COVER PAGE

Non-binding guide of good practice
for implementing Directive 1999/92/EC

Produced for the
European Commission

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Contents

1. How to use this Guide

This Guide is a non-binding aid to protecting workers' lives and health against the danger of explosion. Explosion hazards may arise in all undertakings which work with flammable substances. These include many input materials, intermediate products, final products and wastes from the routine work process. Examples are shown in Figure 1.

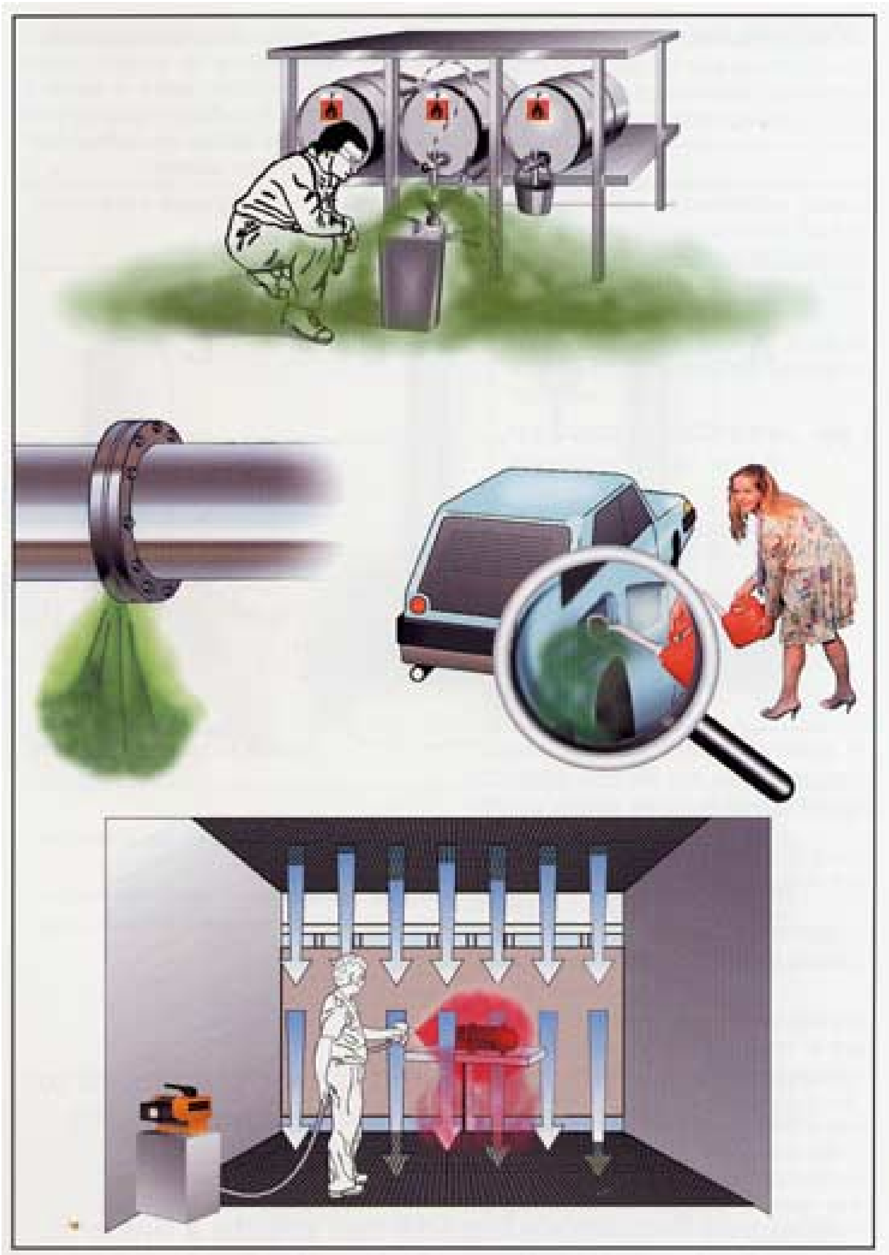
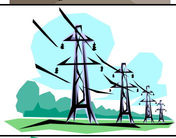
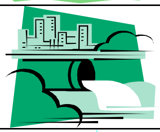
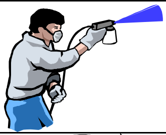
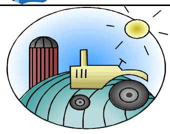
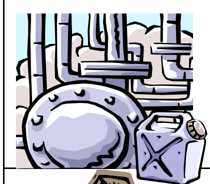
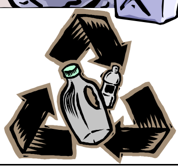


Figure 1: Examples of situations in which explosive atmospheres arise
[From the ISSA leaflet "Gas Explosions", International Section for the Prevention of Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

Virtually all branches are affected, since hazards from *explosive atmospheres* arise in a wide range of processes and operations. Examples are given in Table 1.1.

Table 1.1: Examples of explosion hazards in various branches

	Branch	**Explosion hazard**
	Chemical industry	Flammable gases, liquids and solids are converted and processed in many different processes in the chemical industry. These processes may give rise to explosive mixtures.
	Landfill tips	Explosive gases may arise in landfill tips. Elaborate technical arrangements are needed to avoid uncontrolled gas emission and possible ignition.
	Power generating companies	Non-explosive lump coal may be converted into explosive coal dust in the conveying, grinding and drying processes.
	Waste disposal companies	When waste waters are treated in clarification plants, the gases generated may form explosive gas/air mixtures.
	Gas suppliers	Explosive gas/air mixtures may be formed when natural gas is released, e.g. by leakage.
	Paint-spraying operations	The overspray generated in paint spray bays may give rise to dust explosions.
	Agriculture	Biogas production plants are operated on some farms. Explosive biogas/air mixtures may arise if the gas is released, e.g. by leakage.
	Metal-working operations	When shaped parts are manufactured from metals, explosive metal dusts may be produced during surface treatment (grinding). This particularly applies to light metals. These metal dusts may give rise to an explosion hazard in dust collectors.
	Food and feedstuffs industry	Explosive dusts may arise during transport and storage of grain. If they are exhausted and collected by filtering, explosive atmospheres may arise in the filter.
	Pharmaceutical industry	Alcohols are often used as solvents in the production of pharmaceuticals. Agents and auxiliary materials that give rise to dust explosions, such as lactose, may also be used.
	Refineries	The hydrocarbons handled in refineries are all flammable and, depending on their flash point, may give rise to explosive atmospheres even at ambient temperature. The area around oil processing plant is generally regarded as a place where explosive atmospheres may occur.
	Recycling operations	Processing of waste for recycling can give rise to explosion hazards, e.g. from cans or other containers of flammable gases and/or liquids that have not been completely emptied or from paper or plastic dusts.

An explosion occurs if a **fuel** is present in mixture with **air** (i.e. sufficient oxygen) within the *explosion limits*, together with a **source of ignition** (see **Figure 1**).

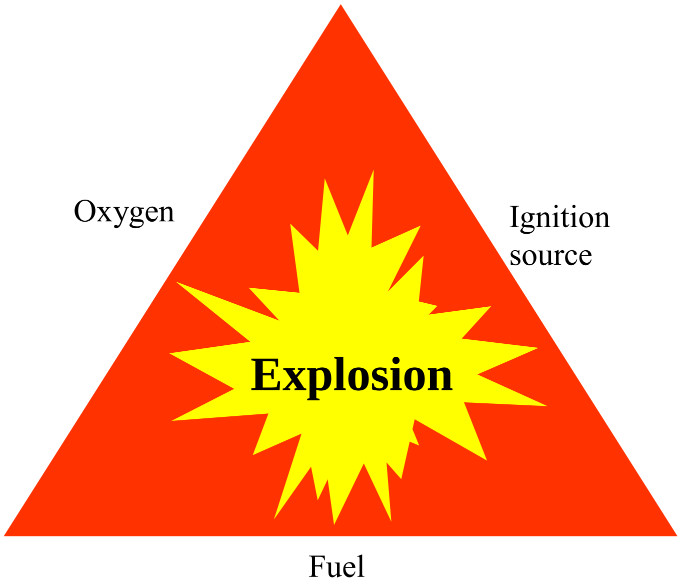


Figure 1.2: Explosion triangle

In the event of an explosion, workers are at risk from uncontrolled flame and pressure effects in the form of heat radiation, flames, pressure waves and flying debris, and from harmful products of reaction and the depletion of the breathable oxygen in the ambient air.

Examples:

1. An explosion occurred during cleaning in a coal-fired boiler. The two workmen suffered fatal burns. The cause was found to be a lamp with a defective supply lead. The short-circuit ignited coal dust that had been raised into suspension.

2. Solvent-impregnated dusts were being blended in a mixer. The workman did not inert the mixer sufficiently before the start of the process. While the dust was being loaded into the mixer, an explosive mixture of solvent vapour and air was formed, and was ignited by electrostatic sparking generated during the filling process. This workman also suffered severe burns.

3. A fire occurred in a mill building. Apertures in the ceiling allowed secondary fires to develop, giving rise to a dust explosion. Four workmen were injured and the whole building destroyed. The material damage amounted to EUR 600 000.

This Guide is intended to enable the *employer*

- to identify hazards and assess the risks;
- to lay down specific measures to safeguard the safety and health of *workers* at risk from *explosive atmospheres*;
- to produce explosion protection documents;
- to make it easier for the *workers* concerned to perform their duties and
- to take the necessary steps and make the necessary arrangements for coordination when several firms are operating at the same workplace.

1.1 Relationship with Directive 1999/92/EC

In accordance with Article 11 of Directive 1999/92/EC of the European Parliament and of the Council on minimum requirements for improving the safety and health protection of *workers* potentially at risk from *explosive atmospheres*, this Guide addresses Articles 3, 4, 5, 6, 7 and 8 and Annexes I and II A of the Directive. Table 1.2 is a concordance of the chapters of this Guide with the Articles of the Directive.

Table 1.2: Match between Articles of the Directive and chapters of this Guide

Articles of Directive 1999/92/EC	Title	Chapters of the Guide
Art. 2	Definition	Annex 1: Glossary
Art. 3	Prevention of and protection against explosions	3.1 Avoidance of explosive atmospheres 3.3 Mitigation of effects 3.4 Application of process control engineering 3.5 Requirements for work equipment
Art. 4	Assessment of explosion risks	2. Assessment of explosion risks
Art. 5	General obligations	4. Organisational measures
Art. 6	Duty of coordination	5. Coordination duties
Art. 7, Annex I, Annex II,	Places where explosive atmospheres may occur	3.2 Avoidance of ignition sources
Art. 8	Explosion protection document	6. Explosion protection document

For ease of use, the order of chapters in this Guide diverges from that of the Articles of 1999/92/EC at two points:

1. assessment of explosion risks in chapter 2 (Article 4 of the Directive) is discussed before explosion protection measures (Articles 3, 5–7 of the Directive);

2. means of preventing the ignition of *hazardous explosive atmospheres* are discussed in chapter 3.2 (Article 7, Annex I and II of the Directive) as part of the technical explosion protection measures under chapter 3 (Article 3 of the Directive).

1.2 Scope of the Guide

This Guide is intended for all undertakings in which working with flammable substances may give rise to *hazardous explosive atmospheres* and hence explosion hazards. "Working" includes manufacture, treatment, processing, destruction, storage, readying, transhipment and in-house transportation in pipelines or by other means.

Note:	In accordance with the legal definition of "explosive atmosphere" in Directive 1999/92/EC, this Guide applies only under atmospheric conditions [see 2.2]. The Directive and Guide thus do not apply under non-atmospheric conditions, but the employer is certainly not absolved of his explosion protection duties under such conditions, to which the requirements of the other worker health and safety legislation continue to apply.

The discussion of the aspects of explosion protection addressed in the various chapters is particularly geared to small firms. This Guide thus concentrates on conveying basic knowledge and principles, which are illustrated with small examples. Specimen forms and checklists for firms can be found in Annex 3. Pertinent regulations and further sources of information are listed in Annex 2.

In accordance with Article 1 of Directive 1999/92/EC, this Guide does not apply to

- areas used directly for and during the medical treatment of patients;
- the use of appliances burning gaseous fuels in accordance with Directive 90/396/EEC;
- work with explosive substances or unstable chemical substances;

- mineral-extracting industries covered by Directives 92/91/EEC or 92/104/EEC;
- the use of means of transport by land, water and air to which the pertinent provisions of international agreements (e.g. ADNR, ADR, ICAO, IMO, RID), and the Community Directives giving effect to those agreements, apply. Means of transport intended for use in a potentially explosive atmosphere are not excluded.

Directive 94/9/EC applies to the placing on the market, putting into service and design of equipment and protective systems intended for use in potentially explosive atmospheres.

1.3 Pertinent regulations and further information

Use of this Guide does not in itself ensure compliance with statutory explosion protection requirements in the various EU Member States. The authoritative instruments are the rules of law by which the Member States have transposed Directive 1999/92/EC. These may go beyond the minimum requirements of the Directive, on which this Guide is based. A list is provided in Annex 2.2, but without any guarantee that it is complete and up-to-date.

As a further aid to implementing the regulations by technical and organisational means, there are harmonised European standards (EN), which may be obtained from the national standardisation institutions against payment. A list is provided in Annex 2.3.

Further information can be obtained from the national regulations and standards and the pertinent literature. Annex 2.4 contains references to individual publications by the competent Member State authorities which are regarded as helpful and incorporated into the Guide. However, inclusion of a publication in the Annex need not mean that all of its content is entirely consistent with this Guide.

1.4 Official and non-official advice centres

Where this Guide does not answer questions arising on how to fulfil the explosion protection requirements, the national sources should be contacted directly. They include labour inspectorates, accident insurance agencies or associations and chambers of commerce, industry and craft trades.

Organisations which are appointed by the Member State authorities and included in the Guide are to be found in Annex 2.5.

2. Assessment of explosion risks

To assess explosion risks, it must be considered whether a hazardous explosive atmosphere can arise and ignite under the circumstances obtaining. This assessment must always relate to the individual case and cannot be generalised. The specific considerations are the probability and duration of the occurrence of a hazardous explosive atmosphere, the likelihood that ignition sources will be present and become effective and the scale of the anticipated effects.

> **Note:** Consideration of the effects is of secondary importance in the assessment process, since explosions can always be expected to do a great deal of harm, ranging from major material damage to injury and death.
>
> Assessment therefore focuses on the likelihood that:
>
> - **an explosive atmosphere will occur**
>
>   and at the same time
>
> - **sources of ignition will be present and become effective.**
>
> On the other hand, little purpose is served by a quantitative approach to risk in explosion protection.

The assessment procedure must be carried out for every work or production process and for every operational status and change of status of a plant. Assessment of new or existing plant should be based on the following operational statuses:

- normal operating conditions, including maintenance;
- commissioning and decommissioning;
- malfunctions, foreseeable fault conditions;
- misuse which may reasonably be anticipated.

Explosion risks must be assessed overall. Important factors are

- the work equipment used;
- the building fabric and configuration;
- the substances used;
- work and process conditions and
- their possible interactions with each other and the working environment.

