the field of explosion protection.

8 It is wise filling in the form together with the insider discussing the operation procedures.

Table 2: An example of a work authorisation form used by Italian firms

Work Authorisation Sheet With ignition sources in hazardous areas	
Work site **Department or areas involved**	....
Type of work, e.g. welding, air fan repairing	....
Type of work	☐ Welding ☐ Cutting ☐ Other ☐ Grinding ☐ Use of forklift ☐ Fusion ☐ Use open flames
Precautions to adapt before starting the work	☐ Make sure no explosive atmosphere is present ☐ Remove combustible and mobile objects and substances ☐ Remove accumulated dust at range of .....m. ☐ Cover non-mobile flammable objects with protection materials, e.g. wooden floors and walls, plastic radiators, etc. ☐ Seal grids and similar openings with non-flammable material ☐ **Eliminate explosive atmosphere in containers and ducts (involved in the work), e.g. by by-passing or cleaning. If this type of work must be performed a separate work authorisation must be issued with detailed instructions.**
Fire fighting equipment	☐ Extinguisher ☐ Water ☐ CO_2 ☐ Dust ☐ Fire hose connected and ready ☐ Person(s) in charge of safety and/or fire fighting Name:..... Name:.....
Fire guard	☐ Provision for fire guard service Position of the nearest fire alarm..... Tel. number of the fire brigade.....:.....
Date:.....	..... Person in charge or delegated signature ..... Person performing the work signature

In the following pages two flow charts will summarise the previous paragraphs.

Figure 5: Logic for explosion risk assessment

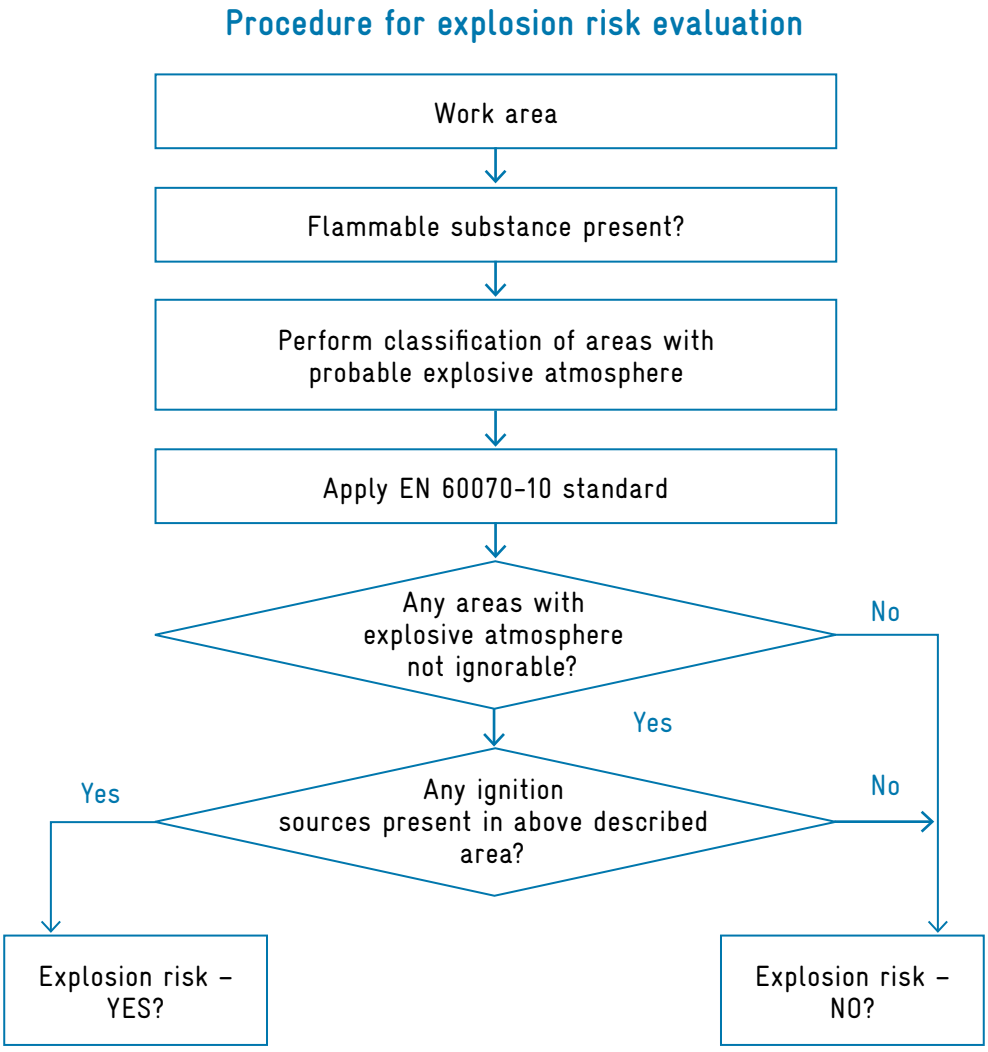
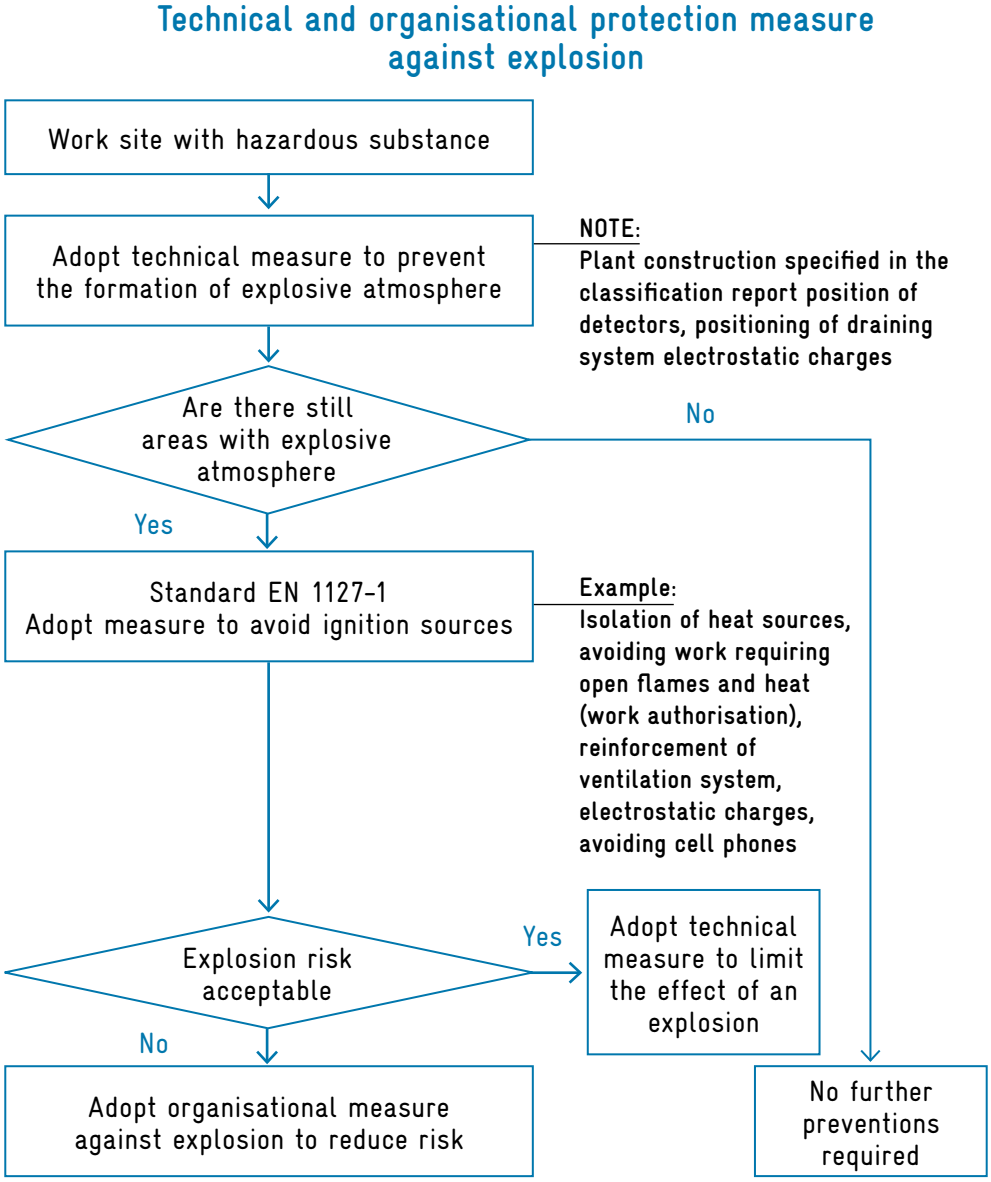


Figure 6: Technical organisational protection measures



1.8 Conformity of equipment by applying Directive 2014/34/EU

Introduction

By identifying and understanding the problems when using flammable substances inside the facility, it is important to deploy equipment and machinery suitable for the hazardous areas.

It is important to understand that with the choice of materials conforming to the 2014/34/EU directive, it is guaranteed that:

- Such products will not create ignition sources
- If no special ambient conditions exist, it is not necessary to evaluate the reliability of the product; this has already been done by the manufacturer. By fixing the obligatory machine plate with the ATEX marking on the equipment and enclosing the declaration of conformity in combination with the user's manual, the product is guaranteed.

How to understand the conformity of a product

Understanding the conformity of a certain product means to understand if a product is appropriate for installation in a hazardous area (Zone 0, Zone 1 or Zone 2). For this the following information is needed:

For the conformity evaluation of a product in accordance with Directive 2014/34/EU, the manufacturer is forced to follow a procedure that is strict and for a higher classification than the area in which the product will be installed. In this context, the word "equipment" includes safety devices, both for control and for regulation, and components.

Equipment to be installed in hazardous areas defined by ATEX bears the following marking: one number + one letter. The equipment is divided into three categories:

- Category 1 equipment
- Category 2 equipment
- Category 3 equipment

The letter that follows can either be:

- "D" (dust) for installation in areas that are hazardous due to gas or dust, or
- "G" (gas) for installation in areas that are hazardous due to gas/vapour/mist

In the present case we must always use the letter "G" (gas) due to the treatment of gas, vapour and mist.

Category 1G equipment (Cat. 1G):

Cat. 1G equipment is appropriate for installation in Zone 0 in the presence of gas. The equipment must have an EC-Type certificate issued by an appropriate authority. Furthermore, the manufacturer must use an approved quality system for the production, perform inspections following the national directives and be audited by the appropriate authorities required by the directive (Form: "Production quality guarantee").

Category 2G equipment (Cat. 2G):

Cat. 2G equipment is appropriate for installation in Zone 1 in the presence of gas. The equipment is divided into the following sub-groups:

1. Electrical equipment or combustion engines
   The equipment must have an EC-Type certificate issued by the notified body responsible for the EC-EU type certification. Furthermore, the manufacturer must use a quality system approved by the appropriate authorities. The manufacturer must declare, checked by the appropriate authorities, that the product conforms to the approved prototype (Form: "Type Conformity").

2. Non electrical equipment
   It is not necessary for the equipment to go through the CE exam performed by appropriate authorities. It is sufficient that the manufacturer provides the technical documentation proving the conformity of the equipment (Form: "Internal Manufacturing Control"). This documentation must however be handed in to the appropriate authority.

Category 3G equipment (Cat. 3G):

Cat. 3G equipment must be installed in Zone 2 in the presence of gas. No CE exam performed by appropriate authorities is required. It is sufficient that the manufacturer provides the technical documentation (Form: “Internal Manufacturing Control”).

Equipment to be installed in a production line and/or pumping/batch plant must be accompanied by a certificate and marked accordingly.

Figure 7: Typical EU-EC type ATEX labelling plate

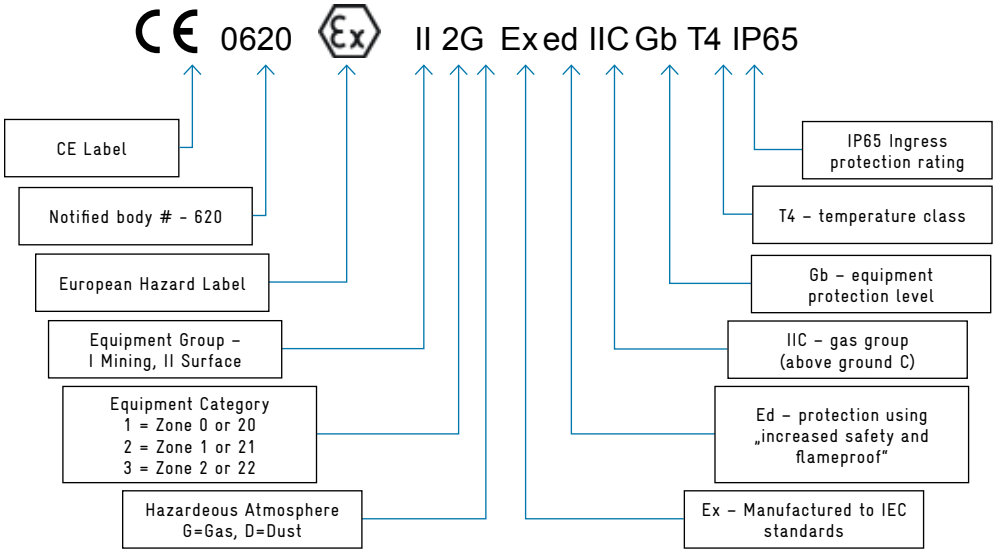


Figure 8: EC-EU Type examination Certificate

[1] EU TYPE EXAMINATION CERTIFICATE

[2] Equipment or Protective System intended for use in Potentially Explosive Atmospheres Directive 2014/34/EU

[3] EU-Type Examination Certificate Number:

[4] Product name:…….....

[5] Manufacturer:…….....

[6] Address:…….....

[7] This product and any acceptable variation thereto of are specified in the schedule to this certificate and the documents therein referred to.

[8] (Name and reg. no. of appropriate authority) notified body number ……. in accordance with Article 17 of the Council Directive 2014/34/EU of 26 February 2014, certifies that this component has been found to comply with the essential health and safety requirements relating to the design and construction of equipment and protective systems intended for use in potentially explosive atmospheres given in Annex II to the Directive.

The examination and test results are recorded in the confidential report no. …….

[9] Compliance with the essential health and safety requirements has been assured by compliance with:

EN 50495:2010

[10] If the sign “X” is placed after the certificate number, it indicates that the equipment or protective system is subject to special conditions for safe use specified in the schedule to this certificate.

[11] This EU Type Examination Certificate relates only to the design and construction of the specified product. Further requirements of the Directive apply to the manufacturing process and supply of this product. These are not covered by the certificate.

EU TYPE EXAMINATION CERTIFICATE

[12] The marking of the component must include the following:

II (2) G Ex e / Ex d
II (2) D Ex tb

This is to certify that the sample(s) of the equipment described herein ("Certified Equipment") has been investigated and found in compliance with the standard(s) indicated on this certificate, in accordance with the ATEX Equipment Certification Program Requirements. This certificate and test results obtained apply only to the equipment sample(s) submitted by the Manufacturer. THE NOTIFIED BODY did not select the sample(s) or determine whether the sample(s) provided were representative of other manufactured equipment. THE NOTIFIED BODY has not established Follow Up Service or other surveillance of the equipment. The Manufacturer is solely and fully responsible for conformity of all equipment to all applicable Standards, specifications, requirements or Directives. The test results may not be used, in whole or in part, in any other document without THE NOTIFIED BODY prior written approval

Certification manager (name) (Signature)

Date of Issue:

Date of expiration:

Notified Body: ……..

---

[13] Schedule

[14] EU-TYPE EXAMNIATION CERTIFICATE No.: ……

[15] Description of the product: ……..

[16] Descriptive Documents: ……..

[17] Specific conditions of use: ……..

[18] Essential Health and Safety Requirements: ……..

EU TYPE EXAMINATION CERTIFICATE

Additional Information

The manufacturer shall inform the notified body concerning all modification to the technical documentation as described in Annex III to Directive 2014/34/EU of the European Parliament and the Council of 26 February 2014.

