MANAGING SAFETY IN WORKPLACES WITH POTENTIALLY EXPLOSIVE ATMOSPHERES

Colm Leahy, Senior Project Engineer, Arup Consulting Engineers and Don Menzies, CEng FIEI, Director, Arup Consulting Engineers outline the implications of the EC ATEX Directives for employers, including suggested solutions for the practical problems commonly encountered at workplaces with potentially explosive atmospheres.

The explosion risk associated with dust and vapour clouds is well documented. A vapour cloud explosion was the last link in a chain of events which led to the Buncefield oil storage depot fire, one of the most dramatic industrial accidents of recent years.

The EC response to the threat to human welfare from the generation of explosive atmospheres at industrial facilities has been to enact a brace of Directives commonly referred to as the ATEX Directives (ATEX being an acronym of the French 'ATmosphères EXplosibles'). Directive 99/92/EC (sometimes referred to as the 'Use Directive') stipulates mandatory health and safety requirements for workplaces where potentially explosive atmospheres arise. Directive 94/9/EC(referred to as the 'Product' Directive) covers equipment and protective systems which may be used in potentially explosive atmospheres. The Directive covers both electrical and mechanical equipment.

ATEX legislation has been transposed into Irish law by S.I. No 258 of 2003: Safety, Health and Welfare at Work (Explosive Atmosphere) Regulations 2003 and SI No 83 of 1999: European Communities (Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres) Regulations, 1999. S.I. No 258 of 2003 sets out an employer's responsibilities with regard to assessment of explosion risk at the workplace and mitigation of any risk identified. S.I. No 83 of 1999 stipulates requirements for equipment for use in potentially explosive atmospheres.

New workplaces coming on stream are obliged to be ATEX-compliant before they commence operation. 2005 and 2006 saw a flurry of activity as companies strove to be become ATEX-compliant before the 30 June deadline. However, with the deadline for compliance for workplaces operating pre-June 2003 past, the focus of existing ATEX and non-ATEX facilities should be on identifying the ramifications of the introduction of new materials, new equipment and/or new processes on-site.

What is an "explosive atmosphere"?

An explosive atmosphere is defined in Council Directive 1999/92/EC as 'a mixture with air, under atmospheric conditions, of flammable substances in the form gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture'. Gases which evolve from liquid surfaces are referred to as vapours. In **Figure 1**, the traditional 'fire triangle' has been modified to show the conditions necessary for an explosion to occur. It is normally understood that an 'explosion' occurs if the combustion of the mixture is accompanied by a pressure wave. It might appear that the inclusion of the 'atmospheric conditions' stipulation precludes pressure vessels such as LPG tanks from consideration in the hazardous area classification of a workplace.

However, even a cursory risk assessment would reveal that leaks could occur at LPG tanks through accidental collision by vehicle, through failure of the tank or during the filling operation. Therefore, careful assessment of the area around an LPG tank would be necessary. Equally, compressed gas cylinders that may be used for welding at a workplace are not considered as being 'explosive' in that the atmosphere within the cylinder is pressurised. However, leaks can occur around cylinder valves or from connected hoses, thus leading to the generation of a potentially explosive atmosphere.

Compliance timeline

The Regulations apply since July 1st 2003 to new workplaces or workplaces which have undergone modifications, extensions or restructuring after July 2003. A lead-in time was allowed for existing workplaces up to June 30th 2006. However, work equipment and protective systems which were "made available" at the workplace after June 30th 2003 must comply with these regulations and with the ATEX product regulations S.I. No 83 of 1999, i.e., the equipment or protective system must be suitable for use in explosive atmospheres and be CE marked to demonstrate its suitability. "Making available" means the transfer of the product, that is, either the transfer of ownership, or the physical hand-over of the product by the manufacturer, his authorised representative in the EU or the importer to the person responsible for distributing these onto the EU market or the passing of the product to the final consumer, intermediate supplier or user in a commercial transaction, for payment or free of charge, regardless of the legal instrument upon which the transfer is based (sale, loan, hire, leasing, gift, or any other type of commercial legal instrument). The ATEX product

Zone	Description
	Flammable Gases and Vapours
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.
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.
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.
	Combustible Dusts
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 for short periods.
Zone 21	A place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is likely to occur occasionally in normal operation.
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.