Places which are or can be connected via openings to places in which explosive atmospheres may occur (hereafter "hazardous places") must also be taken into account in assessing explosion risks.

If an *explosive atmosphere* contains various flammable gases, vapours, mists or dusts, this must be taken duly into account in assessing the explosion risks. The presence of e.g. hybrid mixtures can considerably increase the effect of the explosion.

> **Note:** As a general rule, hybrid mixtures of mists or dusts with gases and/or vapours may form an explosive atmosphere when the concentrations of the individual fuels are still below their lower *explosion limit*.

2.1 Methods

Suitable methods for assessing the explosion risks associated with work processes or plant are those which lend themselves to a systematic approach to checking plant and process safety. In this context, "systematic" means that the work is done in a structured manner, on an objective and logical basis. An analysis is made of the existing sources of *hazardous explosive atmospheres* and the effective sources of ignition which could occur at the same time.

In practice, it is usually sufficient to determine and assess the explosion risk by working systematically through a set of focused questions. A simple procedure is described in chapter 2.2 below using typical criteria.

Note:	Other methods of risk assessment described in the literature, for identifying hazards (e.g. use of checklists, failure mode and effects analysis, operating error analysis, HAZOP analysis) or assessing hazards (e.g. event tree or fault tree analysis), are worthwhile for explosion protection purposes only in exceptional cases, e.g. to determine ignition sources in complex plants.

2.2 Assessment criteria

Assessment of the explosion hazard thus does not depend solely on whether sources of ignition are present or may arise.

The following four conditions must be satisfied simultaneously for explosions with hazardous effects to occur:

- a high *degree of dispersion* of the flammable substances;
- concentration of the flammable substances in air within their *explosion limits*;
- *hazardous quantities* of an explosive atmosphere;
- an effective source of ignition.

To check whether these conditions are met, explosion risks can in practice be assessed by means of six questions. Figure 2.1 shows the assessment flowchart, with the questions underlined. The criteria for answering them are explained in the sections indicated. The first four questions are used to determine in principle whether there is an explosion risk and whether explosion protection measures are necessary at all. Only if this is the case should the other two questions be considered to determine whether the proposed protective measures limit the explosion risk to an acceptable level. This step must be performed in conjunction with the choice of protective measures in accordance with chapter 3 of this Guide and repeated if necessary until an overall solution appropriate to the circumstances is found.

For assessment purposes, it must be borne in mind that explosion protection parameters are generally valid only under atmospheric conditions. In line with the ATEX Guidelines on Directive 94/9/EC, an ambient temperature between -20 °C and 60 °C and a pressure range of 0.8-1.1 bar can still be regarded as atmospheric. Under non-atmospheric conditions, the safety parameters may be significantly different.

Examples:	**1.**	The minimum ignition energy can be greatly reduced at elevated oxygen concentrations or temperatures.
	2.	Elevated initial pressures give rise to higher maximum *explosion pressures* and rates of pressure rise.
	3.	The range between the *explosion limits* is widened at elevated temperatures. This means that the *lower explosion limit* may be lower and the *upper explosion limit* higher.

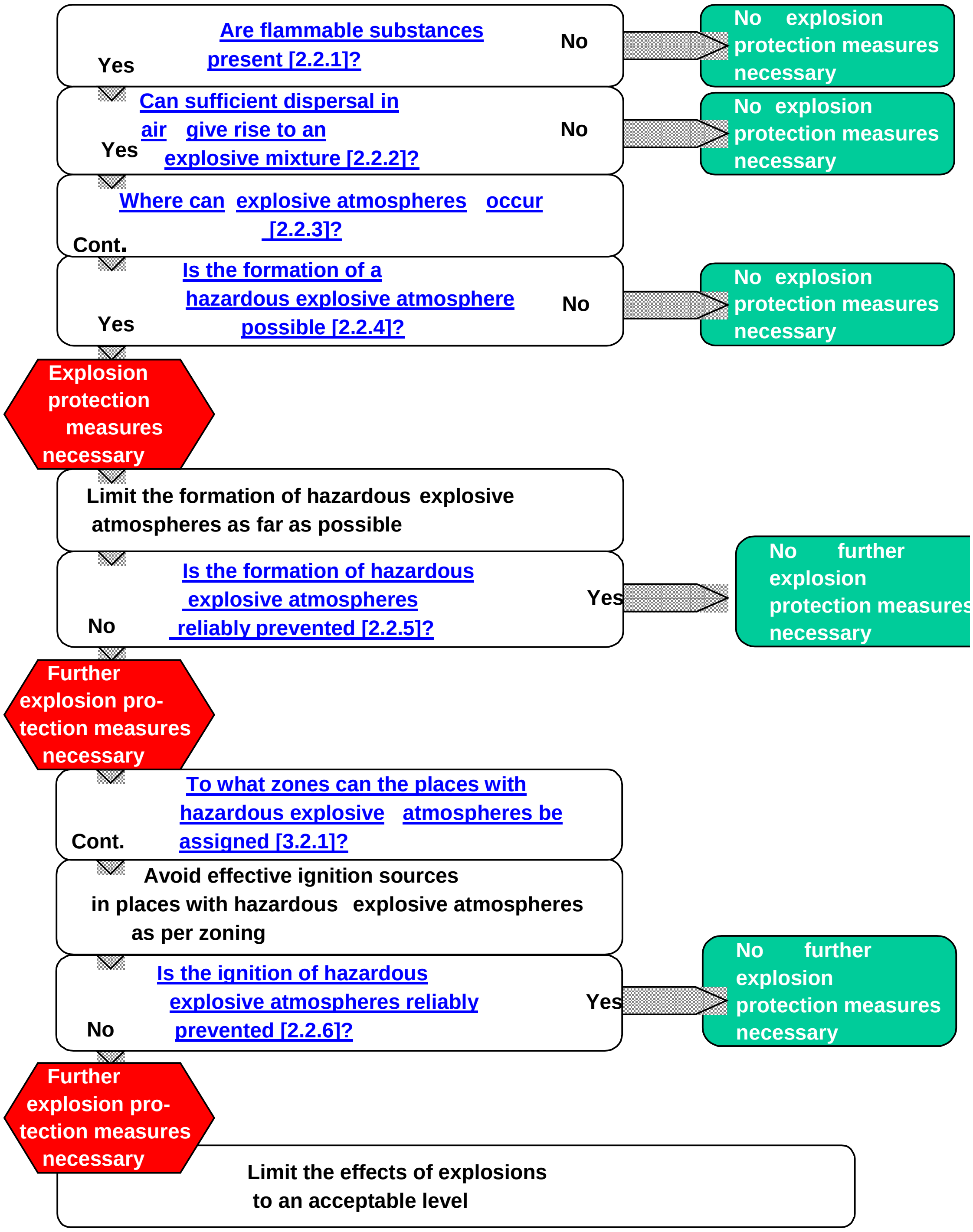


Figure 2.1: Assessment flowchart for recognition and prevention of explosion hazards

2.2.1 Are flammable substances present?

An explosion will occur only if flammable substances are present in the working or production process. This means that at least one flammable substance is used as a raw or auxiliary material, arises as a waste, intermediate or final product or can be formed in the event of a common operational malfunction.

Example:	Flammable substances may also occur accidentally, e.g. when weak acids or lyes are stored in metal containers. In such cases hydrogen may be formed by electrolysis and accumulate in the gaseous phase.

All substances capable of an exothermic oxidation reaction are to be regarded as flammable. In particular, these include substances which in accordance with the Dangerous Substances Directive 67/548/EEC are classified and labelled as flammable (R10), highly flammable (F) or extremely flammable (F+), as well as all other *ignitable* substances.

Examples:

1. **Flammable gases and gas mixtures**, e.g. liquefied gas (butane, butene, propane, propylene), natural gas, combustion gases (e.g. carbon monoxide or methane) or gaseous flammable chemicals (e.g. acetylene, ethylene oxide or vinyl chloride).
2. **Flammable liquids**, e.g. solvents, fuels, petroleum, heating, lubricating or waste oils, paints, water-insoluble and water-soluble chemicals.
3. **Dusts of flammable solids**, e.g. coal, wood, food and feedstuffs (e.g. sugar, flour or cereals), plastics, metals or chemicals.

Note:	A number of substances are not readily flammable under normal conditions but are explosive when mixed with air if the particle size is particularly small or the ignition energy sufficiently high (e.g. metal dusts, aerosols).

Explosion hazards need be further considered only if flammable substances are present.

2.2.2 Can sufficient dispersal in air give rise to an explosive mixture?

Whether an *explosive atmosphere* can form in the presence of flammable substances depends on the propensity to ignite of the mixture formed with air. If the necessary *degree of dispersion* is attained **and** if the concentration of the flammable substances in air lies within their *explosion limits*, it must be assumed that an explosive atmosphere is present. By their very nature, gases and vapours have a sufficient *degree of dispersion*.

To answer the above question, one must take into account the following properties of the substances and their possible processing states.

1. Flammable gases and gas mixtures:

- Lower and upper explosion limit
- Maximum (sometimes also minimum) concentrations of the flammable substances arising or obtaining during work with them

2. Flammable liquids:

- Lower and upper explosion limit
- Flash point

Note:	*Explosive mixtures* are not to be assumed to be present inside containers if the temperature within the container is at all times kept far enough below the *flash point* (by about 5 K to 15 K).

- Working or ambient temperatures

Note:	If e.g. the maximum working temperature is not far enough below the *flash point* of the liquid, explosive vapour/air mixtures may be present.

- Manner of working with a liquid (e.g. spraying, squirting and dispersal of a jet of liquid, evaporation and condensation)

Note:	If liquids are dispersed into droplets, e.g. by spraying, *explosive atmospheres* may be formed even at temperatures below the *flash point*.

- Use of a liquid at high pressure (e.g. in hydraulic systems)

Note:	Where there are leaks in the enclosures of high-pressure flammable liquids, the liquid may, depending on size of leak, overpressure and material stability, squirt out and form explosive mists, which may then become explosive vapours.

- Maximum (sometimes also minimum) concentrations of the flammable substances arising or obtaining during work with them

3. Dusts of flammable solids:

- Lower and upper explosion limit

Note:	In practice, *explosion limits* are not as useful for dusts as for gases and vapours. The dust concentration can be greatly changed when deposits are raised into suspension or suspended dust settles. *Explosive atmospheres* may thus arise when dust is raised into suspension. Conversely, they may also arise through partial settling out of suspended dust which was initially at a concentration above the upper *explosion limit*.

- Particle size distribution (the < 500 µm fines fraction is of interest), moisture, smouldering point
- Presence or formation of dust/air mixtures or dust deposits

Examples:	**1.** grinding or screening;
	2. conveying, filling or discharging;
	3. drying.

- Maximum (sometimes also minimum) concentrations of the flammable substances arising or obtaining during work with them

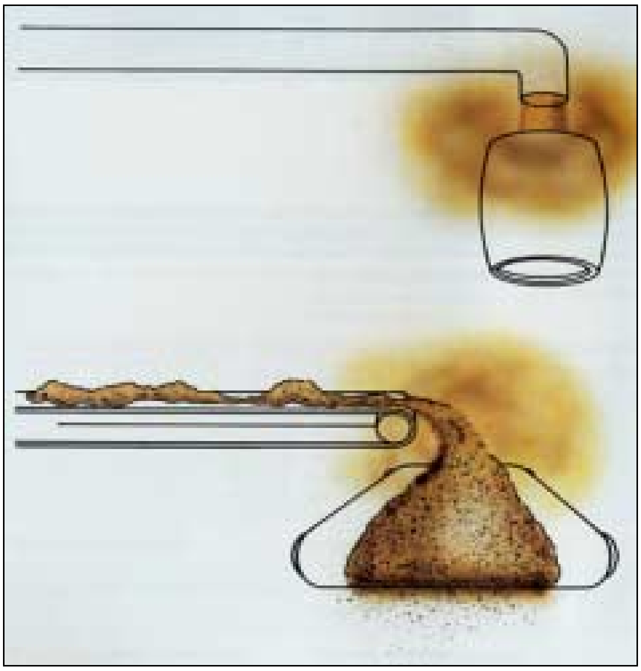


Figure 2.2: Examples for the formation of dust/air mixtures in filling and transport operations [From the ISSA leaflet "Dust Explosions", International Section for the Prevention of Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

2.2.3 Where can explosive atmospheres occur?

If *explosive atmospheres* can be formed, one must determine where they occur at the workplace or in the plant in order to delimit the potential risk. To this end, the properties of the substances and the plant, process engineering and environmental factors applying must in turn be taken into account.

1. Gases and vapours:

- Density ratio to air – the heavier gases and vapours are, the faster they sink, mixing progressively with the available air and accumulating in trenches, conduits and shafts.
  - Gases are generally denser than air.

Note:	Exceptions are gases of subatmospheric density (e.g. acetylene, ammonia, hydrogen cyanide, ethylene, carbon monoxide, methane and hydrogen).

  - Once a mixture has formed, there is no need to consider the possibility that it may be separated into light and heavy components by gravity alone. Heavy accumulations sink and spread out. They can also "creep" over long distances and then be ignited.
- Even slight air movements (natural draught, people moving about, thermal convection) may considerably speed up mixture with air.

Figure 2.3: Spread of liquefied gases (example)
[From the ISSA leaflet "Gas Explosions", International Section for the Prevention of Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

2. Liquids and mists:

- *Evaporation number*, characterising the amount of explosive atmosphere that forms at a particular temperature
- Size of evaporation area and working temperature, e.g. when liquids are sprayed or squirted
- Overpressure by means of which the sprayed liquids are discharged and form explosive mists

3. Dusts:

- Occurrence of dust raised into suspension, e.g. in filters, during transport in containers, at transfer points or inside dryers
- Formation of dust deposits, especially on horizontal or slightly inclined surfaces, and raising of dust into suspension

Other local and operating conditions must also be taken into account:

- Manner of working with substances: under gas-, liquid- or dust-tight enclosure or in open apparatus, e.g. charging and discharging
- Possible leakage at valves, pipe connections, etc.
- Ventilation conditions and other spatial factors
- Places which are not ventilated, e.g. unventilated below-grade areas such as trenches, conduits and shafts, are particularly prone to the presence of flammable substances or mixtures.

2.2.4 Is the formation of a hazardous explosive atmosphere possible?

If an *explosive atmosphere* occurs locally in such quantities as to require special protective measures to maintain the safety and health of the workers concerned, it is described as a *hazardous explosive atmosphere* and the places in question are classified as *hazardous places*.

Once the existence of an *explosive atmosphere* has been established, whether it is a *hazardous explosive atmosphere* thus depends on its volume and the harmful consequences of any explosion. In general, however, it can be assumed that an explosion will cause substantial harm and hence that a *hazardous explosive atmosphere* may be formed and a *hazardous place* exists wherever *explosive atmospheres* occur or may occur.