All these procedures result in providing with the equipment:

A. one label fixed on the equipment

B. one certificate (manufacturers declaration of conformity) to accompany the equipment

C. the user manual

The above-mentioned EU certificate and EU label on the equipment have to be issued for all the categories.

For all the certification issued by the supplier or certified institute, copies of the documentation proving the proper build according to the category have to be kept on the premises of the supplier for verification by the notified body mentioned in the certificate and label, by end-users or other organisations in case of need.

2. SUBSTANCES IN USE

2.1 Introduction

Examples of blowing agents used in XPS include:

Table 3: Examples of blowing agents used in XPS

Sub-stance	Cas.N°	Safety classifica-tion EC 1272/2008	Temperature Classifica-tion	Flammable limits LFL-UFL	Other warnings EC 1272/2008	UN N°
R600a	75-28-5	H220	T1	1.5-9.4	– H280	1969
DME	115-10-6	H220	T3	2.8-24.4	– H280	1033
152a	75-37-6	H220	T1	4-18.5	– H280	1030
u-HFC e.g.	High	Single safe barrier	Single safe barrier	Single safe barrier	– CE marking – Conformity certificate – Notified body certificate	1, 2
HFO 1234ze	29118-24-9	**	T2	**	– H280	3163
Ethanol	64-17-5	H225	T2	3.1-27.7	– H319	1170
Methyl-formate	107-31-3	H224	T2	5-23	– H302, H332, H319, H335	1243
Methylal	109-87-5	H225	T3	2.2-19.9	– H319	1234
Pentane-N	109-66-0	H225	T3	1.1-8.7	– H366, H304, H411	1265
R32	75-10-5	H220	T1	12.7-33.4	– H280	3252

** : No LEL and UEL was assigned at standard testing conditions, 20°C, exhibits flammable limits at temperatures >28°C

Information also regarding the source of the chemical:

The CAS N° is a unique numerical identifier assigned by the Chemical Abstracts Service (CAS) to every chemical substance.

The United Nations N° (UN N°) identifier is specifically important for the transport of substances.

Note that in the past the terminology LEL and UEL was used, but since IEC 60079-10-1 2015 this has been changed to LFL and UFL:

- LFL: Lower Flammable Limit whereby the concentration of flammable gas, vapour or mist in air below which an explosive gas atmosphere will not be formed
- UFL: Upper Flammable Limit whereby the concentration of flammable gas, vapour or mist in air below which an explosive gas atmosphere will not be formed

NOTE: The above-mentioned list of blowing agents is mostly used in combination with CO_2, ethanol or DME systems. HFC-134a is not mentioned as it is banned in the EU due to the high GWP.

When used, the plant therefore must conform to ATEX directives. This is independent of the amounts used, or whether they are used in mixtures to reduce the flammability level and/or other methods to reduce the flammability. The responsibility in all cases lies in the hands of the user of the products and not the producer of the blowing agent.

It is emphasised that it is necessary to carefully verify blends since in many cases, due to different boiling points, the components can separate. Even if a mixture may be non-flammable, single components may be flammable.

2.2 Behaviour of liquid and gaseous products

Vapour Pressure:
Evaporation occurs at the surface of a liquid. If the surface is exposed to the atmosphere, evaporation generally occurs continuously. If, however, the surface is within an enclosed space, evaporation will occur only until the air within the enclosed space becomes saturated with vapour. The vapour pressure and the extent of vaporisation depend on the temperature of the liquid. When the pressure in an enclosed cylinder reaches the vapour pressure of a specific liquid no further evaporation will occur.

Further evaporation will only occur when the liquid or vapour is removed from the container and therefore the pressure lowered.

When there is a container, cylinder or drum, equilibrium will be created between the liquid and gas phase of the substance. This means that when liquid is retrieved the space created will be filled with vapour. At the end, after all the liquid has been removed from the container, cylinder or drum will be entirely filled with vapour.

The blowing agents used in the production of XPS are always in liquid state at a certain temperature and pressure when introduced into the extruder, but e.g. R600a will be in gas phase at ambient conditions and ethanol liquid therefore we distinguish:

- Some liquids are in liquid phase at 20°C at atmospheric pressure
- Other liquids are in gas phase at 20°C (in this case the supplier provides the liquefying of the product in order to supply the product in liquid state)

At an atmospheric temperature and pressure, ethanol for example is liquid, while R600a is in vapour phase. The liquefying of a gas is the function of the boiling temperature in its liquid state and the atmospheric pressure. The lower the temperature, the higher the pressure must be to reach the liquid state and vice versa. The pressure will be higher for a storage container, can or tank, with low boiling points blowing agents stored at higher temperatures. The liquid containers with blowing agents with boiling point temperature less than 20°C will be sealed and under pressure, while blowing agents in containers with boiling point temperature above 20°C can be stored at atmospheric pressure.

Specific weight:
It is the relation between the weight of a certain volume of liquid at 15.5°C (60°F) and the weight of an equal volume of distilled water at 4°C (39.2°F) and 760 mm Hg.

Gas specific weight:
It is the relation between the weight of a certain volume of gas in dry state and the weight of an equal volume of dry air at 0°C and 760 mm Hg.
The specific weight of a liquid and a gas:

Specific weight of a liquid and gas is defined as the weight of a volume unit expressed in kilogram/litre (kg/l) or kg/m³ or gr/cm³. The specific weight of water is 1 (1 litre of distilled water at 4°C = 1 kg). Therefore, the "specific weight" and "density" are represented by the same number.

The relation between the weight of 1 m³ of the product in liquid phase and the weight of 1 m³ in vapour phase gives the quantity of vapour that can be obtained from 1 m³ of liquid.

For isobutane (R600a) for e.g. we have[9]:

- 1 m³ of isobutane in liquid phase weighs 563 kg
- 1 m³ of isobutane in vapour phase weighs 2.45 kg

The relation gives: 563/2.45 = 229 m³

From 1 m³ in liquid phase we will have 229 m³ in gas phase.

This result shows that 1 litre of isobutane in liquid phase poured in a certain area (e.g. a production department) occupies a volume of 229 litres.

This volume of vapour has a tendency to mix and spread throughout the entire volume of a space creating an explosive atmosphere. Considering the Lower Flammable Limit (LFL) of isobutane (R600a), which is equal to1.8% vol, it equates to:

- 1 litre of isobutane in liquid phase = 229 litre of vapour
- 229 litre of vapour will create a situation of LFL for a space with the volume of 12,722 litre (229:0.018 = 12.7 m³).
- Considering a typical alarm of sensors at 15% of LFL, the alarm is triggered at a volume equal to (229:0.018*15%) = 1.91 m³

This helps us understand the danger of even a small release of blowing agent. In a very short time span, situations of potential danger for an entire space can be created. It is also important to note that the cases examined in this document are treated in the same manner as they would be gas, vapour or mist. In fact a gas can be distinguished from vapour or mist because it follows the Ideal Gas Law: pv/m.R.T = constant, where:

9 Specific weight at 15°C and standard atmospheric pressure

- p = pressure
- v = occupied volume at a constant temperature
- m = mass of substance
- R = Universal gas constant
- T = absolute temperature.

Vapour and mist do not follow the Ideal Gas Law. Furthermore, the law is only applicable to ideal gases and not to those gases which we are treating. For our reasoning, we may however consider a gas being real if it is being used far from its point of liquefying, with the approximate application of the Ideal Gas Law.

Even though gas, vapour and mist are treated the same way, from the safety point of view, it must not be forgotten that it is the result that counts, which is the creation of a potentially explosive atmosphere in case of leakage or damage.

Furthermore, all blowing agents used in this field are heavier than air, or more precisely, in atmospheric pressure and environment temperature they have the tendency to stratify towards floor level. This will increase the potentially explosive area indicated in the previous example, as a function of the geometrical disposition of the plant. This means that there would no longer be a cube with a given volume but a cloud with a decreasing height spreading throughout the space.

The term "Potentially explosive atmosphere" is used to describe the presence of a hazardous substance flowing freely due to leakage or damage, which can provoke an explosion. For this to happen, the following circumstances must occur at the same time:

a. the substance must mix with oxygen in the surrounding air in appropriate proportions
b. the mix must be ignited by a spark, arc, naked flame or hot surface

Gas, vapour and mist are therefore considered flammable if they are mixed in appropriate proportions with oxygen and may cause an explosion[10].

10 It is important to consider the difference between the gases apart from explosive substances. The last ones contain both combustible substance and comburent and therefore may explode in absence of oxygen.

2.3 Fire triangle

Figure 9: The fire triangle

For an explosion to occur there must be three components present at the same time:

a. Combustible or fuel, representing the substance
b. Oxidator, the oxygen in the surrounding air[11]
c. Ignition source[12]

For an explosion to occur, flammable material and air must be mixed in precise proportions called Explosion Limits.

2.4 Explosion limits

Explosion limits or flammability limits of a gas or liquid vapour are limits identifying the range of concentration in which, if the mixture of air-vapour or flammable gas is ignited (by a spark, for instance) a combustion of the mixture takes place. This combustion can be in the form of an explosion, deflagration or just a fire, depending on various factors (concentration of combustible first of all, type of container, etc.). The range of the explosion is limited by a minimum and a maximum percentage of combustible in the air (or less frequently, other combustible agents). These percentages are so-called Lower Flammable Limits (LFL) and Upper Flammable Limits (UFL), and provide the range in which a combustion can occur:

11 The air that surrounds us contains approx. 22% oxygen.
12 The EN 1127-1 identifies 13 different types of sources potentially efficient

- For concentrations below LFL, there is not enough combustible for propagation of the flame
- For concentrations above UFL, the atmosphere is saturated with flammable material (not enough air) and there is no oxygen for the propagation of the reaction[13].

The situation of concentrations over UFL is typical for a tank containing flammable liquid, for example petroleum, solvents, pentane, etc., stored at atmospheric pressure. The vapour developed by the flammable liquids makes the atmosphere constantly saturated and therefore above the UFL, but will nevertheless be considered as Zone 0. Unfortunately this can change during filling /emptying processes or during maintenance. In general, the use of UFL should be handled with special attention.

Controlling the concentration of blowing agent and vapours is in fact one of the main problems in the field of safety that will be addressed within the following chapters. In some cases of elaborations to reduce the concentration of one gas that is extremely explosive, inert gases (like nitrogen) can be used to replace air (oxidator) to make the mixture less hazardous. This operation is called "inertisation".

Important measurements

Flash point:
The flash point is the minimum temperature at which, at atmospheric pressure, a substance, generally liquid creates vapours with concentrations within the limits of flammability.

It is understood that:

a. if the flash point is above the environmental temperature or operating temperature the probability of an ignition to occur is low.
b. if the flash point is low the ability for the substance to ignite is high.

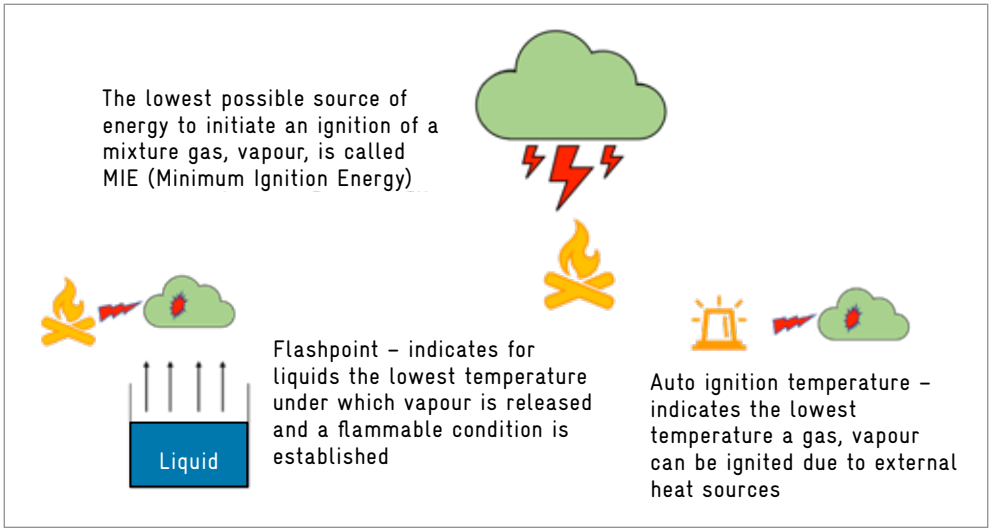
Auto Ignition Temperature:
The auto ignition temperature is the minimum temperature at which ignition may set off explosion or combustion. It must be ensured that the protection is from both, an explosion and cause combustion.

13 There are cases of aborted explosions that have been proved hazardous. E.g inside storage tanks of flammable liquid rendered inert (by use of the saturation system)

In the risk analysis this temperature has to be taken into consideration as the temperature classification indicated in § 2.1 may not be superseded by any component or equipment.

For more detailed information on the measurements and characteristics please refer to the GIZ Proklima publication "Guidelines for the safe use of hydrocarbon refrigerants", September 2010.

Figure 10: Flashpoint, auto ignition temperature and concept of MIE



The concept of minimum ignition energy has been introduced to distinguish the risks involved in the use of the different flammable substances. This provides a classification which we already have seen on the marking of components. To illustrate this, see the table below:

Table 4: Classification of Minimum Ignition Energy (MIE) for surface applications Group II and Group III and reference values of MIE

Surface industry			
Group II		Group III	
Electrical equipment for places with an explosive atmosphere		Electrical equipment for places with an explosive DUST atmosphere	
Sub-division	Ignition energy	Sub-division	Explosive atmosphere
IIA	260 Microjoules	IIIA	Combustible flyings
IIB	95 Microjoules	IIIB	Non-conductive dust
IIC	18 Microjoules	IIIC	Conductive dust

Examples	MIE µJ
Acetylene	19
Ethylene	85
Hydrogen	20
Methane	280
Propane	260

Therefore, we have temperatures for vapours and gasses as well as a classification according to the MIE for selection of the appropriate components, systems to be used.

Material Safety Data Sheet

A material safety data sheet (MSDS) provides all the required information mentioned in the previous sections. These MSDS must be provided by the supplier and approved by certified institutes.

For the sake of cross reference international chemical databases can be consulted, e.g. GESTIS Substance Database from the Institute for Occupational Safety and Health of the German Social Accident Insurance (www.gestic-en.itrust.de). The safety data can be consulted using the CAS N°.

3. ATEX AREA

3.1 Hazardous areas

The hazardous areas/zones within the facility consist of the areas where flammable substances are in use or stored or where they could be transferred to. The polystyrene extrusion production plants use large quantities of blowing agent. For example, a small production plant produces 250 kg/h of polystyrene and consumes approximately 30 kg/h of isobutane.

These are considerable quantities but even with the use of a blowing agent mix of CO_2 and ethanol the flammable component of the blowing agent would have a consumption of approximately 5 to 7 kg/h.

The blowing agent is always stored in tanks positioned on the outside of the facility where the production takes place. Generally 1 or 2 tanks are used, each with the capacity of 10 to 30 m^3.

The product used as blowing agent can be in gas phase or liquid at atmospheric conditions. In the first case, pressurised tanks and for the second case atmospheric pressure tanks are used.

To prevent accidents, the tanks are under ground or placed on the ground but covered with dirt[14]. The tank is loaded by the use of specific tank trucks unloading the product with pumps[15].

The production cycle is described as follows:

1. The blowing agent is withdrawn from tank and pumped with a pressure of 3-5 bar towards the high pressure pump
2. The high pressure pump increases the pressure of the foaming agent to 150-180 bar. The high pressure pump then injects the foaming agent into the extruder[16].
3. In the extruder the blowing agent is mixed with polystyrene.
4. When the mixture, blowing agent and polystyrene comes out of the extruder, the foaming agent expands the polystyrene cells and a panel is produced.

14 The tanks with liquid are under ground to avoid heating by the ambient air, sunlight, while the tanks with gas are positioned above ground being already pressure vessels.
15 The underground tanks can be loaded from tank truck by gravity, without the use of pump.
16 The high pressure pump is installed in a room separate from the extruder.