Table 1: Definition of hazardous zones.

must comply with the Directive at the moment of transfer. Work equipment in use before June 30th 2003 can continue to be used provided it complies with the legislation in force at that time e.g. 'Ex' equipment which is suitable for the application and complies with a harmonised European standard is acceptable.

What are the implications for employers?

The principle obligation on workplaces in operation pre-July 2003 is the preparation of an Explosion Protection Document (EPD). The steps involved in preparation of the EPD are outlined in **Figure 2** (page 258).
The first step is to carry out a risk assessment i.e. identification and examination of any explosion risks. This enables the operator to eliminate or minimise the risk.
The risk assessment must be carried out by a person who is 'competent in the area of explosion protection'. The assessment must, at a minimum, address the following issues:

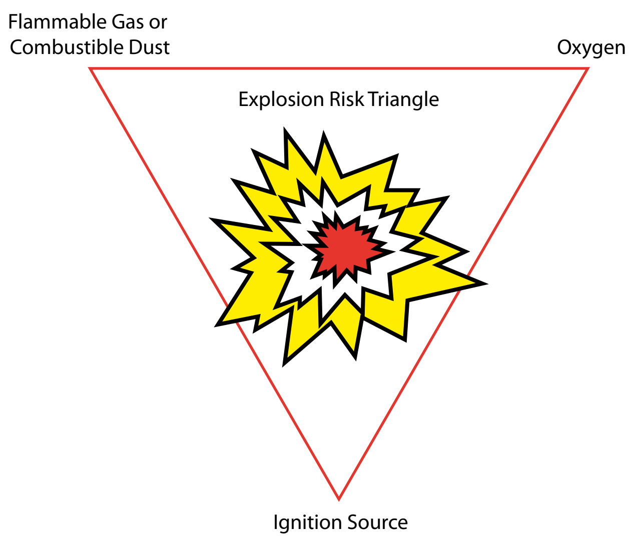
- the likelihood that explosive atmospheres will occur and their persistence
- the likelihood that ignition sources, including electrostatic discharges will be present and become active and effective
- the installations, substances used, processes and their possible interactions the scale of the anticipated effects.

The risk assessment generates a hazardous area classification for the workplace based on the likelihood and persistence of explosive atmospheres. A written and diagrammatic description of the hazardous (with respect to explosion) zones is required. The prescribed diagram format is given in the International Electrotechnical Commission (IEC) standards: Electrical Apparatus for Explosive Atmospheres Part 10: Classification of Hazardous Areas (IEC 60079-10:2002), and Electrical Apparatus for Use in the Presence of Combustible Dust Part 10: Classification of Areas Where Combustible Dusts are or May be Present (IEC 61241-10:2004).
Hazardous areas at a facility are classified into Zones on the basis of the likely frequency of occurrence of an explosive atmosphere and the likely duration of the atmosphere once generated. Zones are defined as indicated in **Table 1**. The hazardous area classification must then be incorporated into the EPD for the facility.
Potentially explosive atmospheres at a facility and the minimum requirements for electrical equipment being used in these areas can be readily identified through reference to the EPD. In addition to the incorporation of the facility's hazardous area classification, the EPD must demonstrate that: adequate measures have been taken to implement the regulations the workplace and work equipment are designed, operated and maintained with due regard to worker safety the procedure for implementing any coordinating measures required to ensure the safety of all employees at the workplace, including those not employed by the employer responsible for the workplace is in place.