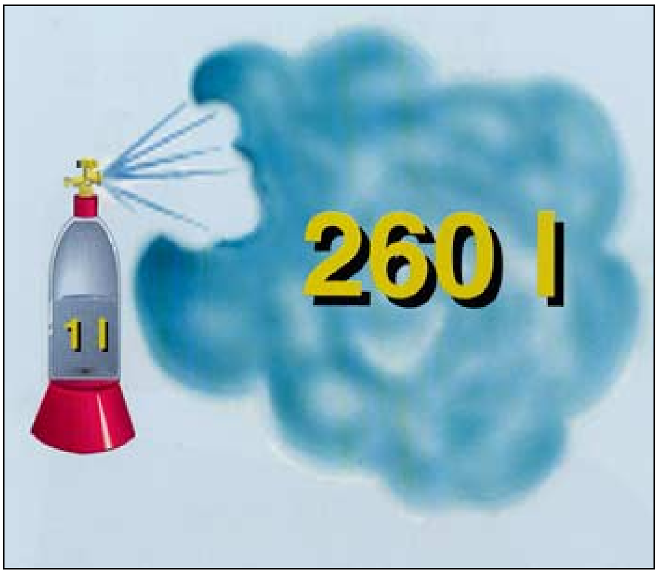


Figure 2.4: Evaporation of even small quantities of flammable liquids (such as liquefied propane) may give rise to large quantities of *explosive atmospheres*.
[From the ISSA leaflet "Safety of Liquefied Gas Installations", International Section for the Prevention of Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

Exceptions to this rule may apply to work with very small quantities, e.g. in laboratories. In such cases, it has to be decided on the basis of local and operational conditions whether the anticipated amounts of *explosive atmosphere* are hazardous.

Examples:

1. A continuous volume of over 10 litres of *explosive atmosphere* in a confined space must always be regarded as a *hazardous explosive atmosphere*, irrespective of the size of the room.

2. A rough estimate can be made by the rule of thumb that in such rooms *explosive atmospheres* must be regarded as potentially hazardous if they occupy more than one ten thousandth of the room volume, e.g. only 8 litres in a room of 80 m^3. However, this does not mean that the whole room is to be regarded as a *hazardous place*, but only the part in which the *hazardous explosive atmosphere* can arise.

3. For most combustible dusts, a deposit less than 1 mm deep evenly distributed over the whole floor area is sufficient, if raised into suspension, to fill completely a room of normal height with an explosive dust/air mixture.

4. Where *explosive atmospheres* are contained in vessels incapable of withstanding the potential *explosion pressure*, much smaller volumes than indicated above must be regarded as hazardous because of the danger which may arise, e.g. from flying debris on rupture. No lower limit for this hazard can be indicated.

A further factor to be taken into account in assessing whether a *hazardous explosive atmosphere* can arise in a particular situation is the destructibility of items of plant in the vicinity of the *explosive atmosphere*.

Note: An explosion may also cause damage in the surrounding area, which in turn causes flammable or other dangerous substances to be released and perhaps ignited.

2.2.5 Is the formation of hazardous explosive atmospheres reliably prevented?

If it is possible for a *hazardous explosive atmosphere* to be formed, explosion protection measures are necessary. An attempt should first be made to avoid the occurrence of *explosive atmospheres*. The explosion protection measures that can be taken to this end are described in chapter 3.1.

The effectiveness of the explosion protection measures taken must be assessed. To this end, all operational statuses and all malfunctions (including rare ones) must be taken into account. Only if the occurrence of *hazardous explosive atmospheres* is reliably prevented is it possible to dispense with further measures.

2.2.6 Is the ignition of hazardous explosive atmospheres reliably prevented?

If it cannot be entirely ruled out that *hazardous explosive atmospheres* may form, measures to avoid effective ignition sources are necessary. The explosion protection measures that can be taken are described in chapter 3.2. The more likely it is that *hazardous explosive atmospheres* will arise, the more reliable must be the avoidance of such sources.

If it cannot be ruled out that *hazardous explosive atmospheres* and effective sources of ignition will occur simultaneously, explosion mitigation measures must be taken as described in chapter 3.3.

3. Technical measures for explosion protection

"Explosion protection measures" means all measures that

- prevent the formation of hazardous explosive atmospheres,
- avoid the ignition of hazardous explosive atmospheres or
- mitigate the effects of *explosions* to such a degree that they are not dangerous.

3.1 Avoidance of hazardous explosive atmospheres

According to Article 3 "Prevention of and protection against explosions" of Directive 1999/92/EC, avoidance of *hazardous explosive atmospheres* must always be given priority.

3.1.1 Use of substitutes for flammable substances

The formation of *hazardous explosive atmospheres* can be prevented by avoiding or reducing the use of flammable substances. An example is the replacement of flammable solvents and cleaning agents with aqueous solutions. As regards dusts, it is sometimes possible to increase the *particle size* of the substances used, so that *explosive mixtures* cannot be formed. Care must then be taken to ensure that further processing does not reduce *particle size*, e.g. through abrasion. A further possibility is to moisten the dust or use paste products, so that they can no longer be raised into suspension.

3.1.2 Limiting of concentrations

Gases and dusts are explosive only within certain limits of concentration in air. Under certain operating and ambient conditions, it is possible to remain outside these *explosion limits*. If these conditions are reliably assured, there is no explosion hazard.

In closed containers and plant, it is usually fairly easy to keep the concentration of gases and vapours of flammable liquids outside the *explosion limits*.

Example:	The concentration in the headspace above flammable liquids can be guaranteed to remain below the *lower explosion limit* if the temperature at the surface of the liquid is at all times kept far enough below the *flash point* (a safety margin of 5 K is usually adequate for pure solvents and 15 K for solvent mixtures). The *upper explosion limit* is usually exceeded for flammable liquids with a low *flash point* (e.g. in a car petrol tank).

Where dusts are concerned, it is harder to avoid *explosive mixtures* by limiting the concentration. If the airborne dust concentration is below the *lower explosion limit*, dust deposits form by settlement if there is insufficient air movement. These can be raised into suspension, creating *explosive mixtures*.

Note:	Dust particles are separated in filters, where they form accumulations which may have considerable fire and explosion potential.

It is also difficult to guarantee that dust concentrations will exceed the *upper explosion limit*. If not sufficiently mixed, the dust particles settle and the concentration falls below this level.

Note:	If the concentration in a plant is above the *upper explosion limit*, there is no explosion hazard within the plant, but a hazard outside it may result as emerging mixtures are admixed with air.

3.1.3 Inerting

A *hazardous explosive atmosphere* can also be avoided by diluting the atmospheric oxygen inside plant or the fuel with chemically non-reactive (inert) materials. This is known as "inerting".

Note:	Formally, inerted containers do not fall within the scope of the Directive, since if inerting is successful there is no explosion hazard and the conditions are not atmospheric. However, inerting is included in this Guide since it is a common protective measure.

To design it, it is necessary to know the highest oxygen concentration at which no *explosion* yet occurs: the *limiting oxygen concentration*. This is determined experimentally. The maximum permissible oxygen concentration is obtained by deducting a safety margin from the *limiting oxygen concentration*. If the fuel is diluted with an inert substance, the maximum permissible fuel concentration must be determined in the same way. The safety margin for a plant is determined in the light of the spatial and temporal variations in the oxygen concentration resulting from operational factors and malfunctions. A further aspect to be considered is the time required for any protective measures or emergency functions triggered to become effective.

Example:	The main inert gases used are nitrogen, carbon dioxide, noble gases, combustion gases and water vapour. Inert dusts include calcium sulphate, ammonium phosphate, sodium hydrogen carbonate, stonedust, etc.

Note:	Dust deposits may give rise to glowing or smouldering fires even at low oxygen or fuel concentrations, well below those which are adequate to ensure reliable avoidance of explosions. A mixture of 95 % wt limestone and 5 % wt coal, for example, can still exhibit a strong exothermal reaction.

Inertisation with gases can generally be practised only in enclosed plant, where it is possible to ensure a fairly low rate of gas replacement. If inert gas is emitted through openings in the plant which are present in normal operation or result from defects, workers may be at risk from oxygen displacement (risk of suffocation). Workers may be poisoned if combustion gases used for inerting are emitted from plant. Openings present in normal operation may, for example, be manual charging ports. If these are opened, it has to be borne in mind that inert gas may be emitted from the plant and atmospheric oxygen may enter it.

3.1.4 Preventing or limiting the formation of explosive atmospheres in the vicinity of plant

Formation of *explosive atmospheres* around plant should be avoided as far as possible. This can be achieved by means of enclosed plant. The items of plant must therefore be leakproof. The plant design must be such that no significant leakage occurs under the foreseeable operating conditions. One of the ways of ensuring this is by regular maintenance.

If the release of flammable substances cannot be prevented, forming of *hazardous explosive atmospheres* can often be avoided by ventilation. The following points must be taken into account in judging how effective ventilation is.

- Gases: to design a ventilation system, one must estimate the maximum amount of gases and vapours that might be released (source strength) and know the source location and dispersion conditions.
- Dusts: ventilation generally affords adequate protection only if the dust is exhausted at source and hazardous dust deposits are reliably prevented.
- In the best case, adequate ventilation can preclude *hazardous places*. However, because of the limitations mentioned, all that is achieved may be a reduction in the likelihood of *hazardous explosive atmospheres* (zone 0 may thus become zone 1 or zone 2, zone 1 may become zone 2) or a reduction in the extent of the *hazardous places* (zones).

Ventilation and associated monitoring systems should be checked by a qualified person against the intended duty before they are first brought into service and should be examined at regular intervals. Ventilation systems with adjustable items (e.g. regulators, baffles, variable-speed fans) should be examined every time the settings are changed. It is desirable for such items to be locked against interference. Where ventilation systems are adjusted automatically, the examination should cover the entire range of settings.

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Figure 3.1: Example of the correct arrangement of ventilation openings
[From the ISSA leaflet "Gas Explosions", International Section for the Prevention of Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

It is recommended that spot checks be made of the concentrations arising at different places and times under unfavourable operating conditions.

3.1.5 Gas alarms

Concentrations in the vicinity of plant can be monitored e.g. by means of gas alarms. Major prerequisites for their use are as follows:

- The substances likely to be present, the location of the sources, maximum source strength and dispersion conditions must be adequately known.
- The instrument performance must be appropriate to the conditions of use, especially as regards response time, alarm level and cross-sensitivity.
- No dangerous conditions may arise on failure of individual functions of gas alarm systems (reliability).
- The number and location of measuring points must be so chosen that the anticipated mixtures can be detected quickly and reliably.
- It must be known what area is at risk until the protective measures triggered by the instrument become effective. In this immediate area – which depends on the above points – sources of ignition must be avoided.

- The protective measures triggered must prevent the occurrence of *hazardous explosive atmospheres* outside the immediate area with a sufficient degree of certainty and spurious triggering may not give rise to other hazards.

Gas alarms for use in *hazardous places* must be approved and suitably marked as safe electrical equipment pursuant to the European Directive 94/9/EC.

Note:	Gas alarms for use as safety, controlling and regulating devices in avoiding ignition sources (e.g. to switch off a non-explosionproof item of equipment on the occurrence of a *hazardous explosive atmosphere*) should undergo individual or type checks of their metrological performance, having regard to their intended use. The requirements of the European Directive 94/9/EC must be satisfied (see also 3.4 Process control engineering).

The performance of gas alarm systems must be verified by a qualified person after installation and at suitable intervals, observing any pertinent national regulations and manufacturer's instructions.

3.1.6 Removal of dust deposits

Dust deposits can be avoided by regular cleaning of work and technical rooms. A proven approach is the use of cleaning schedules prescribing the nature, extent and frequency of cleaning and the responsibilities of those concerned. These instructions can be tailored to the specific case. Particular attention should be paid to (e.g. elevated) surfaces which are difficult to inspect or reach, where considerable amounts of dust may be deposited over time. Where appreciable quantities of dust are released as a result of operational malfunctions (e.g. damage to or bursting of containers, leakage) additional steps should be taken to remove the dust deposits with as little delay as possible.

Wet cleaning and exhausting of dust deposits (using central extraction systems or explosion proof mobile industrial vacuum cleaners) has proved to have safety advantages. Cleaning processes in which dust is raised into suspension should be avoided (see Figure 3.2). It should be borne in mind that wet cleaning can create extra problems of disposal. Where light-metal dusts are collected in wet scrubbers, it must be borne in mind that hydrogen may be formed. The practice of blowing away deposited dust should be avoided.

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Figure 3.2: Removal of dust deposits
[From the ISSA leaflet "Storage of dangerous substances", International Section for the Prevention of Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

The cleaning arrangements can be laid down as part of operational instructions for working with flammable substances.

Note:	Only vacuum cleaners of explosion proof design (containing no ignition sources) may be used to exhaust flammable dusts.

3.2 Avoidance of ignition sources

If it is not possible to prevent the formation of a *hazardous explosive atmosphere*, its ignition must be avoided. This can be achieved by protective measures which avoid or reduce the probability of *ignition sources*. To lay down effective precautions, one must know the various types of ignition source and the ways in which they operate. The probability that a *hazardous explosive atmosphere* and a *source of ignition* will coincide is estimated and the extent of the measures required is determined accordingly.

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Figure 3.3: Examples of the most common potential ignition sources
[From the ISSA leaflet "Dust Explosions", International Section for the Prevention of

Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

3.2.1 Zoning of hazardous places

A *hazardous place* is a place in which an *explosive atmosphere* may occur in such quantities as to require special precautions to protect workers against explosion hazards. Such a quantity is termed a *hazardous explosive atmosphere*. As a basis for assessing the extent of protective measures, any remaining *hazardous places* must be classified in terms of *zones* according to the likelihood of occurrence of such atmospheres.

Zone 0: A place in which an *explosive atmosphere* consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.

Note: The term "frequently" is to be understood to mean "for most of the time".

Example: Zone 0 conditions generally arise only inside containers or plant (evaporators, reaction vessels, etc.).

Zone 1: A place in which an *explosive atmosphere* consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.

Example: This may include:

- the immediate vicinity of zone 0;
- the immediate vicinity of feed openings;
- the immediate area around fragile vessels or pipes made of glass, ceramics and the like;
- the immediate area around inadequately sealed glands, e.g. at pumps and valves;
- the inside of plant such as evaporators or reaction vessels.

Zone 2: A place in which an *explosive atmosphere* consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Note: The above definition of zone 2 has been taken from the English version of Directive 1999/92/EC. Slightly different definitions are to be found in translations into other languages.

Example: Zone 2 may include, e.g.

- places surrounding zones 0 or 1.

Note: Places where flammable substances are transported only in pipes which are durably *technically leakproof* are not *hazardous places*.

Zone 20: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently.

Note: The term "frequently" is to be understood to mean "for most of the time".

Example: In general, these conditions arise only inside containers, pipes, vessels, etc., i.e. usually only inside plant (mills, dryers, mixers, pipelines, silos, etc.), when explosive dust mixtures in potentially hazardous quantities can form over long periods or frequently.

Zone 21: A place in which an *explosive atmosphere* in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.

Example:	This zone can, for example, include places in the immediate vicinity of e.g. powder filling and emptying points and places where dust layers occur and are likely in normal operation to give rise occasionally to an explosive concentration of combustible dust when mixed with air.