5. The panel is then cooled down along the production line and cut in the Cutting Center[17].
6. The scrap from the cutting is evacuated by a specific system and stored in a silo. This scrap will later be recycled[18].
7. Scrap of larger dimensions produced during start-up must first be grinded before being stored in the silo.

Inside the facility there are ATEX areas in the following places:

1. Blowing agent storage tank
2. Point where tank truck stops to load the blowing agent into the tank
3. The pumps feeding the high pressure pump
4. Inside the high pressure pump room
5. Inside the building where Extruder and Cutting Center can be found
6. Along the gas feeding line to the circuits
7. Along the circuits transporting the scrap
8. Inside the storage silo
9. Inside the scrap mill
10. Inside the finished product storage
11. Depending on transportation and handling conditions, between the above-mentioned areas can also be ATEX areas.

The above listed areas, which are more or less hazardous, must be evaluated under ATEX.

The safest and easiest way to classify the sites is to apply the standard: IEC-60079-10-1:2015 – "Electrical apparatus for explosive gas atmospheres part 10, Classification of hazardous areas".

In order to apply the standard properly and precisely to specify exactly where in the facility the hazardous areas can be found, it will be necessary to engage an expert in the field who will:

17 The Cutting Center is inside a cabin positioned inside the production area.
18 The waste material, scrap, is completely milled.

- apply the EN-60079 standard
- consider all conditions: chemical, climatical, geometrical and topographical of the facility
- edit a project

The following schematic in Figure 10 shows all the aspects that have to be taken into account when considering the above issues.

3.2 Identification methods for hazardous areas

Identification methods for hazardous areas as follows:[19]

From Chapter 1 it is known that ATEX identifies three hazardous zones for gas:

- Zone 0
- Zone 1
- Zone 2

It is important to emphasise the following:

- Classification of the ***area*** is defined by the presence of hazardous substance
- The area, identified both as ***risk level*** and as ***geographical area***, is determined by the sources emitting or which may emit hazardous substances in the environment. These elements are called "Emission Sources" (ES).

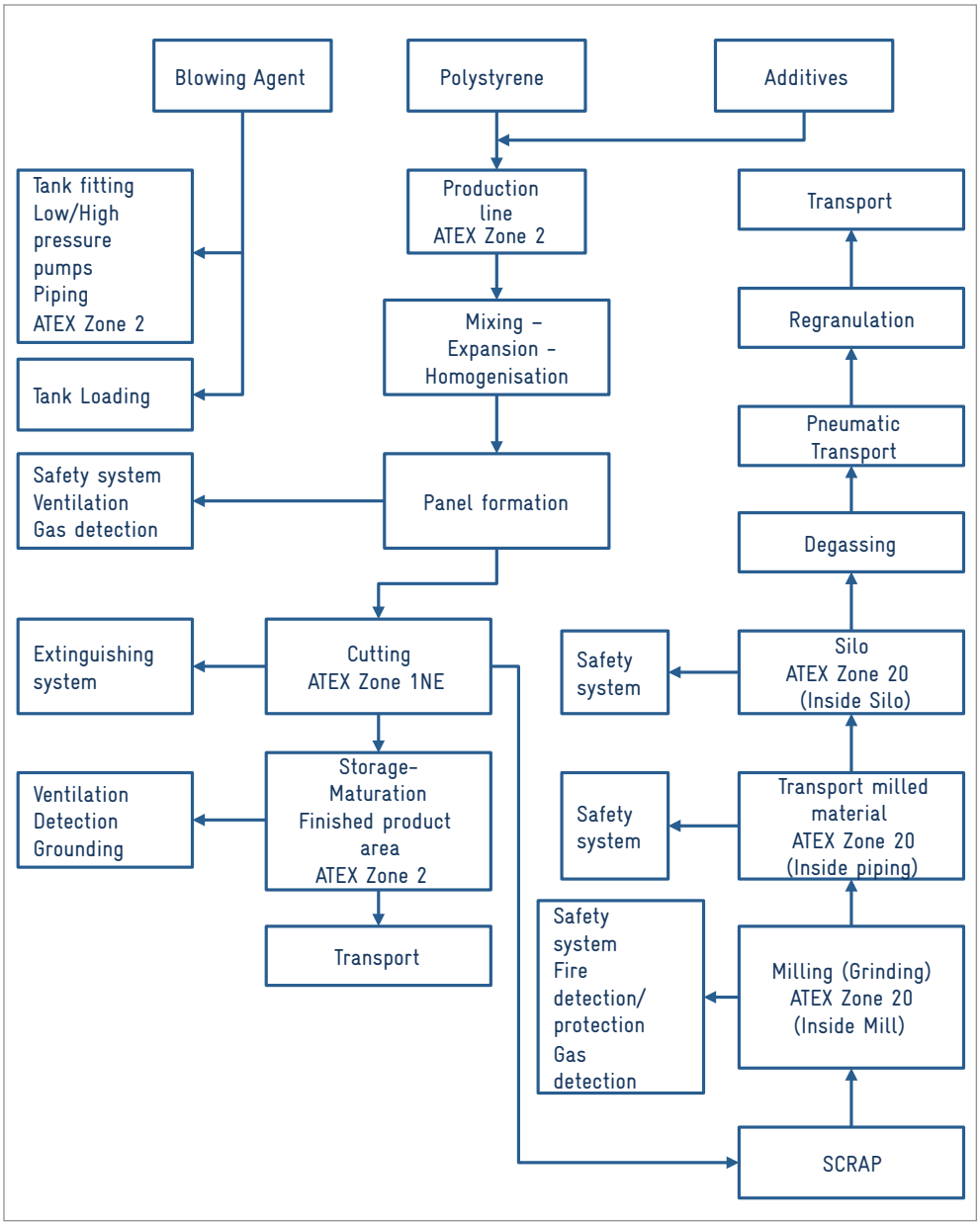
In order to identify the hazardous areas, the following must be identified and classified:

- Emission Sources (ES)
- Openings
- Ventilation (level and availability)

These are discussed below in detail.

19 For a more thorough examination of the matter see standard EN-60079-10-1.

Figure 11: Schematic summary of aspects to consider for an XPS production line



Emission Sources

The emission sources can be classified in three levels:

1. Continuous grade, also named level 0
A source continuously emits hazardous substance for long periods of time, e.g. from the relief valve of a tank.

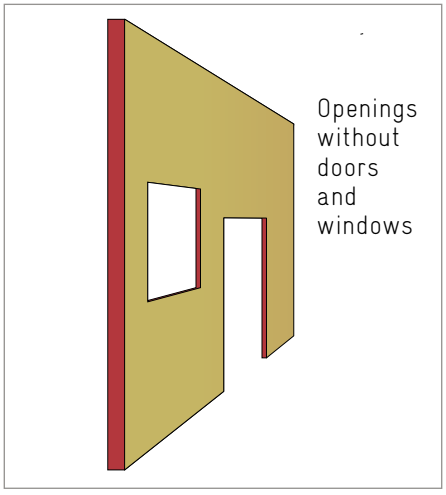
2. First grade
A source emitting hazardous substance periodically or occasionally during normal operation. A typical example may be loading or unloading valve of a mixer in use only for a few minutes per day. For XPS this could be situations like degassing of the injection pipes of the filler equipment.

3. Secondary grade
A source not emitting hazardous substance during normal operation but could, in case of damage, emit hazardous substance. A typical example can be a flange with sealing, where in normal operation no release of flammable substances is expected, or e.g. the inside of ventilation ducts.

Openings

In this case openings mean doors, windows and every passageway through walls, e.g. passageway for piping. The openings are important for the classification of the environment due to the fact that they represent a way for the hazardous substance to spread from one space to another.

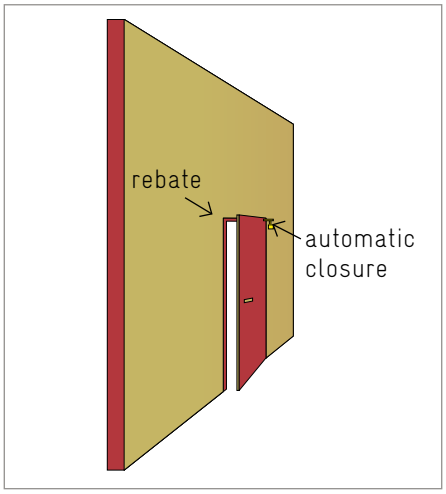
Figure 12: Example of Type A opening



The openings can be divided into four types:

1. Type A
Opening without closure (door, hatch), open frequently or for long periods of time. Passageways for cables and piping are considered Type A, when these passages are not sealed. Figure 12 illustrates an example.

Figure 13: Example of Type B opening



2. Type B

Opening with sealing on all sides, e.g. door with interspaces of not more than 1 mm between door and threshold not opened frequently and that cannot stay open thanks to automatic closure. Figure 13 illustrates an example of Type B opening.

3. Type C

Opening with double or tight sealing on all sides, as shown in Figure 14.

Figure 14: Example of Type C opening

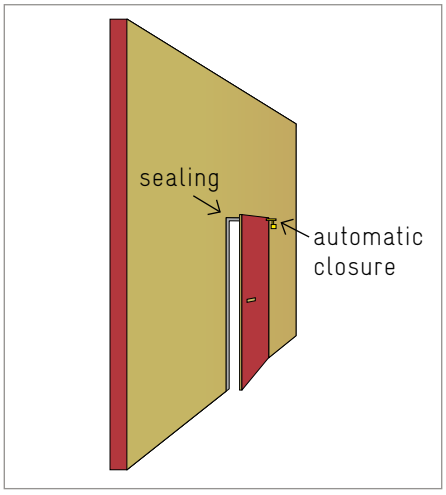
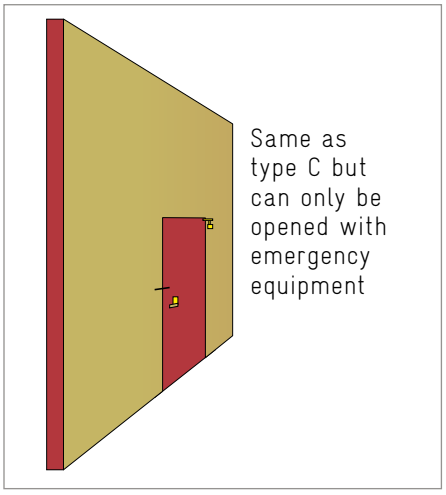


Figure 15: Example of Type D opening



4. Type D

Opening with same features as for Type C, but with the possibility of opening soley using special equipment or in case of emergency. This type of opening can be obtained by combining Type C opening, next to hazardous area, with Type B opening. Figure 15 illustrates an example of Type D opening.

It is understood that opening Type A does not limit the level of classification of the area. The hazardous area and the area next to it connected by a Type A opening must have the same classification.

The Type B opening normally allows the passage of emissions from one hazardous area to another that is less hazardous. If the area where the emission source is positioned is classified as Zone 0, for zoning of the other side, an emission grade of primary has to be considered.

An opening Type C means passage of emissions in two steps: If the zone is 0 at the emission source, then on the other side of the opening the emission grade secondary should be considered.

An opening Type D means passage of emissions in three steps. If the zone is 0, on the other side of the opening there is "no emission source". If on the one side is Zone 1, the emission grades for the other side can be lowered by one step.

Table 5 summarises the openings of a room. The adjacent room or area is than classified as follows:

Table 5: Summary of openings and classification

Opening type	Zone classification of the room	Adjacent area
A	0	0
B	0	1
C	0	2
D	0	Non-hazardous

Ventilation

The ventilation system is extremely important for the identification of the level of hazardous atmospheres potentially explosive (In the following sketches the blue/green colour is the emission distribution inside the room). The standard regards three levels of ventilation grade and three levels of availability that form the efficiency of the ventilation system:

1. Low ventilation (LV)

A low ventilation is a system with fresh air-flow that is not able to dilute the flammable substance in order to reach LFL (Lower Flammable Limit). In this case the flammable region occupies the entire volume of the closed environment with the tendency to extend the area through openings. When the emissions cease, the environment may remain hazardous for some hours due to limited dilution of the hazardous atmosphere. Figure 16 illustrates the air flow in a low ventilation system.

2. Medium ventilation (MV)

A medium ventilation is a system that is able to dilute the flammable substance in order to reach LFL at a limited distance from the ES (Emission Source). In this case the flammable region does not occupy the entire volume of the environment but is limited to some volume of space around the ES. When emission ceases the flammable mixture, it dilutes within a relatively short time (approximately 10 min). Figure 18 illustrates the air flow in a medium ventilation system.

Figure 16: Low ventilation

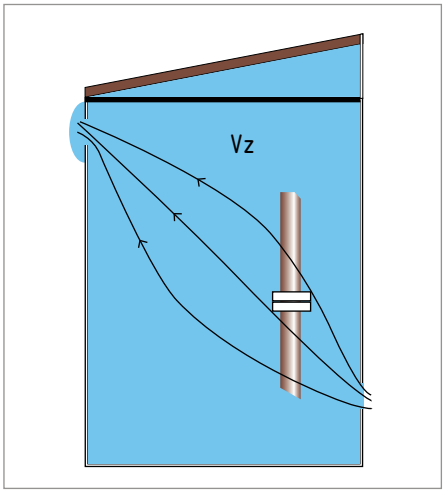
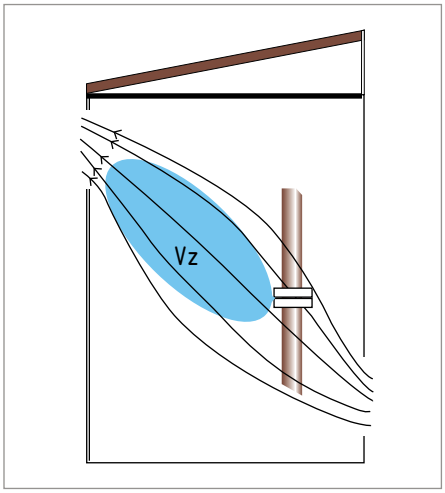


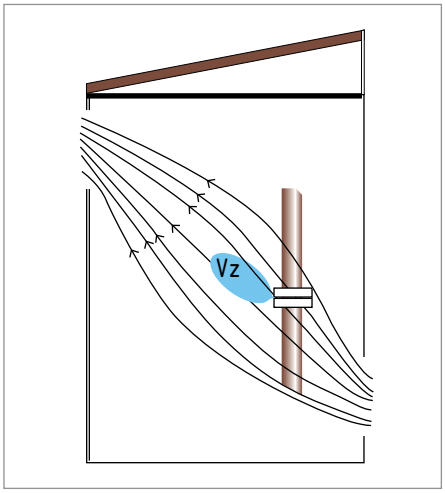
Figure 17: Medium ventilation



3. High ventilation (HV)

A high ventilation system is able to maintain a low concentration of the flammable substance below LFL. The explosive atmosphere in this case is concentrated around the ES at a radius of approximately 10 cm. When emission ceases the flammable mixture, it disperses within a few seconds. Figure 18 illustrates the air flow in a high ventilation system.

Figure 18: High ventilation



Furthermore, besides the ventilation level, the ventilation availability must be evaluated, i.e., ensuring that a constant air flow is maintained to some extent. This availability is classified by the following degrees:

Good availability: Ventilation is continuously present with constant air flow. No interruption allowed during operation. Always applicable to open space or closed space without closures (doors, windows).

Fair availability: Ventilation is continuously present with constant air flow. Short interruption allowed during operation.

Poor availability: Ventilation does not respect the previous criteria, however, there is some dilution of the hazardous atmosphere.

When it is not possible to obtain the level **poor availability**, the environment must be considered:

"Not Ventilated"

The standard emphasizes that the definition of the level of ventilation should not be considered as rigid. This leaves some leeway for the designer of the facility to evaluate the ventilation, considering the general concept of safety.

However, systems must always strive to obtain **good ventilation as minimum, meaning a high ventilation (HV) with minimum good availability**.