Hazardous area classification procedure

The IEC standards mentioned above may be referenced in determining the extent of zones. Several examples of zoning for different situations that might give rise to explosive atmospheres at a workplace are given in these documents.
A hazardous zone arises within a gas/vapour flammable envelope and within combustible dust clouds of sufficient concentration. The flammable envelope of a gas/vapour is the concentration range (in air) within which the gas/vapour can ignite and explode.
The flammable envelope is defined by the explosive limits of the gas/vapour. There are two explosive limits for any gas or vapour, the lower explosive limit (LEL) and the upper explosive limit (UEL). At concentrations in air below the LEL, there is not enough fuel to continue an explosion; the atmosphere is said to be 'vapour lean'. At concentrations above the UEL, the concentration of fuel is so great that there is insufficient oxygen present for ignition to occur; the atmosphere is said to be 'vapour

Figure 1 - Explosion Risk Triangle



rich'. The extent of the hazardous zone may be estimated or calculated. Examples given in the guidance documentation can serve as useful zoning 'templates'.

Figure 3 shows the hazardous area classification for a bunded tank for a flammable liquid, as recommended by the European Commission. Modelling software can also be used to predict the behaviour of gases/vapours under different weather conditions.

The Health and Safety Authority (HSA) is the competent authority for the implementation of ATEX legislation in Ireland. The HSA recommends the use of the PHAST program in the modelling of major accident hazard scenarios at Seveso sites. The PHAST graphs function can prove very useful in a hazardous area classification exercise. A footprint graph of the vapour cloud within the material's explosive limits can be produced (refer to **Figure 4**). This shows the horizontal dispersion of the explosive cloud. A sideview graph can be generated to show the vertical limit of the explosive cloud.

Ventilation

One of the principal factors which affects the type and extent of zones is ventilation. The ventilation in the area where an explosive atmosphere could arise determines how quickly the released material will be diluted by air to below its LEL or its combustible concentration in the case of dusts. Therefore, the type of ventilation (i.e. natural or forced) around the source of release has an effect on the extent of the hazardous zone. Natural ventilation (i.e. outdoors or indoors with approximately 5 – 6 air changes per hour) leads to stable zones, the extent of which can be determined using the methods described above. Forced ventilation, through rapid dilution of the released gas/vapour/dust can lead to a reduction in the vertical and horizontal extent of zones and reduction in the length of time a zone persists. In certain cases forced ventilation can even prevent an explosive atmosphere arising. The effectiveness of the ventilation depends on two factors.

(i) Degree

- Ventilation is described as being of high, medium or low degree.
- High ventilation can reduce a hazardous zone down to a negligible extent. For example, a Nederman arm (ATEX-certified) can be used to extract flammable vapours over a filling operation. Similarly, a laminar flow booth can dramatically reduce the zones for a flammable drum filling operation.
- Medium degree ventilation can prevent the persistence of the explosive atmosphere after the release has stopped. It leads to stable zones with definable vertical and horizontal boundaries.
- Low degree ventilation leads to unstable zones.

(ii)Availability

- The availability of ventilation can be described as good, fair or poor. Good ventilation is assumed to be present continuously. Standby fans or standby electricity might be necessary in order to classify ventilation as good.
- Fair ventilation is expected to be available during normal operation. Poor ventilation does not meet the standards of good or fair but discontinuities are not expected to occur for long periods.

Grade of release

Three grades (continuous, primary and secondary) of release are defined. The grade of release designated

Hazardous Area Classification	Equipment Operating Scenario to be considered
Zone 0/20	Normal operation and foreseeable and rare malfunctions
Zone 1/21	Normal operation and foreseeable malfunctions
Zone 2/22	Normal operation only

Table 2: Risk assessment scenarios for 'old' equipment.