Zone 22: A place in which an *explosive atmosphere* in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Note:	The above definition of zone 22 has been taken from the English version of Directive 1999/92/EC. Slightly different definitions are to be found in translations into other languages.

Example:	This zone can include, e.g.: • places in the vicinity of plant containing dust, if dust can escape at leaks and form deposits in potentially hazardous quantities.

N.B.

- Layers, deposits and heaps of combustible dust must be considered, like any other source which can form a *hazardous explosive atmosphere*.
- "Normal operation" means the situation when installations are used within their design parameters.

Note:	Deposited combustible dust has considerable explosion potential. Dust deposits may accumulate on all deposition surfaces in a technical room. A primary explosion may raise deposited dust into suspension and initiate a chain reaction, causing many successive explosions with devastating effects.

3.2.1.1 Example of zoning for hazardous places resulting from flammable gases

Figure 3.4 shows a tank for flammable liquids. The tank is in the open air, is filled and emptied regularly and is connected to the ambient atmosphere by means of a pressure equalising port. The flash point of the flammable liquid is close to the average annual temperature and the density of the resulting vapours is greater than that of air. There is thus a chronic risk of *hazardous explosive atmospheres'* occurring inside the tank. The inside of the tank is therefore classified as zone 0.

Vapours may occasionally be emitted from the pressure equalising port and may form *explosive mixtures*. The area around the opening is therefore classified as zone 1. Under infrequent adverse weather conditions, the vapours may run down the outside of the tank wall and form a *hazardous explosive atmosphere*. An area around the tank is therefore classified as zone 2. The size of the zones outside the tank depend on the anticipated amount of vapour release. This depends on the properties of the liquid, the size of the aperture and the frequency of filling and emptying, as well as the average change in the liquid level. The size of the *hazardous places* largely depends on the availability of natural ventilation.

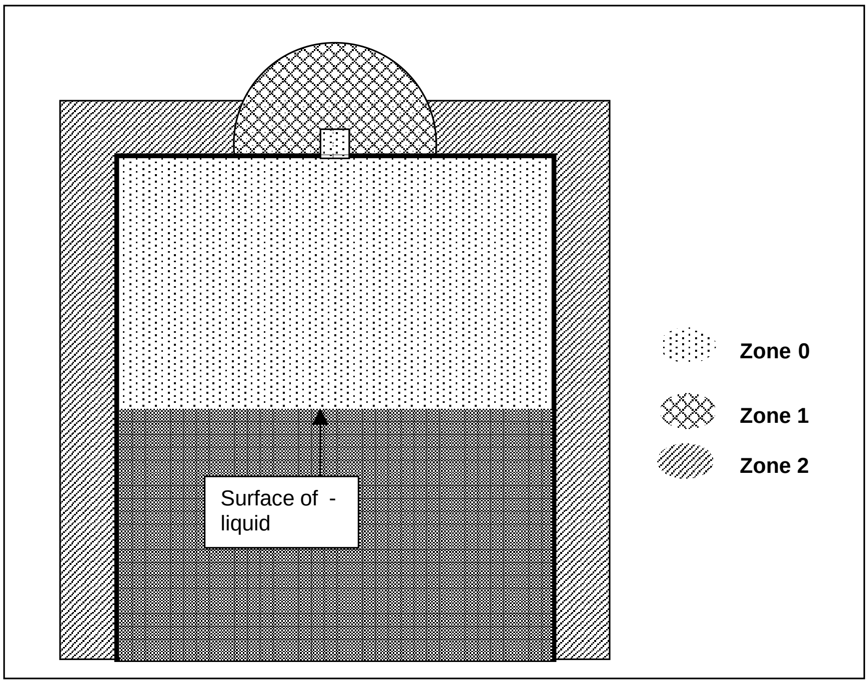

Figure 3.4: Example of zoning at a tank for flammable liquids

3.2.1.2 Example of zoning for hazardous places resulting from flammable dusts

Figure 3.2 shows a mill with a (manually charged) feed hopper, product discharge and filter. A pulverulent, flammable product is loaded by hand from a drum into the hopper.

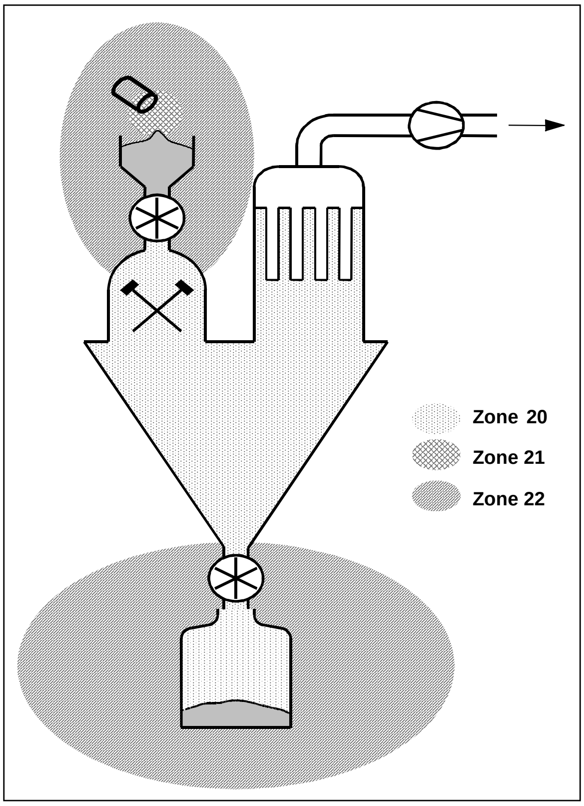

Figure 3.5: Example of zoning for flammable dusts

During the loading process, an *explosive mixture* of dust and air may occasionally form in the area where the drum is emptied into the loading hopper. This area is classified as zone 21. There are dust deposits in an area around the hopper. These may form a *hazardous explosive atmosphere* when raised into suspension, which occurs infrequently and briefly. This area is classified as zone 22.

In normal operation, there is a cloud of dust in the mill. A dust cloud is also formed at regular intervals by cleaning of the filter bags. The inside of the mill and the filter are therefore classified as zone 20. The ground product is discharged continuously. A dust cloud consisting of an explosive mixture is thus formed in normal operation in the discharge container, which is therefore classified as zone 20. As a result of leakage, there are dust deposits around the discharge. This area is classified as zone 22. The size of zones 21 and 22 depends on the dusting propensity of the product used.

3.2.2 Extent of protective measures

The extent of protective measures depends on the likelihood that hazardous *explosive atmospheres* will arise (zoning) and should therefore be determined in accordance with Table 3.1 below.

Table 3.1: Extent of protective measures in the various zones

Zoning	Ignition sources*) to be reliably avoided:
0 or 20	• in normal operation (no malfunction) • in foreseeable cases of malfunction and • in the event of rare malfunctions
1 or 21	• in normal operation (no malfunction) and • in foreseeable cases of malfunction
2 or 22	• in normal operation (no malfunction)

*) In zones 20, 21 and 22, the possibility of deposited dust ignition must also be taken into account.

The table applies to all types of *ignition source*.

3.2.3 Types of ignition source

Standard EN 1127-1 distinguishes thirteen types of ignition source:

- hot surfaces
- flames and hot gases
- mechanically generated sparks
- electrical apparatus
- stray electric currents, cathodic corrosion protection
- static electricity
- lightning
- electromagnetic fields in the frequency range from 9 kHz to 300 GHz
- electromagnetic radiation in the frequency range from 3×10^{11} Hz to 3×10^{15} Hz or wavelength range from 1000 µm to 0.1 µm (optical spectrum)
- ionising radiation
- ultrasonics
- adiabatic compression, shock waves, gas flows
- chemical reactions

This guide discusses only ignition sources that are of particular importance in operational practice. Further details on the various types of ignition source and their assessment can be found in EN 1127-1.

3.2.3.1 Hot surfaces

Explosive atmospheres can be ignited by contact with hot surfaces, if the temperature of a surface reaches the atmosphere's ignition temperature.

Example:	Surfaces which become hot in normal operation are e.g. heating systems, some electrical equipment and hot pipes. Hot surfaces resulting from malfunction are e.g. moving parts which overheat because of inadequate lubrication.

If hot surfaces can come in contact with *explosive atmospheres*, a safety margin should be ensured between the maximum surface temperature and the atmosphere's *ignition temperature*. This margin depends on the zoning and is determined in accordance with EN 1127-1.

Note:	Dust deposits have an insulating effect and therefore inhibit dissipation of heat into the surrounding atmosphere. The thicker the layer, the less heat dissipates. This can lead to heat build-up and hence to a further rise in temperature. This process can result in ignition of the dust layer. Equipment which according to Directive 94/9/EC can be operated safely in an explosive gas/air atmosphere is thus not necessarily suitable for operation in places where there is a dust explosion hazard.

3.2.3.2 Flames and hot gases

Both flames and incandescent solid particles can ignite *explosive atmospheres*. Even very small flames are among the most effective sources of ignition and must therefore generally be eliminated from *hazardous places* belonging to zones 0 and 20. In zones 1, 2, 21 and 22, flames should occur only if they are safely enclosed (see EN 1127-1). Naked flames from welding or smoking must be prevented by organisational measures.

3.2.3.3 Mechanically generated sparks

Friction, impact and abrasion processes, such as grinding, can give rise to sparking. Such sparks can ignite flammable gases and vapours and certain dust/air mixtures (especially metal dust/air mixtures). In deposited dust, smouldering can be caused by the sparks, and this can be an ignition source for *explosive atmospheres*.

Ingress of foreign materials, e.g. stones or tramp metals, into equipment or items of plant must be considered as a cause of sparking.

Note:	Friction, impact and abrasion processes involving rust and light metals (e.g. aluminium and magnesium) and their alloys may initiate an aluminothermic (thermite) reaction which can give rise to particularly incendive sparking.

Incendive frictional and impact sparking can be limited by choosing suitable material combinations (e.g. in fans). The combination of light metal and steel (except stainless steel) must always be avoided at places where friction, impact or abrasion can occur in equipment which in normal operation has moving parts.

3.2.3.4 Chemical reactions

Chemical reactions which develop heat (exothermic reactions) can cause substances to heat up and thus become a source of ignition. Such self-heating is possible if the rate of heat generation exceeds the rate of heat loss to the surroundings. If heat dissipation is impeded or the ambient temperature is high (e.g. in storage), the rate of reaction can so increase that the conditions for ignition are attained. Among the decisive parameters are the volume/surface ratio of the reacting system, the ambient temperature and the residence time. The high temperatures developed can lead to the ignition of explosive atmospheres and also the initiation of smouldering and/or burning. Any flammable substances arising from the reaction (e.g. gases or vapours) can in turn form explosive atmospheres with the surrounding air and thus greatly increase the hazardousness of such systems.

In all zones, substances prone to spontaneous combustion should therefore be avoided as far as possible. When it is necessary to work with such substances, the necessary protective measures must be tailored to each individual case.

Note: Suitable protective measures are, e.g.

1. inerting;
2. stabilisation;
3. improving heat dissipation, e.g. by dividing the substances into smaller portions or providing separating spaces between stored quantities;
4. temperature and pressure control;
5. storage at lowered temperatures;
6. limiting residence times.

3.2.3.4 Electrical apparatus

Even at low voltages, electrical sparking and hot surfaces may occur as sources of ignition in electrical apparatus (e.g. on making and breaking circuits and as a result of stray electric currents).

Electrical equipment should therefore be used in hazardous places only if it complies with Directive 94/9/EC. In all zones, equipment should be designed, constructed, installed and maintained in accordance with the current harmonised European Standards.

3.2.3.5 Static electricity

Separation processes involving at least one material with a specific electrical resistance of over 10^9 Ωm or objects with a surface resistance of over 10^9 Ω may under certain conditions give rise to incendive discharges of static electricity. Figure 3.6 shows various ways in which electrostatic charges may result from charge separation.

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Figure 3.6: Examples of charge separation which can lead to electrostatic charges
[From the ISSA leaflet "Static Electricity", International Section for the Prevention of Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

The following forms of discharge may occur under normal operating conditions:

- **Spark discharges**
  Spark discharges may arise from charge accumulation on unearthed conductive parts.
- **Brush discharges**
  Brush discharges may arise on charged parts made of non-conductive materials, which include most plastics.
- **Propagating brush discharges**
  In fast separation processes (e.g. films moving over rollers, pneumatic transport, drive belts), there is the risk of "propagating brush discharges".
- **Cone discharges**
  Cone discharges may occur, e.g. during pneumatic filling of silos.

All the above forms of discharge are to be regarded as capable of igniting most gases and solvent vapours. Dust/air mixtures can also be ignited by these forms of discharge, though brush discharges are to be regarded as a possibly effective source of ignition only for highly explosible dusts.

For the necessary assessment and possible protective measures, see CENELEC Report R044-001 "Guidance and recommendations for the avoidance of hazards due to static electricity".

Examples: Important protective measures are:

1. earthing all conductive objects and installations;
2. wearing suitable footwear at all times on suitable floorings, total person-to-earth resistance not to exceed 10^8 Ω;
3. avoiding materials and objects of low electrical conductivity;
4. reducing non-conductive surfaces.

3.3 Mitigation of the effects of explosions (mitigation measures)

In many cases, it is not possible to avoid explosive atmospheres and sources of ignition with a sufficient degree of certainty. Measures can then be taken to limit the effects of an *explosion* to an acceptable extent. Such measures are

- explosion-resistant design;
- explosion relief;
- explosion suppression;
- prevention of flame and explosion propagation.

These measures generally relate to mitigation of the hazardous effects of explosions starting within installations. Equipment and protective systems which comply with Directive 94/9/EC are generally used in mitigation measures.

3.3.1 Explosion-resistant design

Items of plant, such as containers, vessels and piping, are so constructed that they can withstand an internal *explosion* without rupturing. The initial pressure in the item of plant must be taken into account if it differs from normal atmospheric pressure.
In general, a distinction is made between *explosion-resistant* designs

- for the maximum explosion overpressure;
- for the reduced explosion overpressure associated with explosion relief or suppression.

Plant design can be either explosion pressure resistant or explosion pressure shock resistant.

Note: If the inside of plant is divided into subvolumes or two tanks are connected by a pipeline, during an *explosion* in one of the subvolumes the pressure in the other may be increased and the explosion may thus enter it at an elevated initial pressure. Pressure peaks thus occur which may be higher than the "*maximum explosion pressure*" determined for atmospheric conditions. If such arrangements cannot be avoided, appropriate measures should be taken, e.g. explosion-resistant design sufficient for the elevated *explosion pressure* or *explosion decoupling*.

3.3.1.1 Explosion-resistant design

Explosion pressure resistant containers and vessels withstand the expected *explosion overpressure* without becoming permanently deformed. The design is based on the expected *explosion overpressure*.

Note: For most gas/air and dust/air mixtures, the *maximum explosion overpressure* is 8–10 bar, but it may be higher for light-metal dusts.