An overview is shown in Table B.1 of the EN 60079-10-1:2015 enclosed in Appendix 2.

The classification of good-fair-poor availability of ventilation is not a real technical measure. Therefore, when a ventilation system is installed it is advisable to verify that around the area of emission a good availability of air is present. For this purpose smoke generators are excellent tools to verify that although a high ventilation is installed, it actually also removes the smoke from the emission source. However, it must also be borne in mind that smoke is neutrally or positive buoyant, whereas the blowing agents under consideration are negatively buoyant. Therefore there are special smoke generators e.g. from Dräger that simulate this behaviour.

3.3 Classification of zone

The zones are classified by using three parameters:

- Source level
- Ventilation level (HV – MV – LV)
- Ventilation availability

The extension of the zone is defined by:

- The volume of the department in which the ES is positioned
- The presence and the type of openings to the other departments

The ES always generates an area connected to the level of emission:

- **Continuous = Zone 0**
- **Primary = Zone 1**
- **Secondary = Zone 2**

When the level of ventilation is high and with good availability, the zones are of neglible extent (NE).

The zones are named:

- **Zone 0 NE**
- **Zone 1 NE**
- **Zone 2 NE**

In this case, the zones do not affect the classification even though a good practice is to avoid ignition sources in the proximity.

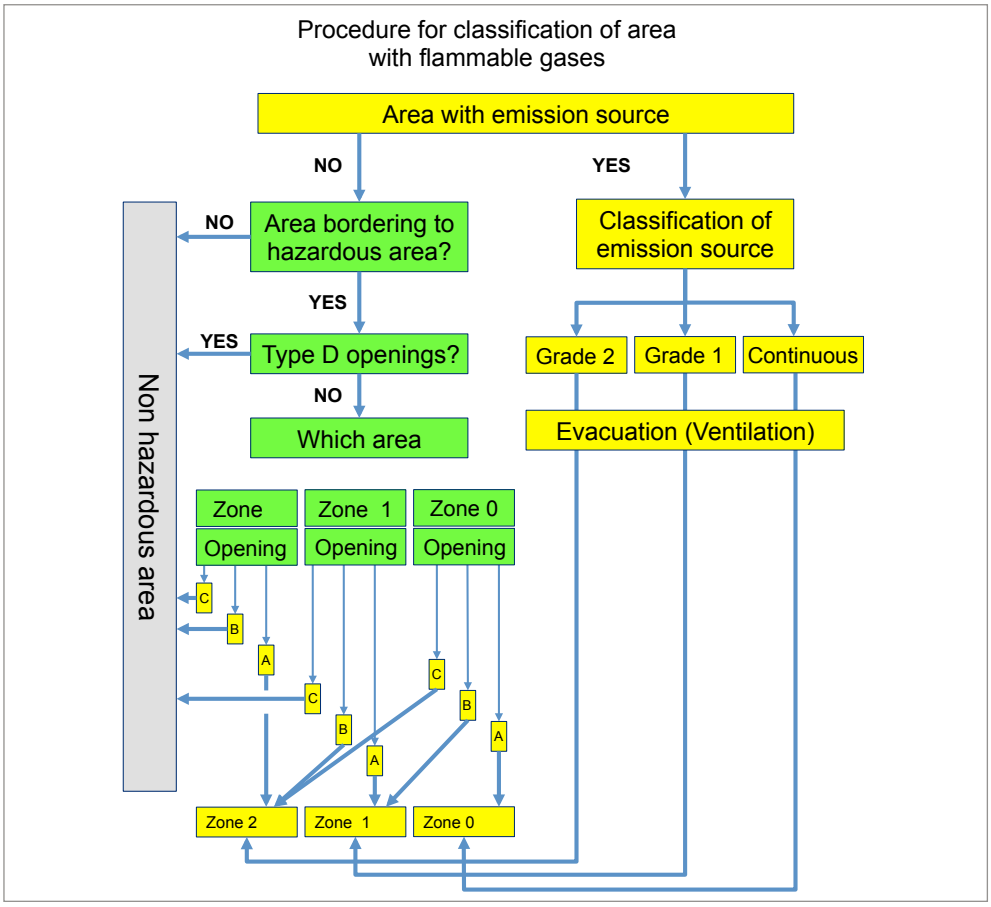
When the zones are classified NE, the classification is only valid for when the conditions under which the analysis has been done are present. When changes are applied to the area, e.g. additional equipment, modifications, the analysis has to be repeated and verified. It is therefore common practice to have equipment in this area suitable for Zone 2 also when not strictly required by ATEX. Therefore, if there is a temporary removal of the Zone NE classification, it does not introduce any hazard. A temporary removal is in no case advisable as it has a direct impact on the adjacent zones, see the previous paragraph!

When the ventilation is low, some partial volumes of the environment must be evaluated. For example, underground shafts may have to be classified as Zone 0 (in case of gas heavier than air) even if in normal case the zone would be classified as 2. It must also be considered whether a small leakage, e.g. at the foaming head, could accumulate in an underground shaft and create an explosive atmosphere and ignite by electrostatic discharge or other source.

3.4 Examples of a standard installation classification

The examples can be viewed in the flow chart presented in Figure 19. A detailed description of the examples is provided in the following sub-sections.

Figure 19: Procedure schematic for area classification



Storage area with fixed pressurised tank

The following zones can be identified:

The tank which is installed in the open air, positioned and fixed on a supporting structure, gives a medium ventilation level and a medium ventilation availability.

The emission source (ES) which is created by:

- manual and safety valves positioned on the tank,
- loading nozzle,
- pump seal in the low pressure pumping station,
- feeding line,

gives:

the emissions occurring only for short periods of time and with low frequency. This means that the ES are not predicted during normal operation and consequently evaluated as emission of secondary grade, which results in the following:

1. Medium ventilation level
2. Medium ventilation availability
3. Secondary grade emissions

Result: The area is classified as: Zone 2.

Tank Truck stop area

The tank truck stops in an area outside the building. The emission sources are:

2nd Grade Sources: These come from the manual valves, the flexible tubes, the pump sealing inside the low pressure pumping station and from the distribution line.

1st Grade Sources: These come from the flexible tubes connecting the truck and the tank. These sources occur with low frequency and for short period of time but ***always*** when loading. This means they are considered "emission sources predicted under normal operation" and must therefore be classified as **1st Grade Sources**.

Therefore, the tank truck stop area has the following characteristics:

- 1st Grade emissions
- High ventilation
- Fair ventilation availability

Result: The area is classified as: Zone 1

NOTE: In this case, to specify the exact volume of Zone 1, a precise calculation must be performed, knowing the exact environmental conditions of the area. As an example, it can be said that the area extends for 1.5 m around the ES.

High pressure pumping room

The high pressure pump is installed in a well-ventilated room with **Type A openings** towards the outside. The emission sources are: manual valves, flexible tubes, pump sealing and the blowing agent distribution line.

These emissions can occur only with low frequency and for a short period of time, which means they are considered as non-predicted emissions during normal operation. Therefore these are also classified as 2nd Grade emissions in this case.

- 2nd Grade emissions
- High ventilation
- Good ventilation availability

Result: The area is classified as: Zone 2

Gas Injection into extruder

The emission sources consist of automatic and manual valves installed on the extruder. These emissions can occur at low frequency only and for short periods of time. This means that they are considered as non-predicted emissions during normal operation and are classified as 2nd Grade emissions.

- 2nd Grade emissions
- High ventilation
- Good ventilation availability

Result: The area is classified as: Zone 2

The safety analysis in this point must be performed by an expert evaluating each installation. The aim of this document is to view the problems related to the use of foaming agents in the production of polystyrene foam.

Cutting centre

The emission sources consist of panel cells being broken during the cutting process, whereby small gas particles are released from the cells. This type of emission is continuous, giving rise to the following:

- Grade 0 emissions (continuous)
- High ventilation
- Good ventilation availability

Result: The area is classified as: Zone 0 NE

NOTE: For the following areas: Cutting centre, scrap evacuation system, mill; ATEX areas created by dust must be calculated. This subject is not considered in this document, as the focus here is primarily on treating problems related to the presence of blowing agent.

We also have an area in which the foamed XPS boards are transported from the extruder to the cutting centre. The boards are in this stretch of the production line cooling down and blowing agent is released. For this area actually we have a continuous emission but in general the emissions are low and a good ventilated production area should be sufficient.

Gas detectors are installed to signal the presence of gas and to activate the ventilation plant at high speed.
The gas detector installation method will be described hereafter. However, it is important to consider that the quantity of air withdrawn from an area or container must be restored with air from the outside, and this air must not be contaminated.
Figure 18 illustrates a schematic of the procedure for area classification.

3.5 Gas detectors

Introduction

The probability of the formation of explosive atmosphere above the minimum concentration is not uniform. It is most likely that the highest concentrations are with the close proximity of the ES, diluting further away from the ES. It is, however, possible to reach greater quantities at a distance from the ES where the blowing agent is accumulated, such as underground passages, shafts, etc.

The accumulation and dilution of gas are determined by two factors:

- Specific weight
- Ventilation

The specific weight of a gas[20] (kg/m^3) or vapour can be schematised as follows:

Specific weight lower than 0.9:

- Upwards diffusion of vapour
- Possible accumulation underneath roof

Specific weight between 0.9 and 1.1

- Uniform diffusion of vapour with lower intensity moving away from the ES

Specific weight higher than 1.1

- Downwards diffusion of vapour
- Possible accumulation at floor level (underground passage, shaft)

The ventilation and the movement of the air volume generate a dilution more or less extended in function of the above parameters.

Earlier in the chapter, the use of ventilation to dilute the explosive atmosphere has been evaluated. Now an important safety component for the use of flammable substance is introduced: **Explosive Atmosphere Detectors.**

Type of Explosive Atmosphere Detector

In the industrial sector the following detectors are the most frequently used:

- Catalytic combustion
- Infrared

20 Specific weight is referring to air considered as 1

The function of both types is to detect small percentage of flammable gas within the atmosphere of the space where the flammable substance is used. The signal is processed through a processing unit and managed according to the safety procedures described as follows:

Usually the detectors are calibrated to detect and process two levels of concentrations: **15% and 30% of LFL**.

Note that suitable sensors should be used and catalytic type of sensors cannot be used in areas where halogenated refrigerants are used (e.g. R134a, R22) as they can interfere with the measurement.

Installation and function

The gas detectors must be positioned in order to control the area where explosive atmospheres may occur. The function of the detection system is to try to anticipate the formation of an explosive atmosphere or promptly signal a sudden formation in case of production machinery damage.

The safety of the area should be controlled by the ventilation system, controlling it in such a way that there will not be any flammable substances present and allowing the detectors to control that accumulation of dense gas does not occur.

The detectors are encapsulated in Ex-rated enclosures, and connected to a processor unit. Incoming signals are processed in a logical manner, for example:

- Detector signalling LFL 15% - **pre-alarm**
- Detector signalling LFL 30% - **alarm**

- Pre-alarm commands: 2nd ventilator start (reserve ventilator)
  - Yellow light switched on
  - Siren sound switched on

- Alarm commands: Maintaining function of 2nd ventilator
  - red light switched on
  - Maintaining siren sound
  - Blocking the distribution of product
  - Blocking the electrical power

A simple rule to keep in mind when positioning the detectors:

- If vapour is lighter than air the detector must be installed in the upper part of the room.

- If vapour is heavier than air the detector must be installed at floor level.

- If vapour specific weight is between 0.9 and 1 detectors must be distributed both in the upper part and at floor level.

For each ES at least two detectors must be installed. At each point of potential accumulation it is possible to install only one detector (except when it is necessary for surveillance of underground passage or shaft).

Chapter 5-6 demonstrate with practical examples the ventilation system installation and explosive atmosphere detection system installation.

4. ELECTRIC PLANTS: ELECTROSTATIC CHARGES AND ATMOSPHERIC DISCHARGES

4.1 Introduction

All components of an electric system present a potential hazard if they produce or exceed the ignition temperature of flammable material, either during normal operation or due to malfunction.

During normal operation the following components can be hazardous:

- Resistance heaters
- Incandescence lamps
- Electrical motors
- Electrical switches
- Poorly installed electrical wirings

During normal operation and in case of malfunction, the following components may be hazardous:

- Cables
- Junction box
- Batteries

Experts always consider a certain state-of-the-art depending on the standards they are used to. Proper electrical installation has to be done according to the standards in place. Especially improper wiring and connections is a recurring hazard (for example duct tape connected wires, loose wires not properly placed in channels, open electrical cabinets, etc. make each area hazardous even without the presence of flammable substances).

The initiation of an explosion may be caused by sparks or overheating. To avoid initiation of an explosion the following precautions must be provided:

1. Explosion limitation by use of an enclosure and appropriate electrical cabinets.
2. Avoid contact between hot surfaces and the surrounding atmosphere by the use of solid barriers, liquid or gas between the components (e.g. electric power panel with pressurised nitrogen), and separation of the atmosphere inside the box/shield/container from the outside atmosphere of the hazardous area.
3. Lower the energy level of the system so that there will not be enough energy to initiate an explosion. This is called intrinsically safe[21] (e.g. EN 60079-11).

A potential hazard may also be:

- Electrostatic discharge
- Over-currents generated by direct or indirect atmospheric discharges

The safety requirements for electric power systems in explosion hazard areas are established by the EN 60079-14 Standard.

Before describing the methods of protection, certain definitions indicated in the following must first be analysed.

4.2 Construction temperature classification

The initiation of an explosion may be caused by the temperature of the external or internal parts of a component, e.g. a lamp cover or junction box, or bearings inside a motor.

To avoid this hazard, every apparatus installed in a zoned area must be classified by the maximum temperature that it may reach. Such temperature, measured during worst conditions, must not exceed the auto ignition temperature of the hazardous substance (typically more than 100K below the auto-ignition temperature). For example, if a cover of a resistance reaches 280°C it cannot be used in an explosive atmosphere with hydrogen due to the fact that the auto-ignition temperature of hydrogen is lower. Thus the components are classified by temperature as shown in Table 6.

Table 6: Equipment temperature class rating group II electrical apparatus (IEC 60079-11)

Maximum surface temperature in °C:	450	300	200	135	100	85
Temperature class:	T1	T2	T3	T4	T5	T6

21 Only for electronical signal circuits and not for electric power circuits

The standard does not indicate a temperature class for cables but indicates measures to adapt during installation. All cables in hazardous areas must be protected from overload.

4.3 Protection methods allowed by ATEX directive

The IEC 60079-xx standards introduce specific protection measures for electrical apparatus. There are 4 main protection concepts with particular construction parameters. For the different zones there are different concepts which can be used. The following table shows the different concepts and equipment identification codes.

Table 7: Specific equipment codes

Type of protection measures	Equipment code	Description	International standard	Applicable Zone
Intended to prevent a potential ignition arising	Ex e	Increased safety	IEC 60079-7	1,2
	Ex nA	Type n-protection	IEC 60079-15	2
Intended to limit the ignition energy of the equipment	Ex ia	Intrinsic safety 'ia'	IEC 60079-11	0,1,2
	Ex ib	Intrinsic safety 'ib'	IEC 60079-11	1,2
	Ex ic	Intrinsic safety 'ic'	IEC 60079-11	2
	Ex nL	Type n-protection	IEC 60079-15	2
Intended to prevent the explosive atmosphere contacting the ignition source	Ex p	Purge/pressurised protection	IEC 60079-2	1,2
	Ex px	Purge/pressurised protection 'px'	IEC 60079-2	1,2
	Ex py	Purge/pressurised protection 'px'	IEC 60079-2	1,2
	Ex pz	Purge/pressurised protection 'px'	IEC 60079-2	2
	Ex m	Encapsulation	IEC 60079-18	1,2
	Ex ma	Encapsulation	IEC 60079-18	0,1,2
	Ex mb	Encapsulation	IEC 60079-18	1,2
	Ex o	Oil immersion	IEC 60079-18	1,2
	Ex nR	Type n-protection	IEC 60079-15	2
Intended to prevent an ignition from escaping outside to the equipment	Ex d	Flame proof protection	IEC 60079-1	1,2
	Ex q	Sand/ powder (quartz) filling	IEC 60079-5	1,2
	EX nC	Type n-protection	IEC 60079-15	2
Special	Ex s	Special protection	IEC 60079-0	0,1,2

Electrical equipment for the different zones needs to follow specific equipment codes, according to four safety concepts depending on the construction design.