to a given source during the area classification exercise depends on the frequency and likelihood of occurrence of the explosive gas/dust atmosphere. The physical properties of the material also affect the extent of the hazardous zone. In order to cause an explosion, a gas, vapour or dust cloud must encounter a source of ignition (e.g. a spark from a piece of electrical equipment or static generated by the movement of powder over a plastic bag) of greater energy than its minimum ignition energy (MIE). The MIE is the lowest possible electrical energy that upon discharge is sufficient to ignite the mixture of gas, vapour or dust and air. If a sufficiently thick layer of combustible dust is heated to greater than its auto-ignition temperature it will ignite creating a source of ignition for any existing dust clouds. Similarly, gases and vapours may be ignited if the temperature rises above the auto-ignition temperature. The flash point of a liquid or solid is the lowest temperature at which it gives off enough vapour to form a flammable air/vapour mixture near its surface. Materials with a low flash point present a greater fire hazard. The extent of the hazardous zone can also depend on the gas/vapour density. Most vapours are denser than air and therefore fall to ground. Gases such as hydrogen, which are lighter than air, will rise on release. Therefore, a release of hydrogen at high level would not result in a zone extending to ground level.

Selection of work equipment

Following the risk assessment and hazardous area classification, suitable equipment can be selected for use in classified areas. S.I. No. 83 of 1999 stipulates health and safety requirements for equipment and protective systems intended for use in potentially explosive atmospheres. These regulations also require the affixing of the CE marking. The CE marking can only be affixed if the equipment has undergone the appropriate conformity assessment procedure and in respect of which an EC declaration of conformity has been drawn up. The marking is used by the manufacturer as a declaration that he considers that the product has been made in accordance with the provisions of Directive 94/9/EC. The regulations define categories of equipment intended for use in potentially explosive atmospheres. This enables an employer to ensure only equipment that is appropriate for the hazard classification of a given area is used. Equipment is categorised as follows:

Category 1

Equipment must be so designed and constructed that sources of ignition do not become active, even in the event of rare incidents relating to equipment. This category of equipment is suitable for use in areas where explosive atmospheres are highly likely to occur and are present continuously, for long periods of time or frequently i.e. zone 0/20.

Category 2

Equipment must be so designed and constructed as to prevent ignition sources arising, even in the event of frequently occurring disturbances or equipment operating faults, which normally have to be taken into account. This category of equipment is suitable for use where explosive atmospheres are likely to occur i.e. zone 1/21

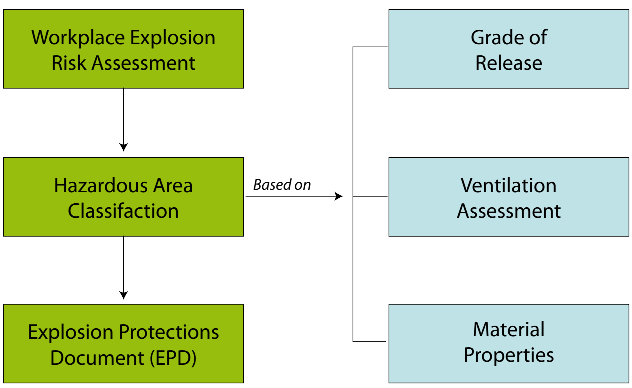
Category 3

Equipment must be so designed and constructed as to prevent foreseeable ignition sources which can occur during normal operation. This category of equipment is suitable for use in areas where explosive atmospheres are less likely to occur and if they do occur, do so infrequently and for a short period of time only i.e. zone 2/22.

ATEX and fuel burning equipment

The application of the ATEX directives to fuel burning equipment can cause confusion. Fuel burning equipment intended for use in a non-commercial environment is specifically excluded from 94/9/EC. There are no specific exclusions in the Directive for other gas and oil burning equipment. However, logically it would seem that fuel burning equipment need not be ATEX certified or suitable for use in a potentially explosive atmosphere of its own creation, as sources of ignition such as hot surfaces and flames are unavoidable. Relief valves, flange connections, pipe fittings and seals can all be sources of release.