3.3.1.2 Explosion pressure shock resistant design

Explosion pressure shock resistant containers and vessels are so constructed that, in the event of an internal explosion, they withstand a shock attaining the expected explosion overpressure, but may become permanently deformed.

After explosions, the affected items of plant must be checked for deformation.

Note:	If "explosion-resistant design" is used as a means of protection, *explosion decoupling* from upstream and downstream parts of the plant must be ensured.

3.3.2 Explosion relief

In the broadest sense, "explosion relief" covers everything that contributes to ensuring that, when an explosion is initiated or propagates to some degree, the originally closed plant within which it is taking place is vented in a safe direction, either briefly or for an extended period, if the actuation pressure is attained.

The *explosion relief device* is intended to ensure that the plant is not subjected to explosion stresses exceeding its strength. A *reduced explosion overpressure* results, which is only a fraction of the *maximum explosion overpressure*.

Note:	The *reduced explosion overpressure* is higher than the *actuation pressure* of the *relief devices*.

Bursting discs or *explosion doors*, for example, can be used as *relief devices*.

Note:	Only tested *relief devices* which comply with Directive 94/9/EC should be used. Self-made *relief devices* are often not effective and have in the past led to serious accidents. Unlocked container lids and covers, doors etc. that are placed over the vent openings are usually not suitable. If in-house designs which have proved satisfactory in practice are nonetheless used, their suitability for explosion protection purposes must be demonstrated by a risk assessment, and the result recorded in the explosion protection document.

The safety-related parameters of the mixture must be known in order to calculate the necessary *relief areas* for plants.

Explosion relief is not permissible if the vented products can endanger persons or cause harm to the environment (e.g. by release of toxic substances).

Note:	When *relief devices* are actuated, a great deal of flame and pressure may develop in the direction of discharge. *Relief devices* must therefore be so installed that the pressure is vented in a safe direction. Venting into work rooms should therefore always be avoided. Experience shows that it can be difficult to comply with the necessary safety clearances when retrofitting *relief devices* in existing plant. **Exception:** If "*Q-Pipe*" systems are used, venting into a room is permissible, since the flame and pressure effects are reduced to such a degree that they are not dangerous. However, the possible release of toxic combustion gases must then be taken into account.

Note:	If "*explosion relief*" is used as a means of protection, explosion decoupling from upstream and downstream parts of the plant must be ensured.

3.3.3 Explosion suppression

Explosion suppression systems prevent attainment of the *maximum explosion pressure* by rapidly injecting extinguishing agents into containers and plant in the event of an explosion. The items so protected need thus be designed to withstand only a *reduced explosion pressure*.

Unlike *explosion relief*, this ensures that the effects of an explosion are contained within the plant. Depending on design, the explosion overpressure may be reduced to about 0.2 bar.

Note:	Explosion suppression systems should be tested and marked as protective systems in accordance with Directive 94/9/EC.

Note:	Explosion suppression may also require explosion decoupling from upstream and downstream parts of the plant.

3.3.4 Prevention of explosion propagation (explosion decoupling)

An explosion occurring in one part of a plant can propagate to upstream and downstream parts, where it may cause further explosions. Acceleration caused by plant fittings or propagation in pipes may intensify the explosion effects. The *explosion pressures* so developed can be much higher than the maximum explosion pressure under normal conditions and may destroy items of plant even if they are of *explosion pressure resistant* or *explosion pressure shock resistant* design. It is therefore important to limit possible explosions to single parts of the plant. This is achieved by *explosion decoupling*.

Explosion decoupling can be performed e.g. by means of

- rapid-action mechanical isolation;
- flame extinction in narrow gaps or by injection of an extinguishing agent;
- arresting of flame by high counterflow;
- water seals;
- rotary valves.

The following aspects are important in practice:

Note:	Since the propagation velocities in explosions of mixtures with air of gases, vapours or mists can sometimes be very high (detonations), active isolation or extinguishing systems are often too slow, and preference is then given to passive devices such as crimped ribbon or water seal arresters. For dust/air mixtures, there is a risk of blockage in narrow-gap devices; here preference is therefore given to active devices such as rapid-action valves or extinguishing barriers.

3.3.4.1 Flame arresters for gases, vapours and mists

Flame arresters can be used to prevent flame transmission in the presence of explosive atmospheres, e.g. through piping, breathers and filling and emptying lines that are not full of liquid at all times. If the formation of a hazardous explosive atmosphere cannot be avoided, e.g. in a non-explosionproof container for flammable liquids, arrangements to arrest flame transmission must be made at permanent openings communicating with places where sources of ignition can be expected to occur and allowing an explosion to be transmitted to the container.

Note:	This applies e.g. to ventilation devices and reservoir level gauges and to filling and emptying lines, if they are not full of liquid at all times.

Conversely, equivalent measures must be taken to prevent the emission of flame from a vessel into a hazardous place.
The operation of flame arresters essentially depends on one or more of the following mechanisms:

- flame extinction in narrow gaps and channels (e.g. crimped ribbon and sintered metal arresters;
- halting a flame front by discharge of the unburned mixtures at an appropriate velocity (high-velocity valves);
- halting a flame front by means of a liquid seal.

Note:	Flame arresting devices are classified as explosion proof, endurance burning proof or detonation proof. Devices which are not endurance burning proof withstand burning for only a limited time (the fire resistance time) and then lose their flame arresting capacity.

3.3.4.2 Decoupling devices for dusts

Flame arresters for gases, vapours and mists cannot be used for dusts because of the danger of blockage. The following are of proven practical value in preventing the propagation of dust explosions through connecting pipework, conveying equipment, etc. and the emission of flame from plant.

- **Extinguishing barriers** The explosion is detected by sensors. The extinguishing agent is injected from dispersers into the pipework and the flame quenched. This does not affect the explosion pressure developed upstream of the barrier. Pipework and vessels downstream of the barrier, too, must be designed to withstand the expected pressure. The extinguishing agent must be appropriate for the type of dust in question.
- **Rapid-action valves or flaps** An explosion travelling through a pipe is detected by sensors. An actuating mechanism closes the valve or flap within milliseconds.
- **Quick-acting shut-off valves (explosion isolation valves)** When a given flow velocity is exceeded, a valve in the pipe closes. The velocity required for actuation is generated either by the blast wave or a sensor-controlled pilot flow (e.g. a jet of nitrogen directed on to the valve cone). The quick-acting shut-off valves so far known may be fitted only in horizontal pipe ranges and are suitable only for pipes with a fairly low dust burden (e.g. the exit side of filter units).
- **Rotary valves** Rotary valves may be used as "flame traps" only if their non-transmission of an internal ignition and their pressure resistance have been proven under the service conditions obtaining. In the event of an explosion, a sensor must stop the rotor automatically, so that no burning product is discharged.
- **Explosion diverters** An explosion diverter consists of pipe segments joined by a special fitting. The seal to atmosphere is in the form of a venting device (cover plate or bursting disc; actuation overpressure usually $p \leq 0.1$ bar). The aim is to prevent explosion propagation by diverting the flow through 180 degrees while providing explosion relief on opening of the venting device at the point of flow reversal.
  Projection of fragments of the venting device must be prevented, e.g. by means of a wire guard. Venting must always take place in a safe direction, never into working areas or travelling ways.
  This means of protection may not be used if persons can be endangered or the environment harmed by the discharge.
  Explosion diverters do not always reliably prevent the propagation of explosions. However, development of the flame front is so disrupted that a slowly moving explosion is the worst that is to be expected in the downstream pipe run. Where mixtures at explosive concentrations are not to be expected in the piping, e.g. in many dedusting units, it can be assumed that the decoupling effect is adequate.
- **Product barrier choke** In combination with explosion relief, chokes consisting of an adequate depth of the product being handled (e.g. at a silo discharge) are suitable for decoupling parts of a plant. The amount of material must be monitored by level indicators and must be sufficient to ensure that the explosion pressure cannot cause the flame to penetrate through the product.
- **Double valves** Product discharges from explosion proof vessels can be protected with a double valve system to prevent flame transmission. The valves must be at least as strong as the vessels. They must be controlled to ensure alternating closure such that there is always one valve closed.

Note:	All explosion decoupling systems should be tested and marked as protective systems in accordance with Directive 94/9/EC.

3.4 Application of process control engineering

The explosion protection measures so far described can be kept operational, monitored or triggered by safety, controlling and regulating devices (hereafter referred to as process control engineering – PCE). Generally, PCE devices can be used to avoid the occurrence of *hazardous explosive atmosphere*, *ignition sources* or the harmful effects of an explosion.

Potential *ignition sources*, such as a hot surface, can be monitored by PCE devices and controlled to ensure that a safe value is not exceeded. Potential *ignition sources* can also be switched off when a *hazardous explosive atmosphere* arises. For example, non-explosionproof electrical equipment can be made dead when a gas alarm is triggered, if this allows the potential ignition sources within the equipment to be de-energised. The occurrence of *hazardous explosive atmospheres* can be prevented, e.g. by starting a fan when the maximum permissible gas concentration is reached. The use of such PCE devices can reduce the size of *hazardous places (zones*), make it less likely that a *hazardous explosive atmosphere* will arise or prevent it from arising altogether. PCE devices in conjunction with devices for preventing the harmful effects of an explosion are protective systems (e.g. explosion suppression systems) and are described under mitigation measures in chapter 3.3. The design and scale of such PCE devices and the measures triggered by them depend on the probability of occurrence of a *hazardous explosive atmosphere* and of effective *ignition sources*. The reliability of the PCE devices in conjunction with the technical and organisational measures taken must be such as to ensure that the danger of an explosion is limited to an acceptable level, under all operating conditions. In certain cases, it can be useful to combine PCE devices for preventing *ignition sources* with PCE devices for preventing *hazardous explosive atmospheres*.

The degree of reliability required of PCE devices depends on the assessment of the explosion risks. Reliability of the safety function of PCE devices and their components is achieved by fault avoidance and fault control (having regard to all operating conditions and the planned maintenance and/or testing arrangements).

Example:	If assessment of the explosion risks and the explosion protection strategy leads to the conclusion that there will be a high risk without PCE devices, e.g. that *hazardous explosive atmospheres* are present continuously, for long periods or frequently (zone 0, zone 20) and that an operational malfunction is liable to give rise to an effective *ignition source*, the PCE devices must be so designed that a single PCE fault cannot make the safety arrangements ineffective. This can be achieved e.g. by redundant use of such devices. A comparable result can be achieved if a single PCE device for avoiding hazardous explosive atmospheres is combined with an independent single PCE device for avoiding effective ignition sources.

Table 3.2 shows approaches to using these devices, instead of or in addition to process engineering measures, in order to avoid effective ignition sources under normal operating conditions and for likely and infrequent malfunctions.

Example:	A transmission with several bearings is to be operated in zone 1. In normal operation, the temperature of the bearings is reliably below the *ignition temperature* of the gas/air mixture. In the event of a fault (e.g. resulting from a loss of lubricant), the bearing temperature may reach the *ignition temperature* if no protective measures are taken. An adequate standard of safety can be achieved by monitoring the temperature of the bearings, the unit being shut down if the *maximum permissible surface temperature* is reached.

The requirements for PCE devices as shown in Table 3.2 can likewise be applied to the avoidance of *hazardous explosive atmospheres* if the likelihood of potential ignition sources is given and it is necessary to ensure that the area in question meets the criteria for a particular zone.

Example: Solvent-covered workpieces are dried in a drying cabinet. In the event of a malfunction, the surface temperature of the heating unit can reach the ignition temperature. A PCE device linked to a fan has to be used to ensure that the solvent concentration does not exceed the limit value (LEL minus safety margin specific to the plant). This fan-linked device must remain effective in the event of a malfunction (e.g. a power cut).

Table 3.2: Use of PCE devices to reduce the probability of effective ignition sources

Hazardous place	Occurrence of ignition sources	Requirements for PCE devices
None	Operationally necessary	None
Zone 2 or zone 22	Operationally necessary	Suitable single device for avoiding ignition sources
	Unlikely in normal operation	None
Zone 1 or zone 21	Operationally necessary	Two suitable devices for avoiding ignition sources*
	Unlikely in normal operation	Suitable single device for avoiding ignition sources
	Unlikely in normal operation or in the event of malfunction	None
Zone 0 or zone 20	Unlikely in normal operation	Two suitable devices for avoiding ignition sources
	Unlikely in normal operation or in the event of malfunction	Suitable single device for avoiding ignition sources*
	Unlikely in normal operation, in the event of malfunction or in the event of rare malfunctions	None

* or an equivalent device type-tested in accordance with 94/9/EC

Note:

1. The PCE measures described can be adopted only if the physical, chemical and process parameters relevant to explosion protection can in fact be regulated or controlled, in an acceptably economic way and within a sufficiently short time. Materials properties, for example, generally cannot be influenced by such devices.
2. The PCE devices used must conform to European Directive 94/9/EC or the related harmonised standards. PCE devices must always be type-tested if the equipment to be protected falls within the scope of Directive 94/9/EC and the latter prescribes a type examination.

3.5 Requirements for work equipment

The employer must ensure that *work equipment* and all *installation materials* are suitable for use in *hazardous places*. In doing so, he must take account of the possible ambient conditions at the workplace in question. The work equipment must be so assembled, installed and operated that it cannot cause an explosion.

3.5.1 Selection of work equipment

Equipment and *protective systems* in the places where *hazardous explosive atmospheres* may be present must be chosen in accordance with the categories set out in Directive 94/9/EC.

Table 3.3: Equipment for use in the various zones

Zones	Usable categories	If designed for
0	II 1 G	• gas/air mixture • vapour/air mixture • mist
1	II 1 G or 2 G	• gas/air mixture • vapour/air mixture • mist
2	II 1 G or 2 G or 3 G	• gas/air mixture • vapour/air mixture • mist
20	II 1 D	• dust/air mixture
21	II 1 D or 2 D	• dust/air mixture
22	II 1 D or 2 D or 3 D	• dust/air mixture

Note: If equipment is to be used in hybrid mixtures, it must be suitable for such use and tested if appropriate. An item of equipment marked II 2 G/D is thus not necessarily suitable and permissible for use in hybrid mixtures.

Further criteria such as *temperature class*, *type of protection* and *explosion group* must be considered to ensure safe operation of equipment in hazardous places. These criteria depend on the combustion and explosion properties of the substances used.

If the assessment of explosion risks (material properties, processes) indicates that the potential risk to workers and other persons is greater than usual, the equipment chosen may have to have a higher degree of protection. If the manner in which mobile work equipment is used may lead to its operation in areas with different hazard potentials (different zoning), it should be selected on the basis of the worst case. If an item of work equipment is used in both zone 1 and zone 2, it must satisfy the requirements for operation in zone 1.

Exceptions are permissible if suitable organisational measures ensure safe operation for the whole period in which the mobile equipment is used in a hazardous place, e.g. by suitable ventilation. Such work equipment may be used only by suitably trained personnel (89/655/EEC).