Table 8: Main features of the protection methods

Equipment code	Description protection concept
Ex i Intrinsic safety	This is a protection concept that restricts the electrical energy within the equipment to a level which is below that which may cause an ignition or that limits the heating of the equipment surface. There are two main sub-types: • Ia this type allows for the occurrence of two faults during operation • Ib allows for the occurrence of one fault during operation • (the fault occurrence makes ia type mandatory for use in zone 0 and ib zones 2 and 3)
Ex d Flame proof	The equipment that may cause an explosion is contained within an enclosure which can withstand the force of an explosion and prevent transmission to the outside hazardous atmosphere. This method of protection also its prevents the hazardous atmosphere entering the enclosure and coming into contact with the equipment.
Ex m Encapsulation proof	A protection concept whereby equipment that could potentially cause an ignition is encapsulated within a compound or resin so a to prevent contact with the explosive atmosphere. The concept also limits the surface temperature of the equipment under normal operating conditions.
Ex e Increased Safety	Precautions are applied to the installation to ensure increased security against the possibility of excessive temperatures and sparks from electrical equipment. Equipment that normally causes sparks is excluded from use with this method of protection.
Ex p Pressurised	One process ensures that the pressure inside an enclosure is sufficient to prevent entrance of a flammable gas, vapour, dust or fibre and prevent a possible ignition. Another process maintains a constant flow of air (or an inert gas) to dilute and take away any potentially explosive atmosphere.
Ex o OilImmersion	All equipment that has the potential to arc and potentially cause an ignition is immersed in a protective liquid or oil. The oil provides insulation to prevent ignition.
Ex q Powder Filling	All equipment that has the potential to arc is contained within an enclosure filled with quartz or glass powder particles. The powder filling prevents the possibility of an ignition.
Ex n Non Sparking	A type of protection where precautions are taken so that electrical equipment that has the potential to arc is not capable of igniting a surrounding explosive atmosphere. Several subtypes: • Ex nA where components used in construction are non sparking • Ex nC where components used in construction are non-incendive • Ex nR where components used are tightly enclosed to restrict the access of air and prevent ignition • Ex nL where components used in construction do not contain enough energy to cause an ignition
Ex s Special	This method has no specific parameters or construction rules. In essence it is any method of protection which can provide a pre-determined level of safety to ensure that there is no potential for an ignition.

4.4 Ingress protection – IP code

Another consideration in the protection of equipment in hazardous areas is the safeguarding against the ingress of solid foreign objects and water. This is known as the degree of ingress protection and is commonly referred to as the IP code.

The relevant standard for the degree of ingress protection is IEC 60529, an overview is detailed below:

Table 9: Ingress protection numerals

1st Numeral	Degree of protection	2nd Numeral	Degree of protection
0	No protection at all against solid objects	0	No protection at all against the ingress of water
1	Protection against solid objects greater than 50 mm in diameter	1	Protected against falling water drops
2	Protection against solid objects greater than 12,5 mm in diameter	2	Protected against falling water drops at an angle of 15°
3	Protection against solid objects greater than 2,5 mm in diameter	3	Protected against sprayed water at an angle of up to 60°
4	Protection against solid objects greater than 1,0 mm in diameter	4	Protected against the splashing of water from any direction
5	Protection against the ingress of dust in such an amount that it will not interfere with the operation of the equipment	5	Protected against water jets from any direction
6	Total protection against the ingress of any dust	6	Protected against powerful water jets from any direction
		7	Protected against the ingress of water when temporary immersed between 0,15 m and 1 m
		8	Protected against the ingress of water when continuously immersed to a specified depth

A typical application for flammable areas is IP 65, (6) therefore protected against the ingress of dust and to a high extent any vapours or gas. (5) As well as protected against water jets from any direction. However, the appropriate selection has to be evaluated for the area where it will apply.

4.5 Atmospheric discharge protection (lightning)

Introduction

Protection against atmospheric discharge (lightning) is described in the **EN 62305** standard.

Atmospheric discharges have four types of impact:

1. Facility directly hit by lightning
2. Facility indirectly hit by lightning (e.g. ground near the structure gets hit by lightning)
3. Incoming lines directly hit by lightning
4. Incoming lines indirectly hit by lightning

For a plant with storage and handling of flammable material it is always necessary to perform an evaluation of the risk of atmospheric discharge.

Basic principles for protection against atmospheric discharge include:

- Protection of facility, plants and equipment
- Protection of personnel in the facility
- Protection of incoming telecommunication lines
- Protection of electric power supply and metal piping

Damage due to lightning

Lightning can cause three types of damage:

- Damage to living beings
- Damage to material due to fire, explosion, mechanical failure, toxic substance leakage and **ignition of explosive atmosphere** in zoned areas.
- Electrical apparatus failure due to overcharge.

Protection against lightning

Direct hit: The facility must be protected by an external lightning protection system (LPS), usually a Faraday cage.
Indirect hit: All openings in the "cage" must be electrically connected directly to the "cage" by source protective device (SPD).

An expert evaluation of lightning impact on the facility and/or flammable storage area must always be performed.

General protection methods include:

- Installing a “cage” LPS on classified buildings
- Grounding of system for all metallic objects in contact with the protected area
- Applying tension dischargers to all conductors in contact with the protected area or zoned area

The protection methods must also be applied on underground tanks.

4.6 Grounding system – electrostatic discharge

All metallic objects in the zoned area must be ground connected and the grounded plant must be connected to the dispersion plant. There are some complicated calculations for the planning of a dispersion plant, given the resistivity of the ground. In general, experience is relied upon, considering the following:

a. An underground copper wire of 50 mm² without cover at 1 m depth, running alongside the outer wall of the facility guarantees efficient dispersion.
b. The electrical resistance measures will guarantee safety
c. Steel or copper spikes in the ground will contribute to the ground resistance when the copper wire does not provide a sufficiently low resistance.

According to general usage, the earth resistance in an ATEX environment should be less than 1 Ohm. For lightning protection, an earth resistance of considerably less than 10 Ohm is needed. These values are normally given by the national laws for erection of electrical/ATEX equipment.

4.7 Electrostatic charge

The accumulating electrostatic charges may provoke spark or sufficient energy to ignite an explosive atmosphere. It is therefore always necessary to avoid any accumulation of electrostatic charge in an ATEX area[22]. The electrostatic charge originates from being in contact between two bodies of different kind. An electron transfer takes place during the contact and one body will have an excess negative charge, while the other will have an excess positive charge. When the two bodies are separated, an electric charge takes place.

To avoid an electrostatic charge, besides avoiding synthetic material, the best method is to ground-connect and make the objects, conducting parts and the conveyors of flammable substances equipotential. It is not necessary to ground-connect the metal objects that are not exposed to electrostatic charge, such as window and door frames.

Generally, the plant structures are mechanically ground-connected through bolts or welding, which are good methods for the electrical continuity. The bolt (or similar) must have a resistance less than 1*106Ohm for a secure ground-connection.

The equipment and machinery installed are already protected and certified by the constructor and certification organisation. However, it is advisable to adapt and follow the most common precautions, as listed below:

- DO NOT use non-conductive pipes and containers in the presence of high resistance flammable liquids.
- In zone “0” areas no high-resistance containers are allowed. Only very small containers for sampling.
- Avoid any rapid filling of tanks which occurs when loading underground tanks by gravity.
- Avoid dragging air or gas into liquid.
- Reduce to a minimum the mixing revolutions.
- Do not use vapour in tank cleaning operations.
- Reduce the power and pressure of the cleaning equipment when cleaning the tanks.

Before proceeding to the loading of a liquid from tank-truck, an equipotential connection between the truck and the vessel must be performed.

22 Note that many flammable substances accumulate electric charges.

NOTE: The closing of the circuit must be performed according to ATEX. Furthermore, the connecting pliers must have insulated handles to avoid discharges.

- Transfer from barrel to container by a mobile pump may cause sparks between pump and barrel especially when the pump is inserted. Before transfer it is therefore necessary to ground-connect pump-barrel-container.
- Thorough evaluation of the conveyor, ventilator and engine belts installed in the ATEX area must be performed.
- Personnel must be equipped with anti-static garment. Shoes must have ground-resistance of less than10^5Ohm.
- It may be useful to go as far as the deionisation of the environment. The installed machinery must be ATEX certified and ground-connected.
- Body and flexible tube of the pressurised fire-extinguishers installed in ATEX areas must be ground-connected.

5 STORAGE PLANT AND BLOWING AGENT DISTRIBUTION

5.1 Storage systems

The blowing agent for XPS is stored in metal containers, either pressurised or in balance with the atmospheric pressure. Gas in liquid phase is contained in pressurised containers. Liquids are contained in atmospheric pressure containers.

The blowing agents normally used in the production cycle are:

a. R600a (isobutane)
b. DIMETHYLETHER (DME)
c. R152a
d. U-HFC e.g HFO-1234ze
e. ETHANOL
f. METHYLFORMATE
g. METHYLAL
h. PENTANES

The first four agents are pressurised gases. This means that inside the containers, at an ambient temperature of 20°C and atmospheric pressure, a positive pressure can be found. If the liquid blowing agent in the container were in contact with the surrounding atmosphere it would enter into gas phase more or less rapidly. The blowing agents ethanol, methylformate, methylal and pentanes (e-h, respectively) are liquid and stored in containers without positive pressure. If the liquids get in contact with the surrounding environment they remains liquid until the boiling point temperature is reached.

NOTE: Even liquids may suffer very slow spontaneous evaporation as a function of temperature. Users of this guide are referred to technical literature for further information about the difference between liquid and gas.

There are two different types of storage depending on the blowing agent in use:

- Pressurised tank storage
- Atmospheric pressure tank storage

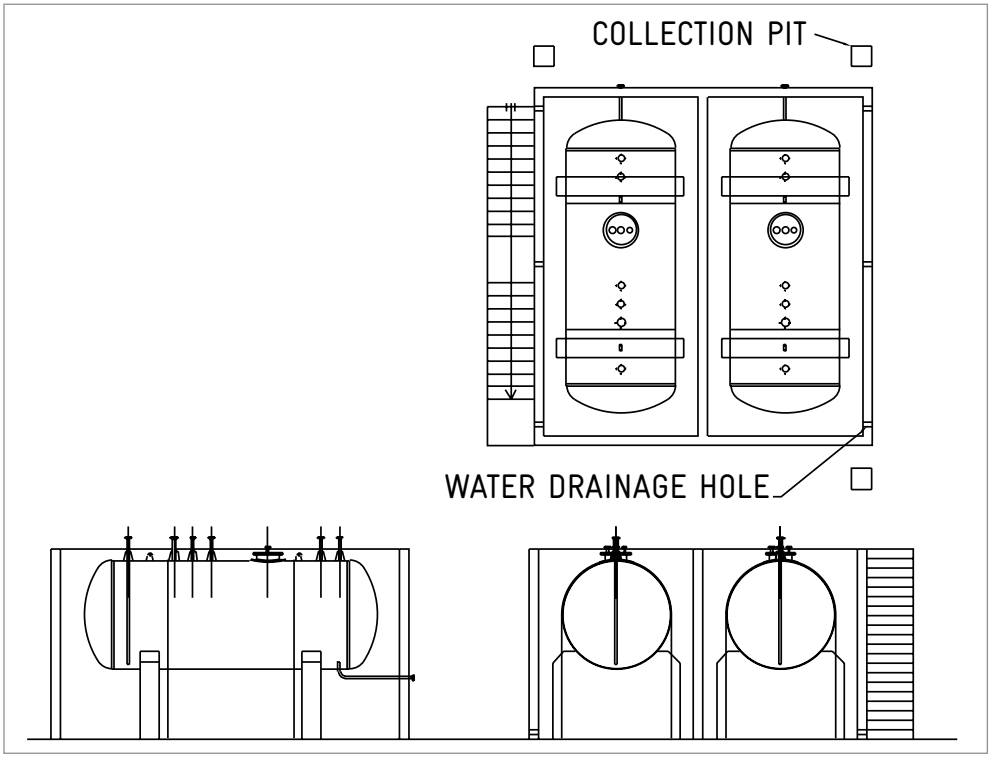
5.2 Pressurised tanks

The pressure tanks and pressurised plants are subject to **ATEX**, as well as to the European pressure equipment directive, **PED 2014/68/EU**, which indicates methods for the construction and installation of pressure equipment. This document does not examine the PED directive. However, it is important to know that pressure tanks and plants must be ATEX and PED (EU) certified. PED is applicable to all containers with a pressure higher than 0,49 bar. The fixed tanks with a capacity of between 5 m^3 and 50 m^3 are positioned either underground or above the ground. Generally, in XPS production plants, tanks of 30 m^3 are used to optimize the transportation of the blowing agent.

5.3 Construction method for storage areas

Usually the tanks are carbon steel horizontal tanks with capacity of 30 m^3. The size of the tank is chosen to optimise transport and loading of the blowing agent. Plants using a mix of CO_2 and flammable liquid can use smaller tanks of approximately 10 m^3. Figure 20 illustrates a layout of the tank construction.

Figure 20: Layout of storage tank construction



The tank is positioned on a reinforced concrete or steel structure[23]. Reinforced concrete is preferred in order to avoid structural collapse in case of fire. Tanks containing liquid blowing agents with boiling point above atmospheric temperature are placed in tanks underground. In this case the tanks must have double walls to avoid and monitor leakage in case of damage.

In some countries it is allowed to install tanks in the open air. In this case, insulation must be provided to avoid overpressure due to heating from the sun.

The tank must be:

a. Installed outside the facility, in an open-air area.
b. Distant from hazardous operations and ignition sources.
c. Protected from blow/impact from manoeuvring vehicles.
d. Positioned maintaining safety distances.

In this case the tanks represent the "centres of hazard" that determine the hazardous areas. For better understanding see also the production line in Figure 22 in Chapter 6.

The determination of the hazardous distances varies from country to country. It is, however, important to follow these indications:

- distance to border of establishment should be kept to about 7.5 m
- distance between tank truck position and tank should be about 3.0 m
- distance between flammable liquid tanks and non-flammable should be kept at 15.0 m[24]
- distance between hazardous elements should be maintained at around 7.0 m
- distance to railway, school, etc. should be at least 15.0 m

Important: The values indicate maximum distances. They should be evaluated case by case according to the standards of each country. Furthermore, the tanks must be constructed according to the PED Standard for "pressure containers".

The tanks must also be positioned at a safe distance from the air intakes and openings, preventing any gas leakage from the safety valve from accumulating in the following areas:

- Heating provisions
- Compressor room
- Electrical generators

23 Armed concrete is obligatory in Italy.
24 The gas emitted by the safety valve can leak into the adjacent non-flammable substance tank through the balance valve.

- Electrical cabinets
- Water drainage, grounding shafts, cable shafts and other passages

As indicated in section 3.4, the tank is a Zone 2 area with emissions only from damage or malfunction.