Figure 2 - EPD Preparation Procedure



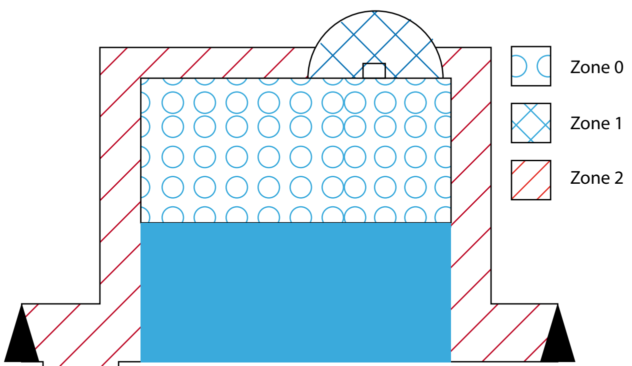


Figure 3 - Hazardous Area Classification for a Bundled Flammable Liquid Storage Tank (COM(2003) 515 final)

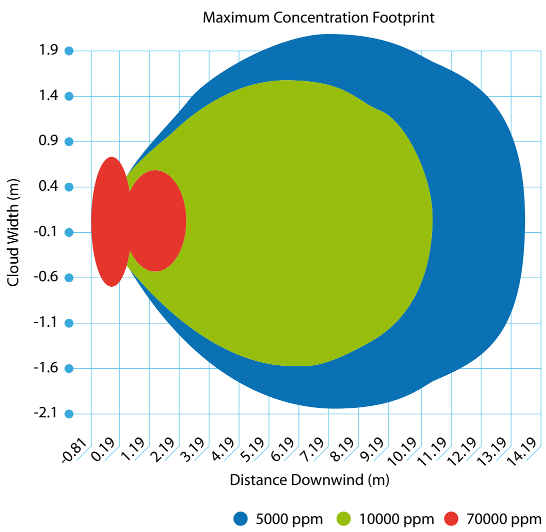
Diagrams courtesy of ARUP

Risk assessment of electrical and mechanical work equipment in use or made available at the workplace before June 30th, 2003.

After completion of the hazardous area classification, the work equipment operating in potentially explosive atmospheres should be identified. For this equipment, possible sources of ignition should be identified e.g. static, mechanical sparks, electrical sparks, surface temperature. When risk assessing a piece of equipment, the operating scenarios for the equipment which must be considered are dependent on the zone in which it is used (see Table 2). Where malfunctions do not occur or are not thought credible, the reasons why must be established. Where no reason can be determined why malfunction will not occur in future, a protective system should be considered, e.g. inerting, explosion suppression, explosion venting.

Where a fuel/fuel vapour leak occurs from fuel burning equipment, other electrical and mechanical equipment in the resulting potentially explosive atmosphere must be suitable for use in that atmosphere. Where the fuel burning equipment is used in a potentially explosive atmosphere created by a separate source, it must be of the appropriate ATEX category or be proven to be suitable for use in that area. For example, a new forklift truck for use in zone 2 should be certified as category 3, at least. ATEX and the issue of hazardous area classification have introduced new terminology to the industrial health and safety lexicon. While extensive guidance on interpretation of the legislation is available, Irish regulations state that ATEX issues must be dealt with by persons 'competent in the area of explosion protection'. Therefore, employers should source expertise in this area where new processes/ modifications to existing processes/new materials/new work equipment appear to have explosion hazard implications. In order to ensure worker safety and avoid project delays and unnecessary capital expenditure, the issues should be assessed before modifications are made. Φ

Figure 4 - Hydrocarbon Flammable Vapour Cloud Footprint



References

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).

NSAI (2003) Electrical Apparatus for Explosive Gas Atmospheres Part 10: Classification of Hazardous Areas (IEC 60079-10:2002).

NSAI (2004) Electrical Apparatus for Use in the Presence of Combustible Dust Part 10: Classification of Areas Where Combustible Dusts are or May be Present (IEC 61241-10:2004).

ATEX Guidelines (Second Edition) Guidelines on the Application of Council Directive 94/9/EC of 23 March 1994 on the Approximation of Laws of the Member States Concerning Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres.

Communication from the Commission concerning the non-binding guide of good practice for implementing 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.