3.5.2 Assembly of work equipment

Work equipment and connecting devices (e.g. pipework, electrical connections) must be so assembled that they cannot cause or trigger an explosion. They may be put into service only if the assessment of explosion risks establishes that their operation does not cause ignition of an *explosive atmosphere*. This also applies to work equipment and associated connecting devices which are not *equipment* and *protective systems* within the meaning of Directive 94/9/EC.

In accordance with the European Directive 89/655/EEC (safety and health requirements for the use of work equipment by workers at work) the employer must ensure that the equipment and installation materials used are suitable for the actual operating and service conditions; where necessary, this also applies to working clothes and personal protective equipment.

4. Organisational measures for explosion protection

If there is a potential risk of explosion at a workplace, this also implies that the work organisation must meet certain requirements. Organisational measures must be taken where technical measures alone cannot ensure and maintain explosion protection at the workplace. In practice, the work environment can also be made safe by combining technical and organisational measures.

Example:	When *explosion relief* devices are actuated, flame and pressure develop in the direction of discharge. When a vented silo is being filled, for example, no one may stand on its roof.

Organisational measures so arrange the working procedures that workers cannot be harmed by an explosion. Arrangements must also be laid down for inspection, maintenance and repair to ensure that technical measures remain operational. Organisational measures must also take account of possible interaction between explosion protection measures and working procedures. These combined explosion protection measures must ensure that workers can perform the work assigned to them without danger to their safety and health or to the safety and health of others.

Figure 4.1: Examples of organisational explosion protection measures
[From the ISSA leaflet "Gas Explosions", International Section for the Prevention of Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

The following organisational measures must be carried out:

- produce written operating instructions;
- instruct workers in explosion protection;
- ensure workers have suitable qualifications;
- apply a permit-to-work system for dangerous work;
- maintenance;
- testing and surveillance;
- mark hazardous places.

The organisational measures taken must be recorded in the explosion protection document (see chapter 6). A few examples are shown in Figure 4.1.

4.1 Operating instructions

Operating instructions are activity-related binding instructions and rules of conduct issued in writing by the employer to the employees. They describe the workplace-related dangers to human beings and the environment and indicate the protective measures taken or to be observed.

Operating instructions are produced by the employer or a qualified person whom he appoints to perform the task and must be observed by workers. They relate to a particular workplace or part of the establishment. Among the matters to be covered by operating instructions for workplaces where there are explosive atmosphere risks are what explosion hazards exist and where, what explosion protection measures have been taken, where and how what mobile work equipment may be used and whether special personal protection equipment must be worn.

Example:	The operating instructions may include a list of all mobile work equipment permitted for use in the hazardous place in question. They should indicate what personal protective equipment must be worn by persons entering this place.

They must be so worded that all workers can understand and apply them. If the establishment employs workers who do not have an adequate command of the language of the country, the operating instructions must be written in a language that they understand.

It may be appropriate for activity-related sets of operating instructions which describe different hazards or are produced on the basis of different statutory provisions to be combined into a single set of operating instructions, so providing an overall view of the hazards.

It is advisable for the operating instructions in an establishment to have a uniform presentation in order to take advantage of the familiarity effect.

4.2 Worker qualifications

For every workplace, there should be available a sufficient number of workers with the requisite experience and training to perform the explosion protection tasks assigned to them.

Responsible supervision must be ensured whenever workers are present in hazardous places.

Work during which workers may be at risk from explosive atmospheres may be carried out only by qualified persons or under their supervision.

4.3 Training of workers

Employers must provide workers with training which informs them of the explosion hazards at the workplace and the protective measures taken. This training must explain how the explosion hazard arises and in what parts of the workplace it is present. The measures taken should be listed and their operation explained. The correct way of working with the equipment available must be explained. Workers must be instructed in safe work in or near *hazardous places*. This also involves explaining the meaning of any marking of *hazardous places* and specifying what mobile work equipment may be used there (see 3.5.1). Workers must also be instructed in what personal protective equipment they must wear at work. The available operating instructions should be covered during the training.

Note:	Well-trained workers greatly increase safety at work. Any deviation from safe practices can be detected, and hence corrected, more quickly.

Workers must receive training (89/391/EEC):

- on recruitment (before starting work);
- in the event of a transfer or a change of job;
- when work equipment is introduced for the first time or changed;
- when new technology is introduced.

Training of workers must be repeated at suitable intervals, for example once per year. On completion of training, it can be useful to check on what has been learned.

The duty to provide training also applies to the employees of outside contractors. Training must be given by a suitably qualified person. Records should be kept in writing of the date and content of training activities and the participants.

4.4 Permit-to-work system

If work liable to cause an explosion is to be carried out in or near a *hazardous place*, it must be authorised by the person with responsibility for this function within the establishment. This also applies to activities which may interact with other work to cause hazards. A system of permits to work has proved useful in such cases. This may be implemented by means of a permit-to-work form which all concerned must receive and sign.

Example: The permit-to-work form should indicate:

1. where exactly the work is to be carried out;
2. who is to do the work and who is responsible for the place in question;
3. when the work will begin and when it is expected to end;
4. what additional protective measures have been taken;
5. contact persons.

Once the work has been finished, a check must be made to establish whether the plant is still safe or has been made safe again. All concerned must be informed when the work is finished.

4.5 Maintenance

Maintenance comprises repair, inspection, servicing and testing. Before maintenance work begins, all concerned must be informed and the work must be authorised, e.g. by means of a permit-to-work system (see above).

Experience shows that a high accident risk attaches to maintenance work. Before, during and after completion of the work, care must therefore be taken to ensure that all necessary protective measures are taken.

Note: During maintenance, items of equipment or plant which could cause an explosion if inadvertently started during the work should if possible be mechanically and/or electrically isolated. For example, if open flame operations are carried out in a container, all pipes from which a *hazardous explosive atmosphere* may be emitted or which are connected to other containers where such an atmosphere could be present should be separated from the container and blinded off.

When maintenance involving a risk of ignition is carried out in a hazardous place, it should be reliably ensured that it will be free of *hazardous explosive atmospheres* for the duration of the work and if necessary for some time thereafter (e.g. to allow cooling).

The items of plant on which work is to be carried out must as necessary be emptied, depressurised, cleaned, purged and must be free of flammable substances. While work is in progress, such substances should not reach the place where it is being carried out.

Where work may give rise to flying sparks (e.g. welding, flame cutting, grinding), suitable screening should be provided (see Figure 4.2) and a fire sentry posted if necessary.

Error! Unknown switch argument.

Figure 4.2: Example of screening for work giving rise to flying sparks
[From the ISSA leaflet "Safety of Liquefied Gas Installations", International Section for the Prevention of Occupational Risks in the Chemical Industry, International Social Security Association (ISSA), Heidelberg, Germany]

Once maintenance has been completed, steps must be taken to ensure that the explosion protection measures required for normal service are again operative before the equipment is restarted. A permit-to-work system (see above) is particularly useful during maintenance and repair work. It can be useful to use a checklist for the restoration of explosion protection measures.

4.6 Testing and surveillance

Before a workplace containing places where *hazardous explosive atmospheres* may occur is used for the first time, and after any damage or alterations with safety implications, its overall safety must be verified.

The effectiveness of the explosion protection measures taken in a plant must be checked at regular intervals. The frequency of such checks depends on the type of measure. All checks may be carried out by qualified persons only. Qualified persons are persons with comprehensive expertise in explosion protection as a result of their professional training, experience and current professional activity.

4.7 Marking of hazardous places

Directive 1999/92/EC stipulates that the points of entry to places where *hazardous explosive atmospheres* may occur in such quantities as to endanger the health and safety of workers must be marked by the employer with the following warning sign:

Figure 4.3: Warning sign for places where explosive atmospheres may occur

Distinctive features:

- triangular shape,
- black letters on a yellow background with black edging (the yellow part to take up at least 50 % of the area of the sign).

Such marking is required e.g. for rooms in which a *hazardous explosive atmosphere* may arise (such as rooms where flammable liquids are stored). On the other hand, there is no point in marking an item of plant which is protected by mitigation measures. If the *hazardous place* is not the whole space concerned, but only part of it, that part may be marked by yellow/black diagonal stripes e.g. on the floor.

Other details may be added to the warning sign, indicating e.g. the nature and frequency of occurrence of the *hazardous explosive atmosphere* (substance and zone). It may be desirable to place other warning signs in accordance with 92/58/EEC, for example forbidding the use of mobile telephones, smoking, etc.

Workers' attention must be drawn to the sign and its meaning in the course of their training.

5. Coordination duties

Where independent persons or teams are working simultaneously and in proximity to one another, they may inadvertently place each other at risk, particularly since those concerned focus primarily on their own tasks, while nothing or not enough is often known about the commencement, nature or extent of the work being done by others nearby.

Examples: Typical causes of poor coordination between house and contractor's staff, giving rise to particular explosion risks, are as follows:

1. The contractor is not aware of the environmental hazard at the firm where it is engaged and the implications for its own work.
2. The in-house departments often do not know that outside staff are working in the establishment and/or what potential hazard is being imported as a result of the work carried out.
3. The house management is not told how it and its staff have to conduct themselves in relation to the contractor.

Even safe working practices within a team do not exclude the possibility that others in the vicinity may be endangered. The only guarantee against hazardous interaction is timely coordination of all involved.

When work is contracted out, the principal and contractor are therefore required to coordinate their activities in order to avoid placing each other at risk. This duty also relates to the requirement of Article 7 (4) of the Occupational Safety and Health Directive 89/391/EEC, where several employers' workers are working at the same workplace. For worksites, the pertinent national regulations must also be complied with.

5.1 Coordination arrangements

Responsibility for coordination in the interests of safe work rests with the *employer*, as an aspect of work organisation. He has a duty to ensure that operations proceed safely in order to safeguard *workers'* lives and health. To this end, he must acquaint himself with the explosion hazards, discuss protective measures with the persons concerned, issue instructions and check that they are obeyed.

Because of the size of the firm or for other reasons, the employer is not always able to discharge this duty alone. He should therefore appoint suitable persons as managers. These then take over the employer's duties on their own responsibility, coordination duties being taken over by the coordinator.

Note: Specifically as regards work in or in connection with *hazardous places* or work with flammable substances that may give rise to *hazardous explosive atmospheres*, hazardous interaction must be assumed even if it is not immediately apparent. In case of doubt, it is therefore recommended that the employer appoint a coordinator.

In view of his special planning, safety and organisational responsibilities, the coordinator should possess the following qualifications relevant to explosion protection:

- expertise in implementing Directives 89/391/EEC and 1999/92/EC;
- knowledge of the firm's organisational structure;
- leadership qualities to ensure that the necessary instructions are put into effect.

Note: The following are often appointed as coordinators:

1. staff from the planning department;
2. persons in charge of one of the main working groups concerned.

In principle, the coordinator's task is to orchestrate the work of the various groups irrespective of the firms they belong to, in order to detect situations in which they may endanger each other and to be able to take any necessary action. He must therefore be informed in good time of the work to be undertaken.

Note:	The house and contractor's staff should both provide the coordinator in good time with the following information: • planned start of work; • anticipated end of work; • place of work; • workers assigned; • planned method of work; • name of the person(s) in charge.

More specifically, the coordinator's duties comprise site inspections and coordination meetings, as well as planning, supervision and if necessary replanning of work in response to difficulties arising. See checklist A.3.5.

5.2 Protective measures to ensure safe cooperation

In establishments where *hazardous explosive atmospheres* arise, different groups may work together at various levels and in all departments. In laying down and executing measures to avoid hazardous interaction, it is therefore necessary to consider all cases in which the task to be performed and the way it is carried out may lead to persons' working together or in each other's vicinity.

In practice, the coordination measures relevant to explosion protection are usually part of the general coordination functions:

1. at the planning stage;
2. at the execution stage;
3. on completion of the work.

At these various stages, the employer or his coordinator must also ensure that the necessary organisational measures are taken to avoid interaction between *hazardous explosive atmospheres*, *ignition sources* and operational malfunctions.

Examples:	**1.** Prevent the formation of *hazardous explosive atmospheres* around technical plant where ignition sources are to be expected [see 3.1], e.g. by using substitutes for solvent-containing cleaning agents, paints, etc. or providing adequate ventilation. **2.** Avoid using and creating ignition sources in places where *hazardous explosive atmospheres* may arise, e.g. in welding, cutting, soldering and separation work [see chapter 4.4/4.5 and specimen permit A.3.3]. **3.** Prevent malfunctions arising e.g. from interruption of gas supply, inducing of pressure fluctuations or shutdown of power or protective systems as a result of work in adjacent units.

A checklist can be used as an aid to determining whether the agreed protective measures are carried out during the work and whether the persons concerned have received adequate instruction and duly apply these measures [see Annex 3.4].

Note:	Irrespective of individuals' duties, all concerned should: • seek contact; • consult; • show consideration; • respect what has been agreed.

6 Explosion protection document

6.1 Requirements under Directive 1999/92/EC

As one of his duties under Article 4 of Directive 1999/92/EC, the *employer* must ensure that an explosion protection document is drawn up and kept up to date.

This document must at least demonstrate:

- that the explosion risks have been determined and assessed;
- that adequate measures will be taken to attain the aims of the Directive;
- those places which have been classified into *zones*;
- those places where the minimum requirements set out in Annex II to the Directive will apply;
- that the workplace and work equipment, including warning devices, are designed, operated and maintained with due regard for safety;
- that, in accordance with Council Directive 89/655/EEC, arrangements have been made for the safe use of work equipment.

The explosion protection document must be drawn up prior to the commencement of work and be revised when the workplace, work equipment or organisation of the work undergoes significant changes, extensions or conversions.

The *employer* may combine existing explosion risk assessments, documents or other equivalent reports and incorporate them into the explosion protection document.

6.2 Implementation

The explosion protection document is intended to provide an overview of the results of the risk assessment and the consequent technical and organisational protective measures for a plant and its working environment.

A specimen layout for an explosion protection document is shown below. It contains points which can be useful in addressing the above requirements and can be used as an aid in producing such documents.

However, this does not imply that all these points must be included. The explosion protection document should be tailored to conditions in the firm concerned. It should as far as possible be well-structured and easy to read and the degree of detail should be such as to allow a general grasp of its content. The amount of documentation should therefore not be excessive. When necessary, the document should be produced in a form that allows additions, e.g. as a loose-leaf collection. This is particularly recommended for larger plants or where the plant engineering is frequently changed.

Directive 1999/92/EC expressly allows existing assessments, documents or reports to be combined. An explosion protection document may thus contain references to other documents without their being included in full, in particular when these documents can at any time be consulted quickly and conveniently.

It should be ensured that the full explosion protection document (including the documents referred to) is readily to hand.

When establishments have several plants containing hazardous places, it can be useful to divide the explosion protection document into a general and a plant-specific part. The general part explains the structure of the documentation and measures applying to all plants, such as training. The plant-specific part describes the hazards and protective measures in the individual plants.

If operating conditions in a plant change frequently, e.g. as a result of batch processing of different products, the most dangerous conditions should be taken as the basis for assessment and documentation.

6.3 Specimen layout for an explosion protection document

6.3.1 Description of the workplace and working areas

The workplace is divided into working areas. The explosion protection document describes the working areas at risk from *explosive atmospheres*.