Ancillary equipment for the tank includes:

- The safety pressure release valve placed at 1.5 m above the tank: Zone 1

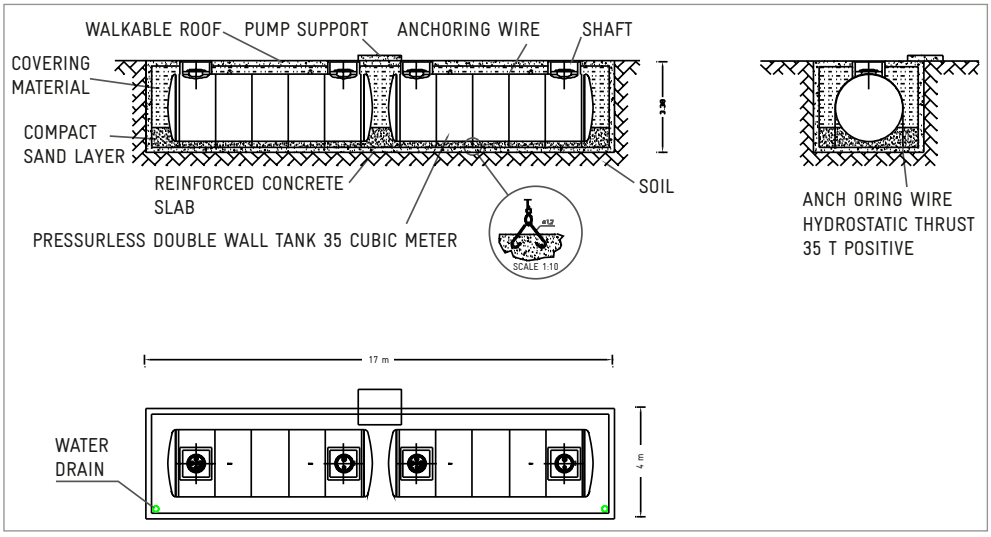
Operations for filling the tank include:

- The tank truck stop area: Zone 1

5.4 Non pressurised tank storage (atmospheric pressure)

Figure 21 shows a sample construction layout of non-pressurised tank storage.

Figure 21: Non-pressurised underground tank storage



The blowing agents that are liquid at ambient temperature are stored in containers without positive pressure. These tanks can be positioned above or below ground. When these tanks are installed above ground, special care has to be taken for protection against direct sunlight by means of insulation or roofing.

It is advised to always use underground tanks for blowing agents, which are liquid at ambient pressure, due to the fact that the safety distances are reduced and that the tanks are very well protected against atmospheric impact and are well-insulated.

Construction details for underground tank storage

Underground tanks are characterised as follows:

- The tanks are made of carbon steel.
- The tanks are double-walled for protection and monitoring of leaks.
- The control for leakage is achieved by means of nitrogen pressure monitoring of the interspaces between the tanks.
- When the production site is in an area of frequent earth quakes or inundation the tanks need to be placed inside a cement containment tub and anchored to the ground.

The placement of the tanks on the factory premises also needs to take into account the safety distances to the factory, streets and other areas. The determination of the hazardous distances varies from country to country. However, the following indications can be used:

- distance to border of establishment should be around 7.5 m
- distance between tank truck position and tank must be maintained at about 3.0 m
- distance between flammable liquid tanks and non-flammable must be around 7.5 m
- distance between hazardous elements should be about 7.0 m
- distance to railway, school, etc. should be about 7.5 m

IMPORTANT: The values indicate maximum distances. They should be evaluated case by case according to the standards of each country. Furthermore, the tanks must be constructed according to the PED Standard for "pressure containers".

The tanks must also be positioned at a distance from the air intakes and opening, avoiding that any gas leakage from the safety valve will accumulate in the following areas:

- Heating provisions
- Compressor room
- Electrical generators

- Electrical cabinets
- Water drainage, grounding shafts, cable shafts and other passages

The tank must also be:

- Installed outside the facility, in an open-air area.
- Distant from hazardous operations and ignition sources.
- Protected from blow/impact from maneuvering vehicles.
- Positioned maintaining safety distances.

The tanks must be classified as:

- Zone 2 with emissions only from damage or malfunction.

Ancillary equipment must be classified as:

- Zone 1 with regards to the safety pressure release valve, 1.5 m above the tank

Operations of refilling must be classified as:

- Zone 1, truck stop area

5.5 Pipe connection between low pressure pump to high pressure pump[25]

The piping connection for feeding the blowing agent from the tank to the high pressure pumps of the extruder requires some attention. A proper connection takes into account the following:

- Use seamless carbon or stainless steel piping
- Test pressure is 40 bar or sufficiently higher than the pump capability
- The best is to have an all-welded design, try to avoid the use of connection flanges
- The piping can be installed over or underground
- The underground placement with a double jacket and leakage monitoring with placement inside a shaft and filling with sand is the most suitable installation.
- Above ground piping needs to have insulation for protection against sunlight, as well as protection and marking to avoid any impact with other vehicles and operations.

25 Point 3 of layout Chapter 6 Figure 22

6 PRODUCTION DEPARTMENT AND TEST CHAMBERS

For guidance through this chapter, a typical production layout is chosen and presented, as depicted in Figures 22-24. This layout includes the equipment necessary for the production of XPS with the following basic materials:

- Polystyrene, also abbreviated as GPPS (General Purpose Polystyrene)
- Additives, which consist of nucleating agent, colour, flame retardant and process aids
- Blowing agent

In this overall layout, the following parts of the plant can be recognised. It should be noted that for clarity and overview not all the items are marked, as the scope of this White Book is mainly the safety aspects.

1) Blowing agent storage and tank truck charging area: considering the quantities of blowing agent used in these productions, it is assumed that the blowing agent is supplied by truck. In this area, there is also the provision of feed pumps to supply the blowing agent to the high pressure pumps;

2) High pressure metering pump room which contains the pumps (mostly diaphragm pumps) for feeding the blowing agent to the extruder. The feed pressures used depend on the blowing agent but are in the range of 200 bar;

3) Piping connection between the tank storage and high pressure metering pumps: pressures depend on the blowing agent and the scope is to maintain the blowing agent in liquid phase;

4) Blowing agent injection point inside the primary extruder of a tandem configuration. This “first” extruder is heating the GPPS and additives, and mixes the melt with the blowing agent. This extruder is either a single screw or more efficient types, such as double screw extruders;

5) Extrusion head: from this position the GPPS and blowing agent exit the “second” extruder, which is also called the cooling extruder. In the whole process the blowing agent is enclosed inside the extruder, while in this position it will come into contact with the atmosphere (i.e. the workshop). Therefore, it is a major area of emissions in contrast to the closed sections where leakage is the only source of emissions;

6) After the extrusion head, the GPPS is moulded into boards by going through a calibration and different roller devices to attain the typical rectangular shape of a board. The cooling section of the XPS boards has the function of reducing the temperature to ambient conditions. This stretch varies in length from 30 to 100 m, depending on the time taken to cool down the boards. The boards are transported over a roller conveyor, which is a large open space. Although emissions will be low, due to the skin of the panel that acts as a barrier, these nevertheless have to be taken into account and, according to the layout, an area of monitoring must be provided;

7) Cutting and milling room: the boards are finished by cutting them to length and milling the sides and in many cases by working the surfaces by, e.g. roughing up. Because these cutting and milling machines are noisy and dust is created they are placed inside a room. In this room the scrap created by the cutting and milling is also transported to specific scrap silos. This transport of the scrap is performed with vacuum suction devices;

8) This area is where the stacking and packaging of the boards is performed;

9) Most of the factories have an area where boards that did not pass the quality inspection are milled. This is also an area of attention, as the boards are filled with blowing agent, and for milling mostly mechanical systems are used;

10) Pelletizing extruder: the scrap can be recycled by pelletizing and re-introduction into the extrusion process. The amount of recycled material depends on the boards produced;

11) Scrap silos: storage of the milled and cutting rests whereby the attention is focused on the separator of the vacuum pump and solid material;

12) Silos of the GPPS and additives: there are mainly large tanks for containing the pelletised or powder material where no blowing agent is present. Thereby, the silos with virgin are separated from the recycled material silos.

Figures 22-24 include the main emission sources (ES), marked in red. Figure 22 shows the possible positions of the gas detectors and ventilations points. The emissions further depend on:

- Technical solutions chosen for the different equipment
- Supplier information and certifications

Therefore, these are only examples and should not be taken as final points. A final evaluation must always be done on each individual plant according to national and/ or international standards and regulation.

Figure 22: Production line sample layout

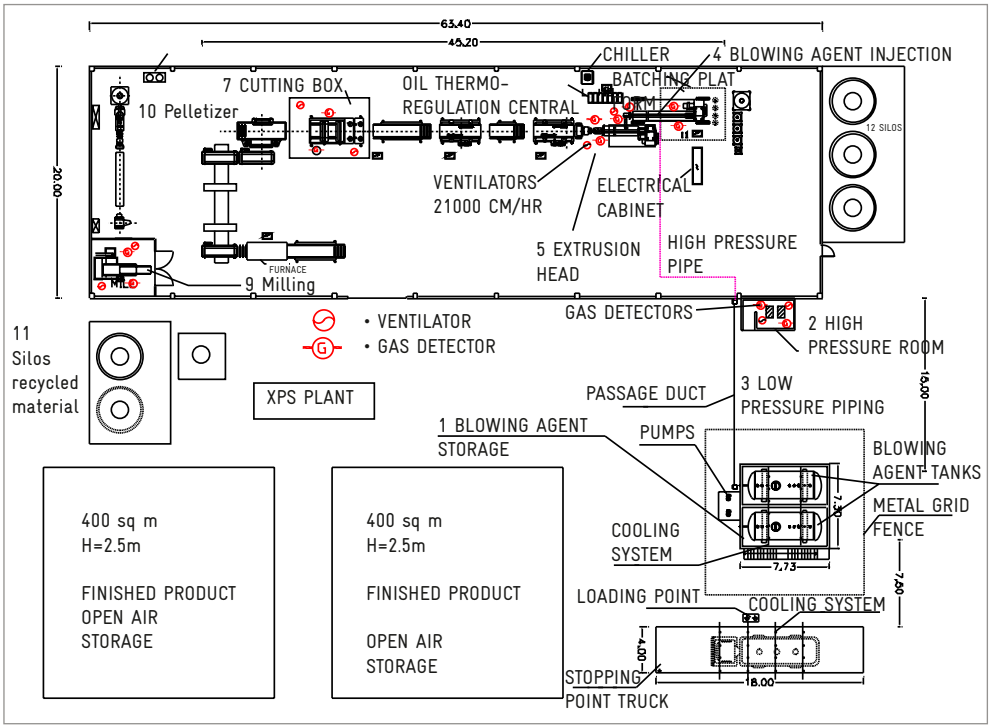


Figure 23: Production line sample layout detail

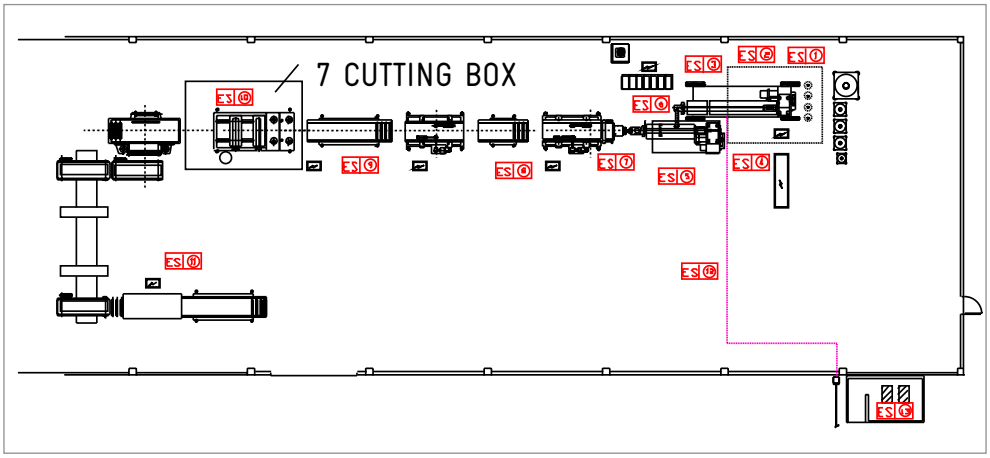
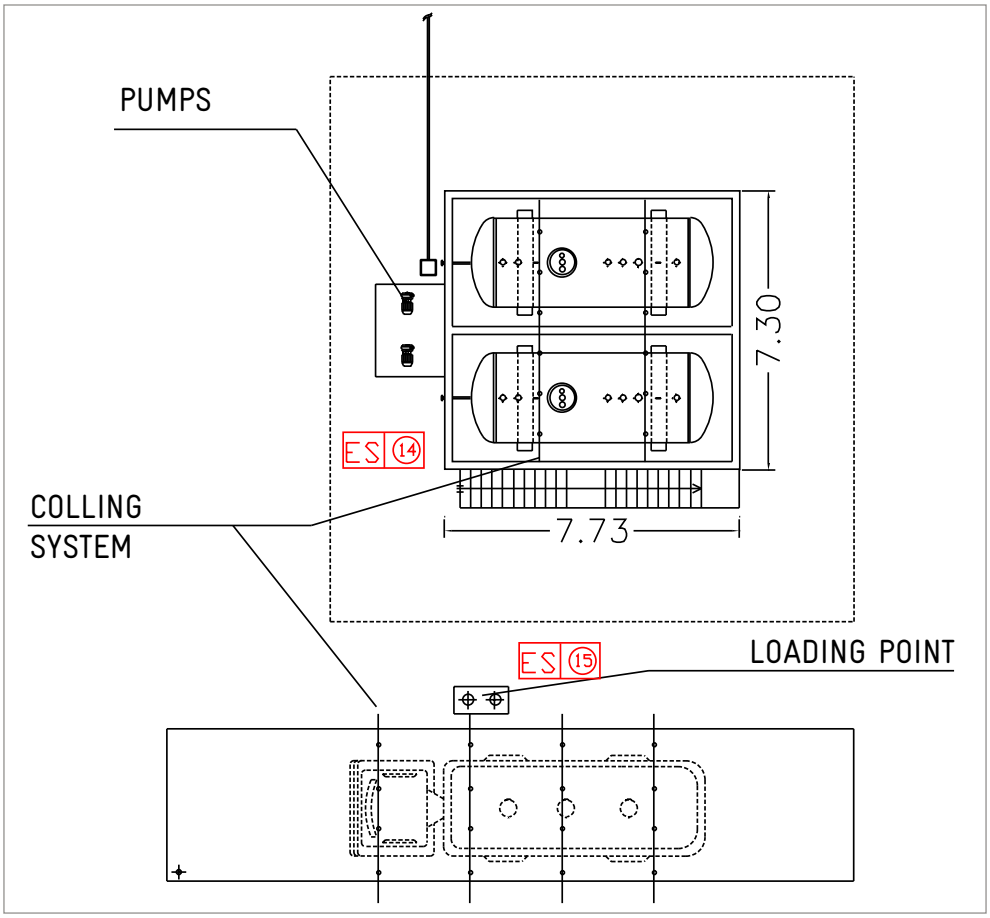


Figure 24: Production line sample layout blowing agent storage detail



6.1 Production process

The XPS is produced by injecting blowing agent into a mass of polystyrene inside the extruder. The function of blowing agent is entirely mechanical. When the polystyrene mass, which consists of polystyrene and the blowing agent, comes out from the extruder head, the liquid becomes gas, expands inside the polystyrene mass, and creates expanded cells, the so-called nucleation process. The blowing agent remains inside each cell. Only approximately 5% to 10%[26] is released into the environment as a function of the GPPS and blowing agent used.

The various phases of the production process include the following, which is also presented in the flow chart of chapter 3.1:

1. Withdrawal of blowing agent from the tank[27] is carried out by a low pressure pump (6-12 bar).
2. Blowing agent is inserted into the extruder by high pressure pump (150-180 bar).
3. The polystyrene and additives (flame retardant, colour, etc.) are introduced into the extruder.
4. The polystyrene melts and the substances are mixed together.
5. The panel is produced and cooled along the line.
6. The panel is then cut.
7. The panel is packed and stored.
8. The scraps from the cutting are ground and stored in silos for further use.
9. The scrap from the starting-up is ground and stored in silos for further use.
10. Before recycling the scrap it must be introduced into an extruder for degassing.

The blowing agent is present in every phase of the production process. This means that the compliance with regard to safety has to be verified for the entire facility where XPS is present.

The installations in the open air must be performed according to the local regulations. Chapter 5 provided some information regarding the safety distances to maintain. However, there are very little differences, for example between the regulations of each European member state.