The description may contain, e.g. the name of the establishment, type of plant, building/room designation and persons in charge, number of workers employed.

Documentation of the buildings and topography may be in graphic form, e.g. site and layout plans, including plans of escape and rescue routes.

6.3.2 Description of the process steps and/or activities

The process should be described in a brief text, perhaps accompanied by a flowchart. This description should contain all information that is important for explosion protection. It should cover the operational steps including startup and shutdown, an overview of design and operational data (e.g. temperature, pressure, volume, throughput, rotational speed, work equipment), the nature and extent of cleaning if relevant, and possibly details of space ventilation.

6.3.3 Description of the substances used / safety parameters

This should in particular indicate what substances form the *explosive atmosphere* and under what process conditions it arises. At this point, it is useful to list the *safety parameters* relevant to explosion protection.

6.3.4 Results of the risk analysis

This section should indicate where *hazardous explosive atmospheres* may arise, possibly distinguishing between the inside of items of plant and their surroundings. Startup and shutdown, cleaning and malfunctions must be taken into account as well as normal operation. The *hazardous places* (*zones*) can be described by means of a text and also represented graphically as a zone plan (see 3.2.1).

The explosion hazards should also be described in this section (see chapter 2). Startup and shutdown, cleaning and malfunctions must be taken into account as well as normal operation. The procedure for process or product changes must also be taken into account.

6.3.5 Explosion protection measures taken

This chapter is based on the risk assessment and describes the resulting explosion protective measures. The principle underlying the protective measures should be stated, e.g. "Avoidance of effective ignition sources". It is useful to distinguish between technical and organisational measures.

Technical measures

- Prevention
  If the explosion protection strategy for the plant is based on preventive measures – avoidance of *explosive atmospheres* or avoidance of ignition sources – the way in which these measures are implemented must be described in detail. (See 3.1 and 3.2)
- Mitigation
  If the plant is protected by mitigation measures, their nature, manner of operation and location must be described. (See 3.3)

- Process control engineering measures
  If PCE measures are part of the explosion protection strategy, their nature, manner of operation and location must be described. (See 3.4)

Organisational measures

The organisational measures must also be described in the explosion protection document. (See chapter 4)

The explosion protection document must demonstrate

- what operating instructions have been produced for a workplace or activity;
- what steps are taken to ensure adequate qualification of the persons employed;
- the content and frequency of training (and the participants);
- any rules for the use of mobile work equipment in *hazardous places*;
- what steps are taken to ensure that *workers* wear only suitable protective clothing;
- whether a permit-to-work system is in place and, if so, how it is organised;
- how maintenance, testing and surveillance are organised;
- how the *hazardous places* are marked.

If forms relating to these points are available, specimens can be attached to the explosion protection document. A list of mobile work equipment authorised for use in hazardous places can also be attached.

6.3.6 Implementation of the explosion protection measures

The explosion protection document should indicate who is responsible for carrying out particular measures or who has been or will be appointed (e.g. to produce and update the explosion protection document itself). It should also indicate when measures are to be carried out. Maintenance plans may be included in this connection.

6.3.7 Coordination of the explosion protection measures

Where workers from several undertakings are present at the same workplace, each *employer* is responsible for all matters coming under his control. The *employer* responsible for the workplace must coordinate the implementation of all the explosion protection measures and state in his explosion protection document the aim of that coordination and the measures and procedures for implementing it.

6.3.8 Annex to the explosion protection document

The annex may contain e.g. EC type-examination certificates, safety datasheets, operating instructions for plant or equipment. However, it may also consist only of references indicating where this information is to found in the company records.

ANNEXES

A.1 Glossary

As an aid to a clear understanding of this Guide, some major explosion protection terms are defined below. Sources are quoted for legal definitions taken from the European directives and harmonised standards. Definitions for other terms were taken from the technical literature.

Components:
"Components" means any item essential to the safe functioning of equipment and protective systems but with no autonomous function. [Directive 1994/9/EC]

Conformity assessment procedure:

Degree of dispersion:
Measure of the (finest) distribution of a solid or liquid (disperse phase) in another solid or liquid (dispersion medium) without any molecular association, as an aerosol, emulsion, colloid or suspension.

Effective source of ignition:
Sources of ignition are often underestimated or overlooked. Their effectiveness, i.e. the ability to ignite an explosive atmosphere, depends e.g. on the energy of the source and the properties of the atmosphere. Under non-atmospheric conditions, there are changes in the parameters of explosive mixtures that determine whether ignition occurs: for example, the minimum ignition energy of high-oxygen mixtures is reduced by several factors of ten.

Employer:
Any natural or legal person who has an employment relationship with the worker and has responsibility for the undertaking and/or establishment. [Directive 89/391/EEC]

Equipment:
"Equipment" means machines, apparatus, fixed or mobile devices, control components and instrumentation thereof and detection or prevention systems which, separately or jointly, are intended for the generation, transfer, storage, measurement, control and conversion of energy and/or the processing of material and which are capable of causing an explosion through their own potential sources of ignition. [Directive 94/9/EC]

Equipment category:
Equipment and protective systems may be designed for a particular explosive atmosphere. In this case, they must be marked accordingly. [Directive 94/9/EC]

Note:	Equipment may also be designed for use in various explosive atmospheres, e.g. in both dust/air and gas/air mixtures.

Equipment group:
Equipment group I applies to equipment intended for use in underground parts of mines, and to those parts of surface installations of such mines, liable to be endangered by firedamp and/or combustible dust. Equipment group II applies to equipment intended for use in other places liable to be endangered by explosive atmospheres. [Directive 94/9/EC]

Note:	Group I equipment is not relevant for the purposes of this Guide. (See 1.2 Scope)

Explosion:
Abrupt oxidation or decomposition reaction producing an increase in temperature, pressure or in both simultaneously. [EN 1127-1]

Explosion group:

Explosion limits:
If the concentration of a sufficiently dispersed flammable substance in air exceeds a minimum value (the lower explosion limit), an explosion is possible. No explosion occurs if the concentration exceeds a maximum value (the upper explosion limit).
Explosion limits change under conditions other than atmospheric. The range of concentrations between the explosion limits widens, e.g. generally as the pressure and temperature of the mixture increase. An explosive atmosphere can form above a flammable liquid only if the temperature of the liquid exceeds a minimum value.

Explosion pressure (maximum):
Maximum pressure occurring in a closed vessel during the explosion of an explosive atmosphere, determined under specified test conditions. [EN 1127-1]

Explosion pressure resistant:
Property of vessels and equipment designed to withstand the expected explosion pressure without becoming permanently deformed. [EN 1127-1]

Explosion pressure shock resistant:
Property of vessels and equipment designed to withstand the expected explosion pressure without rupturing but allowing permanent deformation. [EN 1127-1]

Explosion relief:
Protective measure of limiting the explosion overpressure which will prevent the vessel from exceeding its design strength (explosion resistance) by exhausting unburned mixture and products of combustion by opening a given area. [After VDI 3673 Part 1]

Explosion relief area:
Geometric vent area of an explosion relief device. [After VDI 3673 Part 1]

Explosion relief device:
Device which closes a vent opening during normal operation and opens it in case of explosion. [After VDI 3673 Part 1]

Explosive atmosphere:
"Explosive atmosphere" means 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. [Directive 1999/92/EC]

Explosive mixture:
See "Explosive atmosphere".

Flash point:
Minimum temperature at which, under specified test conditions, a liquid gives off sufficient combustible gas or vapour to ignite momentarily on application of an effective ignition source. [EN 1127-1]

Hazardous explosive atmosphere:
Explosive atmosphere which, if it explodes, causes damage.

Hazardous place (place where explosive atmospheres may occur):
A place in which an explosive atmosphere may occur in such quantities as to require special precautions to protect the health and safety of the workers concerned is deemed to be hazardous. [Directive 1999/92/EC]

Hazardous quantities:
As little as 10 litres of an explosive atmosphere as a continuous volume must generally be regarded as hazardous in confined spaces irrespective of the size of the space.

Hybrid mixtures:
Mixture of flammable substances with air in different physical states, e.g. mixtures of methane, coal dust and air. [EN 1127-1)

Ignitable:

Ignition temperature:
The lowest temperature of a heated wall, as determined under specified test conditions, at which the ignition of a combustible substance in the form of gas or vapour mixture with air will occur. [EN 1127-1]

Intended use:
The use of equipment, protective systems, and devices referred to in Article 1 (2) in accordance with the equipment group and category and with all the information supplied by the manufacturer which is required for the safe functioning of equipment, protective systems and devices. [Directive 94/9/EC]

Limiting oxygen concentration:
Maximum oxygen concentration in a mixture of a flammable substance and air and an inert gas in which an explosion will not occur, determined under specified test conditions. [EN 1127-1]

Lower explosion limit:
The lower limit of the range of the concentration of a flammable substance in air within which an explosion can occur. [After EN 1127-1]

Materials which may form an explosive atmosphere:
Flammable and/or combustible substances are considered as materials which may form an explosive atmosphere unless an investigation of their properties has shown that in mixtures with air they are incapable of independently propagating an explosion. [Directive 1999/92/EC]

Non-hazardous place:
A place in which an explosive atmosphere is not expected to occur in such quantities as to require special precautions is deemed to be non-hazardous. [Directive 1999/92/EC]

Protective system:
"Protective systems" means devices other than components of the equipment defined above which are intended to halt incipient explosions immediately and/or to limit the effective range of an explosion and which are separately placed on the market for use as autonomous systems. [Directive 94/9/EC]

Note:	The term "protective systems" also covers integrated protective systems placed on the market in conjunction with an item of equipment.

Technically leakproof:
A subunit is "technically leakproof" if a leak is not discernible during testing, monitoring or checking for leakproofness, e.g. using foaming agents or leak searching/indicating equipment, but the possibility of infrequent small releases of flammable substances cannot be excluded.

Temperature class:
Equipment is classified by temperature class according to its maximum surface temperature. Similarly, gases are classified according to their ignition temperatures.

Type of protection:
The special measures applied to equipment to prevent ignition of a surrounding explosive atmosphere. [After EN 50014]

Upper explosion limit:
The upper limit of the range of the concentration of a flammable substance in air within which an explosion can occur. [After EN 1127-1]

Worker:
Any person employed by an employer, including trainees and apprentices but excluding domestic servants. [Directive 89/391/EEC]

Zones:
See "Zoning".

Zoning:
Hazardous places are classified in terms of zones on the basis of the frequency and duration of the occurrence of an explosive atmosphere. [Directive 1999/92/EC]

A.2 Legislation, standards and sources of further information on explosion protection

Annex A.2 lists the EU directives and guidelines and the harmonised European standards in the same language as the national version of the Guide. National regulations transposing Directive 1999/92/EC – insofar as they are known at the time of producing this Guide – are given in the language of publication.

The annex contains further sections for completion by the competent national authorities with details of further national regulations, literature and national advice centres.

A.2.1 European directives and guidelines

1999/92/EC	Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC) (OJ L 23, 28.1.2000, p. 57), last corrigendum on 7 June 2000 (OJ L 134, 7.6.2000, p. 36)
94/9/EC	Directive 94/9/EC of the European Parliament and the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres (OJ L 1000, 19.4.1994, p. 1), last corrigendum on 5 December 2000 (OJ L 304, 5.2.2000, p. 42)
92/104/EEC	Council Directive 92/104/EEC of 3 December 1992 on the minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extracting industries (twelfth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC) (OJ L 404, 31.12.1992, p. 10)
92/91/EEC	Council Directive 92/91/EEC of 3 November 1992 concerning the minimum requirements for improving the safety and health protection of workers in the mineral-extracting industries through drilling (eleventh individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC) (OJ L 348, 28.11.1992, p. 9)
90/396/EEC	Council Directive 90/396/EEC of 29 June 1990 on the approximation of the laws of the Member States relating to appliances burning gaseous fuels (OJ L 196, 26.7.1990, p. 15)
89/391/EEC	Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (OJ L 183, 29.6.1989, p. 1)
67/548/EEC	Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances (OJ L 196, 16.8.1967, p. 1), last amended on 6 August 2001 (OJ L 225, 21.8.2001, p. 1)
ATEX Guidelines	Guidelines on the application of Council Directive 94/9/EC of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres, May 2000 (published by the European Commission, 2001)

A.2.2 EU Member States' national regulations transposing Directive 1999/92/EC (*text in italics to be completed by the Commission*)

Belgium

Designation	*Full title (Short title), Date of issue, Source*

Denmark

Designation	*Full title (Short title), Date of issue, Source*

Germany

BetrSichV	Verordnung zur Rechtsvereinfachung im Bereich der Sicherheit und des Gesundheitsschutzes bei der Bereitstellung von Arbeitsmitteln und deren Benutzung bei der Arbeit, der Sicherheit beim Betrieb überwachungsbedürftiger Anlagen und der Organisation des betrieblichen Arbeitsschutzes - Betriebssicherheitsverordnung (BetrSichV)(BGBl. 2002 Teil I S. 3777)

United Kingdom

Designation	*Full title (Short title), Date of issue, Source*

Greece

Designation	*Full title (Short title), Date of issue, Source*

Sweden

Designation	*Full title (Short title), Date of issue, Source*

Spain

Designation	*Full title (Short title), Date of issue, Source*

France

Designation	*Full title (Short title), Date of issue, Source*

Ireland

Designation	*Full title (Short title), Date of issue, Source*

Italy

Designation	*Full title (Short title), Date of issue, Source*

Luxembourg

Designation	*Full title (Short title), Date of issue, Source*

Netherlands

Designation	*Full title (Short title), Date of issue, Source*

Austria

Designation	*Full title (Short title), Date of issue, Source*

Portugal

Designation	*Full title (Short title), Date of issue, Source*

Finland

Designation	*Full title (Short title), Date of issue, Source*

A.2.3 European standards

EN 1127-1	Explosive atmospheres - explosion prevention and protection - Part 1: Basic concepts and methodology; version EN 1127-1:1997
EN 13463-1	Non-electrical equipment for potentially explosive atmospheres - Part 1: Basic method and requirements; version EN 13463-1:2001
prEN 1839	Determination of explosion limits of gases, vapours and their mixtures
prEN 13237-1	Potentially explosive atmospheres - explosion prevention and protection - Part 1: Terms and definitions for equipment and protective systems intended for use in potentially explosive atmospheres; version prEN 13237-1:1998
prEN 13463-2	Non-electrical equipment intended for use in potentially explosive atmospheres - Part 2: Protection by flow restricting enclosure "fr"; version prEN 13463-2:2000
prEN 13463-5	Non-electrical equipment intended for use in potentially explosive atmospheres - Part 5: Protection by constructional safety; version prEN 13463-5:2000
prEN 13463-8	Non-electrical equipment for potentially explosive atmospheres - Part 8: Protection by liquid immersion "k"; version prEN 13463-8:2001
prEN 13673-1	Determination of the maximum explosion pressure and maximum rate of pressure rise of gases and vapours - Part 1: Determination of the maximum explosion pressure; version prEN 13673-1:1999
prEN 13673-2	Determination of maximum explosion pressure and maximum explosion pressure rise of gases and vapours - Part 2: Determination of the maximum explosion pressure rise
prEN 13821	Determination of minimum ignition energy of dust/air mixtures; version prEN 13821:2000
prEN 13980	Potentially explosive atmospheres - Application of quality systems; version prEN 13980:2000
prEN 14034-1	Determination of explosion characteristics of dust clouds - Part 1: Determination of the maximum explosion pressure; version prEN 14034-1:2002
prEN 14034-4	Determination of explosion characteristics of dust clouds - Part 4: Determination of limiting oxygen concentration of dust clouds; version prEN14034-4:2001
prEN 14373	Explosion suppression systems
prEN 14460	Explosion resistant equipment
prEN 14491	Dust explosion venting protective systems
prEN 14522	Determination of the minimum ignition temperature of gases and vapours

A.2.4 Further national regulations and literature (*to be completed by national authorities*)

<u>National regulations</u>

Designation *Full title (Short title), Date of issue, Source*

...