Chapter 4 provided information regarding the areas inside the facility. The next sub-section addresses the minimum safety installations, whereby the flow chart of Figure 10 is used as a guide.

26 The case is an estimate, which depends on many factors.
27 In case of CO_2 and methanol mixture the tanks are two. Here, the consideration is only for flammable blowing agents.

6.2 Emission sources of blowing agent

The evaluation of an installation starts by identifying all the areas where a possible emission can occur. Because this is machine dependent, the supplier of the equipment should have all the required certifications and provide a risk analysis of his supplied equipment.

The Figures 22 and 23 at the beginning of this chapter have shown the most likely sources of emission. This section aims to provide details of the individual positions by means of the following table:

Table 10: Individual positions of emission

Emission point (ES)	Reason for possible emission	Occurrence of emission	Remedy
1	First extruder screw gear box connection. When the screw sealing are worn or the extruder is not yet filled an emission can occur.	rare	Before adding the blowing agent the extruder has to be filled with GPPS melt and programmed into the extruder software. The screw filled with melt will already perform the function of seal, as the injection of the blowing agent is inside the melt. Additional ventilation at the gear box and gas sensor positioned appropriately will provide safeguard.
2	Feed hopper connection to dosing equipment for GPPS and additives.	rare	Same as above. Care has to be taken if the extruder is a single or double screw. In case of a single screw, the hopper is filled with GPPS and a double screw works under starve feed.
3	Manual or automatic screen changer.	high	With filter elements every time the filter is exchanged, GPPS melt and blowing agent is placed in the environment. The quantities will be very low but due to the changing mechanism seals, ventilation must be placed and verify that the gas sensors monitor this area.
4		Emission fact	The piping and injection nozzles are fixed to the extruder by means of high pressure fittings. The injection is performed at high pressure. But when certified fittings are used a leakage will be rare. Safety is already incorporated into the blowing agents control, which monitor abrupt pressure changes. The extruder gas sensor will monitor for small leakages.

Emission point (ES)	Reason for possible emission	Occurrence of emission	Remedy
5	Second extruder screw gear box connection. When the screw sealings are worn or the extruder is not yet filled, an emission can occur.	medium	The second extruder is filled by the first extruder unit and the same applies as under point 1. The difference is that the pressure will be significantly higher of the melt in this position therefore a melt seal or other technical provisions have to be taken to avoid emissions. Ventilation is required as well as coverage of the area by the extruder gas sensors.
6	Melt pipe between first and second extruder	rare	The melt pipe is subjected to thermal excursions but flanged on both sides. Leakage will be rare when regular maintenance is performed. Coverage of the ventilation system of this area is recommended.
7	Die head	always	When the GPPS foam is coming out of the extruder through a slit of 1–2 mm, an expansion to the final thickness of, e.g. 50 mm is attained. This expansion is performed by the blowing agent and a continuous emission will occur in this position. A line producing 600 kg/h and a blowing agent content between 5 to 10% will have a continuous blowing agent emission of 3 to 6 kg/h. Several precautions have to be taken: - Ventilation - Gas sensor - Grounding (the whole line needs to be grounded but this area is of particular importance) - Air ionisation The latter helps to reduce the static electricity build-up due to the friction of the GPPS inside the calibration device.
8	Calibration and take-off	always	After the die head the foam is kept into place by the calibration device and, due to friction static electricity build-up can take place. Emissions will mainly occur on the sides of the panel. In this area where the panel still has a temperature of 50°C or more the same precautions have to be taken as under point 7.

Emission point (ES)	Reason for possible emission	Occurrence of emission	Remedy
9	Cooling section	low	The panel exiting the calibration and take off device starts hardening and a skin is formed. Emissions will occur but these are considered low; the emissions here are not enclosed. Proper placement of gas sensors along the line is advisable.
10	Cutting and milling room	always	Here, there are two ATEX issues: - Emissions by blowing agent - Dust Both are ATEX, as when the boards are cut or milled blowing agent will escape and dust is produced. These machines are, however, placed inside a room for the above reasons and are equipped with a strong ventilation to remove cutting and milling rests. Placement of a gas sensor is strongly advised.
11	Stacking and packaging of the cut and milled boards	low	The boards are finished and cooled down; therefore placement of a gas sensor to monitor the area is advised. Care has to be taken for the packaging material, which should allow "breathing" when the panels are placed in the storage-curing area. This is in order to avoid high concentrations of blowing agent inside a sealed package.
12	Production area	low	Placement of a gas sensor for monitoring of the workshop is advised.
13	High pressure pump room	rare	The equipment consists of certified EX equipment, carbon or stainless steel piping, fittings with metal ferrule and is tested at high pressure for leakage test. The controls monitor pressure and temperature and, as a result, will shut down in case of abnormal values. The equipment is subject to PED standards. The zone is influenced by the equipment and should be at least Zone 2 because a leakage can occur in case of severe malfunction.

Emission point (ES)	Reason for possible emission	Occurrence of emission	Remedy
14	Tank storage emission due to replacement of the "air" inside the tank with blowing agent	Always when charging	Use of a discharge pipe at sufficient height to allow the free dispersion of the "air" (mixture of nitrogen and blowing agent vapour) or with blowing agents with a boiling point higher than atmospheric temperature exchange of the air with the volume of the tank truck and subsequent flushing in a safe area.
15	Tank loading connection emission of blowing agent inside the connection pipe	Always when charging	Reduce to a minimum the pipe connection length by proper positioning of the charging valves, allowing the truck to access as close as possible the loading point.

Defining the zones for the different areas on the basis of a sample layout is difficult. However, it is likely that the positions 3, 7, 8, and 10 are Zones 0, with the possibility to be reduced to Zone 0-NE by proper ventilation.

There is always a continuous emission the extent of which depends on many factors. The other zones should be certified as a minimum Zone 2. All the zones can be made Zone NE with the appropriate ventilation and gas sensors monitoring.

6.3 Hot areas

Extruders have hot temperatures, particularly at the extruder barrels and die head. This hot temperature is created due to the need for melting the polystyrene and therefore the temperatures can go up to 200°C (573 K).

This means that nearly all flammable blowing agents, as well as some non-flammable types will reach the auto-ignition at temperatures of 573 K. Therefore, a verification of this aspect has to be performed and the sections 2, 3 and 9 of the MSDS sheets verified.

This danger cannot be protected even by gas sensors cutting the power supply because the cooling down of the extruders takes time. This aspect has to be taken into consideration when the plant layout is made.

The verification is not always easy, as depending on the test conditions and methods used, a specific blowing agent could be categorised as non-flammable but for the

application of extrusion the contrary could be the case. It is therefore strongly advised to verify this suitability with the organization of XPS extruders, standards institutes, and suppliers.

The following sub-sections provide details of various plant sections.

6.4 Areas subjected to ATEX due to presence of powder / dust

The cutting room, position 7, Figure 23, is a typical area subjected to verification with regards to ATEX, and is considered a dust zone. The zoning is also a function of amount and size of the cutting rests. A proper evacuation of powder rests must be installed; and the evacuation system to remove the powder rests, especially the vacuum pump powder separator and silo, will have a zone classification.

The systems work under vacuum therefore the released blowing agent during the cutting and milling will be released into the atmosphere. The outlet of the ventilation duct on the roof has to follow the prescriptions of the ventilation system for pure blowing agent.

The silo is filled with powder, which might contain to a certain extent blowing agent. The quantities will be low but the silos need to be protected according to ATEX. The internal part of the silo should be treated as a Zone 0 / Zone 20, whereby Zone 20 refers to dust zones which are not further discussed. When the powder is used for recycling, e.g. pelletizing, an analysis is required to verify the blowing agent content inside the powder.

Silos management and protection against powder or dust explosions is a commonly used technology and is therefore not discussed in great detail in this section, like the mentioned Zone 20 above.

6.5 High pressure pump room

This is indicated at point 2 of the layout in Figure 22. A basic rule to follow is: the high pressure pump room must be positioned on the outside of the production department and in contact with the open air. The room must be adequately ventilated and distant[28] from the following:

28 Distant means minimum 7.5 m.

- Air intakes and openings to avoid spreading of the gas in case of damage or malfunction, thereby preventing it from entering non-ATEX areas.
- Heating technical rooms
- Compressor room
- Electrical generators
- Water drainage, grounding shaft, cable ducts and other passages

The space is Zone 2 as a minimum, pumps and ancillary equipment are certified for the use with flammable substances and hermetically sealed; emission is only due to damage and/or malfunction.

The pump room can be constructed using the following materials:

- Concrete
- Brick work
- Sandwich panel. Metal sheet with mineral wool in between (panel Zone 0)

The floor must be constructed with concrete and/or antistatic material. The roof should be constructed with light material and provided with breaking points. The classic fretted metal sheet is the best solution. The pump room should not be constructed in single metal sheets without insulation. In warm climates and during summer the pressure inside the pipes and tanks will rise with the temperature.

The pump room must be equipped with an artificial ventilation system; natural ventilation is not allowed in this case.

The following must be provided:

1. Openings in the upper and the lower part of the room. The openings must be protected by metal grids.
2. The openings must be of **Grade A – No closure**

Connection of the pumps to the extrusion plant:

Inside the room a minimum of two high-pressure pumps are installed, e.g. one for flammable products and one for CO_2. Both pumps must be connected to the extruder by a pipe system constructed in the following manner:

1. Installing a pressure system with nominal pressure 1.5 times higher than the extruder operation pressure.

2. Installing a maximum and a minimum pressure switch on the feeding pipe system connected to visual and sound alarm.
3. Installing a safety valve (adequately dimensioned) with discharge positioned on the outside in a non-hazardous area.
4. Providing an interception valve with pneumatic actuators placed before the entry into the extruder room.
5. The pipe system must be welded or fitted with metal double ferrule fittings and double jacket for leakage monitoring especially when long stretches go through a production site.

The following equipment makes the high pressure pump room complete:

1. Ventilation system
2. Lighting plant (EX)
3. Gas detection system
4. Grounding plant preventing electrostatic charge

Ventilation system[29]

The ventilation system must be constructed in the following way:

1. Installation of air intakes of 100 mm on the side walls
2. Installation of air intakes of 150 mm near each pump attachment. The intake must be equipped with a flexible tube in order to evacuate gas leakage during maintenance operations.
3. Connection of all air intakes to a double-ventilator positioned outside the facility
4. Installation of a gas exhaustion chimney of at least 1.5 m above roof-level (referring to the highest roof-level of the tallest building around the storage room area)
5. Installing: a. Flow-meter to control the ventilation efficiency
   b. Switch for manual operation of both ventilators (fans)

The entire system must be constructed in metal sheet. The sheets may be galvanised or stainless. If galvanised, all components must be ground-connected by a 2.5 mm cable[30] for tubes, and minimum 4 mm² for other apparatus.

The functioning of the ventilation system must be according to the following:

29 The area is assumed to be: 15 m2 (5 m x 3 m)
30 2.5 mm² is sufficient to connect duct for ventilation. For other connections use 4 mm².

1. The system is switched off during normal operation.
2. The system must be connected to the gas detection system described in the later section.
3. If the gas detectors register an explosive atmosphere of 15% of LFL, the ventilator is activated in high mode and an alarm is triggered.
4. If one ventilator is not activated the second will start.
5. The system must be automatically switched on during tank charging.
6. Provide for additional instructions to the personnel for periodically verification of the ventilation system. Periodically means e.g.10 min every 4 hours, during the closing hours of the plant. Alternatively the ventilation system can be kept on continuously at low speed and the flow sensors will indicate any malfunctions.
7. Every ventilator (fan) must have the following features:
   7.1 Type: Backward curved blade
   7.2 Capacity: 3000 Nm^3/h
   7.3 Evacuation power: 100 mm H_20

A double ventilator is shown in Figure 25, whereby the ventilators themselves are placed outside the room. Only the evacuation duct will go inside the room and the whole system is grounded.

Gas detection system

It is assumed that a gas heavier than air is used. If they are lighter than air, the quantity of ventilators must be doubled. Two gas detectors must be installed (catalytic or infrared) at floor-level. The detectors must be connected to the main alarm system.

Electric and connective plants

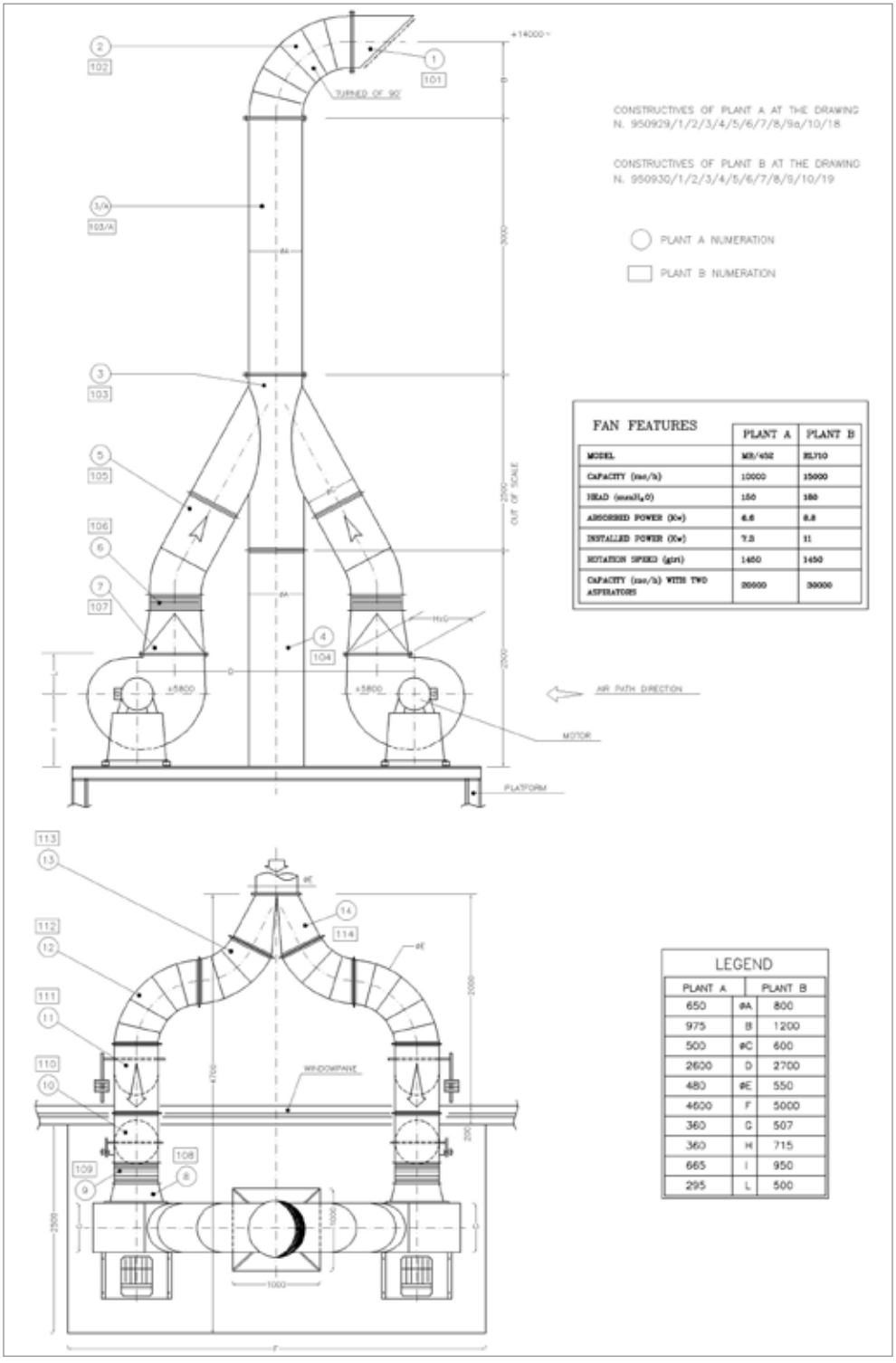
All electric plants must conform to the **EX-d**[31] **methods**, and covers/cases of group **II category 2G** with temperature class minimum **T5**. It is advisable to use this method of protection, which guarantees an important mechanical protection against impact/blow and resistance against disengagement.