<u>Literature</u>

Title, *Author, Date of publication, Source*

...

A.2.5 National advice centres (*to be completed by national authorities*)

Name of the organisation *Contact person, if any* *Street/postbox* *Postcode, locality*	Tel.: ... Fax: ... E-Mail: ...
...	...

A.3 Specimen forms and checklists

A.3.1 Checklist: Explosion protection inside apparatus

A.3.2 Checklist: Explosion protection around apparatus

A.3.3 Specimen: Permit-to-work form for work involving ignition sources in hazardous places

A.3.4 Checklist: Coordination for operational explosion protection

A.3.5 Checklist: Tasks of the operational coordinator for explosion protection

A.3.6 Checklist: Completeness of the explosion protection document

A.3.1 Checklist: Explosion protection inside apparatus

Checklist: Explosion protection assessment I **– Focus: Inside apparatus –**	*Processed by* *Date*

Purpose

To evaluate explosion protection **inside** plant and apparatus, in order to assess the existing explosion protection strategy on the basis of targeted questions and to take any further action necessary. Points of doubt can be resolved by referring to the Guide chapters indicated, consulting local health and safety organisations or studying the current literature.

Apparatus/plant

Item	**Yes**	**No**	**Measures taken/ comments**
Is the presence of flammable substances avoided as far as possible [see 2.2.1]?	☐	☐	
Is the formation of explosive mixtures from the flammable substances present prevented as far as possible [see 2.2.2/2.2.3]?	☐	☐	
Is the occurrence of hazardous quantities of explosive atmospheres precluded as far as possible [see 2.2.4]?	☐	☐	
Can the formation of explosive mixtures inside the apparatus be prevented or limited [see 3.1]? • Can process conditions ensure compliance with safe concentrations [see 3.1.2]? • Is the concentration reliably and permanently kept below the lower explosion limit or above the upper explosion limit [see 3.1.2]? • Is the explosion range avoided during startup and shutdown of the plant [see 3.1.2]? • Can mixtures emerging from the apparatus during operation above the upper explosion limit form explosive atmospheres outside it and is this prevented [see 3.1.4]?	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	

Continued *Page 2/3*

Checklist: Explosion protection assessment I

– Focus: Inside apparatus –

Item	**Yes**	**No**	**Measures taken/ comments**
• When vacuum plant is operated above the upper explosion limit, is air ingress and hence the formation of explosive mixtures prevented?	☐	☐	
• Is the explosion hazard or violence reduced by lowered pressure (operation under vacuum)?	☐	☐	
• Is the formation of explosive mixtures reliably prevented in all operating conditions by injection of inert substances (e.g. nitrogen, carbon dioxide, noble gases, water vapour or inert powders) [see 3.1.3]?	☐	☐	
- When inerting is carried out with water vapour, is the effect of condensation taken into account?	☐	☐	
- Has allowance been made for the possibility that an inerted mixture may again become explosive on addition of sufficient oxygen or air (e.g. on discharge to the open air)?	☐	☐	
• Has a safety margin been specified between the experimentally determined limiting oxygen concentration and the maximum permissible oxygen concentration, taking account of spatial and temporal variations resulting from operational factors and malfunctions and of the delay between triggering of protective measures and their becoming effective?	☐	☐	
• Are undesirable dust deposits or accumulations avoided [see 3.1.6]?	☐	☐	
Is the prevention or limitation of explosive mixtures inside apparatus monitored?	☐	☐	
Can hazardous explosive atmospheres occur inside the plant or apparatus despite the above measures [see 2.2.5]?	☐	☐	

Continued *Page 3/3*

Checklist: Explosion protection assessment I

– Focus: Inside apparatus –

Item	**Yes**	**No**	**Measures taken/ comments**
Are measures taken to prevent the ignition of a hazardous explosive atmosphere [see 3.2/3.2.2]?	☐	☐	
• Are zones known and classified [see 3.2.1]?	☐	☐	
• Are effective ignition sources of the 13 known types to be expected according to the zoning [see 3.2.3]?	☐	☐	
Can a hazardous explosive atmosphere be ignited inside the plant or apparatus despite all the above measures [see 2.2.6]?	☐	☐	
Are the effects of an explosion limited to an acceptable extent by suitable mitigation measures designed in accordance with the state of the art, without endangering the surrounding area (e.g. by venting) [see 3.3]?	☐	☐	
• Explosion-resistant design [see 3.3.1]?	☐	☐	
• Explosion relief [see 3.3.2]?	☐	☐	
• Explosion suppression [see 3.3.3]?	☐	☐	
• Prevention of flame and explosion propagation to upstream and downstream items of plant [see 3.3.4]?	☐	☐	
- Flame arresters for gases, vapours and mists?	☐	☐	
- Decoupling devices for dusts?	☐	☐	
- Explosion decoupling for hybrid mixtures?	☐	☐	

A.3.2 Checklist: Explosion protection around apparatus

Checklist: Explosion protection assessment II **– Focus: Around apparatus –**	*Processed by*
	Date

Purpose

To evaluate explosion protection **around** plant and apparatus, in order to assess the existing explosion protection strategy on the basis of targeted questions and to take any further action necessary. Points of doubt can be resolved by referring to the Guide chapters indicated, consulting local health and safety organisations or studying the current literature.

Apparatus/plant

Item	**Yes**	**No**	**Measures taken/ comments**
Is the formation of explosive atmospheres around apparatus prevented [see 3.1.4]?	☐	☐	
• Are explosive atmospheres prevented by operational measures, design or spatial configuration?	☐	☐	
• Is the apparatus/plant leakproof?	☐	☐	
• Is ventilation or extraction used?	☐	☐	
Are arrangements in place to monitor the concentration around apparatus [see 3.1.5]?	☐	☐	
• By means of gas instruments which trigger an alarm?	☐	☐	
• By means of gas instruments which trigger protective measures?	☐	☐	
• By means of gas instruments which trigger emergency functions?	☐	☐	
Can a hazardous explosive atmosphere occur around the plant or apparatus despite the above measures [see 2.2.5]?	☐	☐	

Continued *Page 2/2*

Checklist: Explosion protection assessment II

– Focus: Around apparatus –

Item	Yes	No	Measures taken/ comments
Are measures taken to prevent the ignition of a hazardous explosive atmosphere [see 3.2/ 3.2.2]? • Are zones known and classified [see 3.2.1]? • Are effective ignition sources of the 13 known types to be expected according to the zoning [see 3.2.3]?	☐ ☐ ☐	☐ ☐ ☐	
What civil engineering measures are taken to limit the effects of an explosion to an acceptable extent, e.g. • Bricking of high-pressure autoclaves?	☐ ☐	☐ ☐	
Are organisational measures taken to ensure the effectiveness of the technical measures [see chapter 4]? • Are operating instructions in place? • Are qualified personnel used? • Are workers given training? • Is a permit-to-work system in place? • Are hazardous places marked?	☐ ☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐ ☐	
Are protective measures in place for maintenance work [see 4.5]?	☐	☐	

A.3.3 Specimen: Permit-to-work form for work involving ignition sources in places with hazardous atmospheres

	Permit-to-work form for work involving ignition sources in places with hazardous atmospheres	
1	Working place	....
2	Task (e.g. weld pipe)	....
3	Nature of work	☐ Welding ☐ Cutting ☐ Abrasive cutting ☐ Soldering ☐ Thawing ☐ ....
4	Precautions taken before starting work	☐ Removal of all movable combustible objects and substances, including dust deposits, within a radius of ...... m and – where necessary – also in adjacent rooms ☐ Covering of the immovable combustible objects, e.g. wooden beams and floors, plastic parts, with protective materials ☐ Sealing of openings, joints and cracks in the building and other apertures such as gratings with non-flammable substances ☐ Removal of cladding and insulation ☐ Elimination of explosion hazard in containers and pipework, possibly by inerting ☐ Closing of openings in pipework, containers and accessories, etc. ☐ Posting of a fire sentry with filled water buckets, fire extinguishers or connected fire hose (spray only for dusts)
5	Fire sentry	☐ While work is in progress Name: .... ☐ After work is completed Name: Duration: hrs
6	Alarm	**Location of the nearest** Fire alarm .... Telephone .... **Fire service telephone number:**
7	Firefighting equipment/extinguishing agent	☐ Fire extinguisher with ☐ water ☐ CO_2 ☐ powder ☐ Filled water buckets ☐ Connected fire hose
8	Permit	The safety measures listed must be taken. The statutory provisions for accident prevention and the insurers' safety regulations must be observed.
	Date	Signature of the manager or the person appointed by him Signature of the person carrying out the work

A.3.4 Checklist: Coordination for operational explosion protection

Checklist: Coordination measures **– Focus: Operational explosion protection –**	*Processed by*	
	Date	
Purpose This checklist may serve as an aid to checking whether the protective measures are being carried out as agreed to allow principal and contractor to work together safely, whether the persons concerned have received adequate instruction and whether they are complying with the agreed protective measures.		
Task		
Item	**Yes**	**No**
Is a check made on compliance with statutory and company regulations implementing Directive 1999/92/EC?	☐	☐
• Has a person (the coordinator) been appointed to coordinate work carried out jointly [see 5.1]?	☐	☐
• Is the appointed person adequately qualified [see 5.1]?	☐	☐
• Is the coordinator known on site?	☐	☐
• Are subcontractors notified to the employer?	☐	☐
Is the work procedure checked for hazardous interaction [see 5.2]?	☐	☐
• Is it impossible for hazardous explosive atmospheres to form in places where there may be ignition sources?	☐	☐
• Is the use or creation of ignition sources prevented in places with hazardous explosive atmospheres?	☐	☐
• Are malfunctions avoided in nearby operations involving hazardous places?	☐	☐
Is the work procedure laid down [see checklist in Annex A.3.5]?	☐	☐
Are the agreed protective measures adapted to take account of the progress of work or of any shortcomings detected?	☐	☐
• Is training provided throughout?	☐	☐
• Is there consultation throughout?	☐	☐
• Are instructions issued throughout?	☐	☐
• Are checks made throughout?	☐	☐

A.3.5 Checklist: Tasks of the operational coordinator for explosion protection

Checklist: Coordination tasks **– Focus: Operational explosion protection –**	*Processed by* *Date*
Purpose To specify the tasks of the person responsible for coordination (preferably a coordinator appointed by the employer) in order to ensure that the work of the groups/contractors concerned is so orchestrated that any possible hazardous interaction is detected and prevented in good time and action can be taken quickly in the event of incidents.	
Task	

Item	**Yes**	**No**
Is a site inspection carried out?	☐	☐
Is a work schedule drawn up?	☐	☐
• Have the place and time of the individual tasks been indicated?	☐	☐
• Have the persons concerned been named, including the persons in charge?	☐	☐
• Has the timeline been specified?	☐	☐
• Have the special requirements for carrying out the work been specified?	☐	☐
• Have specific explosion protection measures been laid down?	☐	☐
• Have the danger zones, and in particular the places where an explosive atmosphere may occur, been determined and marked?	☐	☐
• Have measures been put in place in case of incident?	☐	☐
Are consultations arranged between the persons concerned?	☐	☐
Are checks made on compliance with the work schedule?	☐	☐
Are the operations replanned in the event of an incident?	☐	☐

A.3.6 Checklist: Completeness of the explosion protection document

<table>
<tr><td colspan="3">Checklist: Explosion protection document
– Check on completeness –</td><td>Processed by

Date</td></tr>
<tr><td colspan="4">Purpose
To check the completeness of an explosion protection document, indicating information sources. Points of doubt can be resolved by referring to the Guide chapters indicated, consulting local health and safety organisations or studying the current literature.</td></tr>
<tr><td colspan="4">Explosion protection document (title, location)</td></tr>
<tr><td rowspan="2">Item</td><td colspan="3">Information source</td></tr>
<tr><td>Explosion protection document</td><td>Other documents</td><td>Still to be produced</td></tr>
<tr><td>Description of the workplace and working areas available [see 6.3.1]?
• Textual description
• Site plan
• Layout plan
• Plan of escape and rescue routes</td><td></td><td></td><td>☐
☐
☐
☐
☐</td></tr>
<tr><td>Description of process steps / activities [see 6.3.2]?
• Textual description
• Process flowchart
• P&I flowchart
• Ventilation plan</td><td></td><td></td><td>☐
☐
☐
☐
☐</td></tr>
<tr><td>Description of the substances used [see 6.3.3]?
• Textual description
• Safety datasheets
• Safety parameters</td><td></td><td></td><td>☐
☐
☐
☐</td></tr>
</table>

Continued			*Page 2/3*
Checklist: Explosion protection document – Check on completeness –			
Item	**Information source**		
	Explosion protection document	**Other documents**	**Still to be produced**
Results of the risk analysis described [see 6.3.4]?			
• Hazardous places inside items of plant (textual)			☐
• Hazardous places around plant (textual)			☐
• Zoning (textual)			☐
• Zone plan (graphic)			☐
• Hazards in normal operation			☐
• Hazards during startup and shutdown			☐
• Hazards in the event of malfunction			☐
• Hazards during cleaning			☐
• Hazards in the event of process/product changes			☐
Technical explosion protection measures described [see 6.3.5]?			
• Prevention			☐
• Mitigation			☐
• PCE measures			☐
• Requirements for and selection of work equipment			☐

Continued **Checklist: Explosion protection document** – Check on completeness – *Page 3/3*			
Item	**Information source**		
	Explosion protection document	**Other documents**	**Still to be produced**
Organisational explosion protection measures described [see 6.3.6]?			
• Written operating instructions			☐
• Instructions for use of work equipment			☐
• Description of personal protective equipment			☐
• Evidence of qualifications			☐
• Documentation of training			☐
• Description of the permit-to-work system			☐
• Description of maintenance, testing and surveillance intervals			☐
• Documentation of the marking of hazardous places			☐
Documentation of persons responsible and qualified persons [see 6.3.7]?			☐
Documentation of coordination measures and arrangements [see 6.3.8]?			☐
Content of the annex [see 6.3.9]: • .... • .... •			☐