The features of a plant operating by **EX-d method** are as follows:

- Clamp cases and apparatus issuing sparks must be explosion proof.
- Cable exit/entry from the boxes must be block junction. Electrical ducts must be in galvanised tube according to DIN 2999. This system is resistant to mechanical blow/impact.

31 An Ex-n method by EN 50021 would be sufficient.

Figure 26: Example of double ventilator layout



Lighting plant (illumination)

An explosion proof lighting plant with two ceiling lights is recommended; a 36 watt in Ex-d performance and one equipped with emergency lamp.

Grounding plant

The installed equipment must be ground-connected and a box of antistatic tools (bronze wrenches and hammer) should be available in case bottles are used.

6.6 Extruder

The outside area is considered Zone 2. During normal operations there are no flammable substance leakages.

There may be a leakage in the following:

a. At the point where the blowing agent is injected into the extruder (***point 4 of layout, Figure 21***)
b. At the point where the polystyrene enters the extruder. The mix of polystyrene and blowing agent can be blocked inside the extruder and the blowing agent can leak through the polystyrene entrance. The blowing agent is, at this point, a very hot gas.
c. On the extruder head during start-up and shutting-down of the machine (***point 5 of layout, Figure 21***)

Points (a) and (b) above are 2nd grade ES, while point (c) is a 1st grade ES. With proper ventilation, points (a) and (b) determine a Zone 2 and point (c) determines a Zone 1.

Evacuation system

The evacuation plant should be one for the entire line. An example is presented on how to construct the evacuation system.

For points **(a) and (b)**, the evacuation occurs where the blowing agent may leak.
For point **(a)**, a leakage of liquid phase is likely under pressure (180-200 bar).
For point **(b)**, a leakage of gas phase is likely.

In the standard EN 60079-10 a calculation example for the evaluation of gas leakage can be found. The calculation must be done by an expert. However, a reference value obtained through experience is indicated here as a guide; this **must not** be used for the construction of an evacuation system.

For point C an evaluation occurs as follows:

1. Consider the worst case, with the use of isobutene R600a. The used percentage of gas is approximately 12% of the gas on the weight of polystyrene. With an extruder, which produces approximately 700 kg/h of polystyrene, there will be around 84 kg/h of gas in liquid phase. In the worst case, during start-up, all the 84 kg of gas is released into the environment.
2. It is important to note that 84 kg in liquid phase equals approximately 168 liters. The specific weight of this gas is about 0.5.
3. 168 litres in liquid phase = **168x229** litres gas phase[32] = 38,472 litres = **38.47** m^3.
4. 38.47 m^3 of isobutane (LFL 1.8% vol) will create a minimum explosive volume of 38.47:0.018 = **2,137.00** m^3
5. If a 15% LFL is set as detection value, the resulting volume is 2,137.00:0.15 = **21,370.00** m^3.

These volumes clearly indicate that a good evacuation (ventilation) is required during start-up but also during production. The reason for good ventilation ***during production*** is the release of blowing agent during the formation of the XPS boards. This release cannot be determined ad hoc as many physical parameters of the board, used blowing agent, and raw materials play a role. The determination of this release has to be determined on a case by case basis.

This release during the foaming process actually defines the exit of the extruder during production a Zone "0" which with the use of ventilation and gas detection is reduced to a Zone "0" NE.

To maintain the condition of "good availability" as ventilation category (see Chapter 3.2) and for the guarantee that the ventilation is always present, two ventilators must be positioned on the plant. One will be in stand-by in case of malfunction of the ventilator in use.

It can thus be concluded that the emissions are grade **1 during start-up and grade 0 during production** for point (c) – the extruder head, and grade **2** for points **(a) and (b)**, the points where the blowing agent is injected into the extruder and polystyrene enters the extruder. The grade of ventilation must be high and the availability good. **This would result in the area of the extruder head being classified as Zone 0 NE or 1 NE.**

32 See Chapter 2.2

The evacuation plant can be constructed in the following manner:

- Installing one evacuation hood with dimensions 1000x1000 mm, at the polystyrene entrance into the extruder.
- Installing the first air intake with diameter 150 mm around the blowing agent entrance into the extruder.
- Installing another evacuation hood of dimension 500x500 mm at the exit from the extruder.
- Installing the second air intake with diameter 150 mm under the exit from the extruder.
- Connecting all intakes to a double ventilator positioned on the outside of the facility.

The entire system must be constructed with metal sheet. The sheets may be galvanised or stainless. If galvanised is used all components must be ground-connected by a 2.5 mm² cable for tubes[33], and a minimum 4 mm² for other apparatus.

The functioning of the ventilation system must be as follows:

1. The system always runs during normal operation
2. If a ventilator is not activated the 2nd (reserve) will be activated and must send an alarm signal for immediate repair.
3. The system must be connected to the gas detection system (described below).
4. If the gas detectors register an explosive atmosphere of 15% of LFL, a 2nd ventilator is activated in high mode. An alarm is signalled[34] and an electric system shut down proceeds.
5. The ventilators must always be in stand-by mode, even when production plant is not operating so that in case 15% of LFL is reached, the safety surveillance system starts the ventilation.
6. Provide for additional instruction of periodically functioning of the ventilation system. Periodically means, e.g. 10 min. every 4 hours.
7. Every ventilator (fan) must have the following features:
   7.1 Type: Backward curved blade
   7.2 Capacity: 21,000 Nm3/h
   7.3 Evacuation power: 180 mm H20

33 2.5 mm² is sufficient to connect tubes for ventilation. For other connections use 4 mm².
34 The entire plant must be monitored by a control panel positioned in a non-hazardous area easily accessible to personnel.

Gas detection system

It is assumed that a gas heavier than air is used. If it is lighter than air, the quantity of ventilators must be doubled. Catalytic or infrared detectors must be installed at floor level, 2 m above the floor. The detectors must be connected to the general alarm system.

The detectors must be installed considering the following points:

- Clamp cases and apparatus issuing sparks must be explosion proof.
- Cable exit/entry from the boxes must be block junction. Electrical ducts in galvanised tube must be according to DIN 2999. This system is resistant to mechanical blow/impact.

Lighting plant

The lighting lamp must be for Zone 1 and the electrical plant Ex-d.

Air ionisation

Air ionisation is an additional measure to reduce the static electricity build up during the foaming process and the process of calibration of the boards. The calibration of the boards is done mechanically by pulling the boards with a take-off through an opening covered with Teflon©. Teflon© is used to reduce friction.

For the purpose of reducing static electricity build up, two air ionisation fans are placed each on one side of the extruder head.

Calibration and take off

The equipment for the process of calibration and take-off placed just after the extruder head is also in a zoned area as emissions are taking place during the formation of the XPS board. The measures to be taken are identical to the extruder discussed above:

- Ventilation system with good availability
- Gas detection

Results in: Zone “0” NE.

6.7 Cutting centre

The cutting centre, illustrated in point 7 of the layout in Figure 21, is positioned in a cabin and the area contains continuous ES that is labelled grade 0. The ES is represented by the panel cells being broken and therefore emitting gas particles during the cutting. ES of this type are continuous, which means that the area needs high ventilation grade and good ventilation availability. The result is an area being classified as **Zone 0 NE**.

The scrap evacuation system eliminates the ES and provides the necessary ventilation of the room.

However, the scrap will contain some amount of gas inside the evacuation system and therefore the silo system, which is not discussed here, is also subject to ATEX for reasons of dust and flammable substances. Worthwhile to note further is that these areas with dust are present even if no flammable substances are used!

Gas detection system

It is assumed that a gas heavier than air is used. If they are lighter than air, the quantity of ventilators must be doubled. As for extruder and pump room, catalytic or infrared detectors must be installed at floor level.
The detectors must be connected to the general alarm system. To ensure a good gas detection system, the following must be made mandatory:

- The first detector to be installed in the proximity to the entrance doors
- The second detector must be placed at the point where the panels enter the cabin.
- If there is a situation of 15% LFL, all electric systems must be immediately shut off.

Lighting plant

The lighting lamp must be put outside the cutting centre cabin. The type of protection will depend on the individual construction type of the lighting system. The openings of the cabin must be of Type **"D"**.

7 SUMMARY IDENTIFICATION OF HAZARDOUS AREAS

7.1 Introduction

The determination process of hazardous areas is the classification of areas according to the ATEX standard. The classification must always be performed by an expert in the field.

The purpose of this document is to explain the process to the commissioning company and the person in charge of the installations.

The illustrated examples should be treated as a guide and ***not*** examples of an executive project.

7.2 Quick guide to XPS blowing agent analysis

The basis for risk evaluation is the identification of the substances used in the production process, according to the following:

a. The number of substances used in the production;
b. The number of flammable substances among those;
c. Identifying which substance is flammable.

The number of substances used in the production will depend on the type of technological production cycle and for determining the number of flammable substances and identifying which of those are flammable; the **Material Safety Data Sheet (MSDS)** of each product in use must be consulted as being freely available on the production floor.

All products commercialised within the European Union must be accompanied by a Material Safety Data Sheet, which must contain a minimum of 16 paragraphs covering the following:

1. Identification of the substance and the name of the selling company
2. Chemical composition
3. **Identification of the hazards**
4. First Aid Instructions
5. **Fire fighting measures**
6. Instructions in case of accidental dispersion
7. Handling and storage
8. Personal protection
9. **Chemical and physical characteristics**
10. Stability and reactivity
11. Toxicological information
12. Ecological information
13. Disposal
14. Transportation
15. **Standards and regulation information**
16. Other information

In particular, the information regarding the XPS production activity is included in the sections: **3, 5, 9 and 15. The information contained will help to**:

- Identify if the substance is flammable or not: **point no 3**
- If it is flammable, then fire fighting measures must be identified: **point no 5**
- Identify the characteristics in order to start the classification of hazardous areas: **point no 9**.

Important characteristics of hazardous area are:

1. **Physical state at 20°C**: serves to establish if it is a liquefied gas or a liquid
2. **Flash point**: serves to establish the Temperature Class of the equipment
3. **Flammable limits**: only inferior limit is important. This serves to calibrate the gas detectors.
4. **Gas or liquid density**: serve for the positioning of evacuation nozzles and gas detectors

Once the substance is identified as flammable, the appropriate labelling on the tanks and cylinders should be checked as well as in the areas of use indicated.

7.3 Quick guide to the identification of hazardous areas

To quickly identify hazardous areas, it is important to find out where the substances are used. Generally, they can be found in the following areas of the facility:

- Tank storage area
- Pumping room
- Piping
- Blowing agent injection point first extruder
- Feed hopper
- First and second extruder
- Dye head
- Take off & calibration
- Cooling section
- Cutting and milling room
- Stacking and packaging
- Ventilation ducts
- Storage of finished product
- Silos, powder and dust areas

Once the hazardous area is known, the next step is to identify the locations:

a. Substance is stored in container from which it can get in contact with the surrounding environment due to malfunction or damage. These areas are:

   - Tank storage and fixed tank
   - Piping
   - Ventilation ducts

   These areas are classified as **"Zone 2"**.

Next, these areas must be checked to determine if they are in contact with other areas. If so, then the type of **"Opening"** that connects the areas must be identified.

b. Areas where the substances are in contact with the surrounding atmosphere. For example, at the dye exit. ***Without a ventilation system this area would be classified as Zone 0 or Zone 1.***

c. Check that ventilation system does actually function the way it should, i.e. that it reduces the hazardous area to a point of a few cm3. If this is the case then the area can be classified as **Zone 0 NE**.

It must always be ensured that a facility has:

- **Zone 2**
- **Zone 0 NE**

7.4 Quick guide to the identification of a substance

In order to find out if the machinery/**equipment**/system already installed or to be installed are adequate to the plant, the following procedure can be followed:

- If a flammable substance is in use then verification according to ATEX must be performed.

All machinery/equipment/system installed in these zones must have:

- Plate/label with the EX symbol inside a hexagon
- Certification

Choice of equipment

In general it is recommended to use equipment designed for the zone identified during the safety analysis. The equipment certifications and labels should be verified before use.

APPENDICES

Appendix 1: Typical blowing agents used

- R600a (Isobutane)
- DIMETHYLETHER (DME)
- R152a
- HFO-1234ze
- ETHANOL
- METHYLFORMATE
- METHYLAL
- PENTANES

Please refer to the supplier's safety data sheet of the blowing agent in use for the safety assessment!

Appendix 2: Influence of ventilation on type of Zone

Extract of Table B1 EN 60079-10 2009

GRADE OF RELEASE	VENTILATION						
	DEGREE						
	HIGH		MEDIUM			LOW	
	AVAILABILITY						
	GOOD	FAIR	POOR	GOOD	FAIR	POOR	POOR GOOD FAIR OR POOR
CONTINUOS	ZONE 0 NE NON-HAZARDOUS[1]	ZONE 0 NE ZONE 2[1]	ZONE 0 NE ZONE 1[1]	ZONE 0	ZONE 0 + ZONE 2	ZONE 0 + ZONE 1	ZONE 0
PRIMARY	ZONE 1 NE NON-HAZARDOUS[1]	ZONE 1 NE ZONE 2[1]	ZONE 1 NE ZONE 2[1]	ZONE 1	ZONE 1 + ZONE 2	ZONE 1 + ZONE 2	ZONE 1 or ZONE 0[2]
SECONDARY	ZONE 2 NE NON-HAZARDOUS[1]	ZONE 2 NE NON-HAZARDOUS[1]	ZONE 2	ZONE 2	ZONE 2	ZONE 2	ZONE 1 and even ZONE 0[2]

Note: "+" signifies "surrounded by".
1 zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.
2 will be zone 0 if the ventilation is so weak and the release is such that in practice an explosive atmosphere exists virtually continuously (i.e. approaching a "no ventilation" condition).

Appendix 3: List of standards / references

Standards:

- EU Directive 99/92/CE generally called “ATEX 137directive” on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.
- EU Directive 2014/34/EU generally called “ATEX 114 directive” on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres
- EN 1127-1 Explosive atmosphere – Explosion prevention and protection part 1: Basic concepts and methodology
- Directive 2014/68/EU on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment.
- EC 1272/2008 classification labelling and packaging of substances and mixtures Decision N° 768/2008/EC on a common framework for the marketing of products
- EN 50495 requirement of electrical safety devices, which are used to avoid potential ignition sources of equipment in explosive atmospheres.
- Regulation (EC) N° 765/2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) N° 339/93
- Electrotechnical regulations (International: IEC, European: EN, National: DIN VDE): e.g. IEC 60073, IEC 439-1/A2, IEC 204-1, IEC 1210-2, EN 60079-29-1, EN 50013, EN 60079-11, EN 61000-6-3, EN 60529
- EN 378, refrigerating systems and heat pumps, safety and environmental requirements
- Directive 2006/42/EC on machinery 2nd edition July 2017, “Machinery Directive”.
- IEC 60079-10/EN 60079-10/VDE 0168 part 101: Electrical apparatus for explosive gas atmospheres – classification of hazardous areas / Italian: CEI 31-35 Guide for classification of hazardous areas
- IEC/EN/DIN VDE standards: especially DIN 31000/ VDE 1000, DIN VDE 0116, (EN 60079-0 series)
- EN 61508 – Functional safety of electrical/electronic/programmable electronic safety-related systems
- IEC 61511 – Functional safety- safety instrumented systems for the process industry sector
- EN 13463 – Non electrical equipment for use in potentially explosive atmospheres

References for further reading:

- GTZ Proklima (2010): Guidelines for the safe use of hydrocarbon refrigerants – a handbook for engineers, technicians, trainers and policy-makers – for climate friendly cooling.

- GTZ Proklima (2009): Natural Foam Blowing agents – sustainable Ozone- and Climate-Friendly Alternatives to HCFC's.

- GTZ Proklima (2008): Natural Refrigerants – Sustainable Ozone- and Climate-Friendly Alternatives to HCFC's.

- The most recent updates and additional publications can be accessed online: https://mia.giz.de/esearcha/browse.tt.html

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