

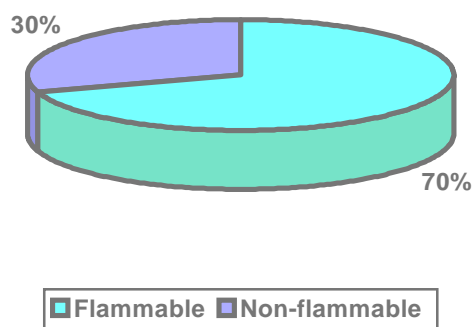
*Paper for the proceedings of  
Powders and Solids: Developments in Handling and Processing Technologies symposium  
held at UMIST, Manchester September 2000 by The Royal Society of Chemistry*

## EXPLOSION HAZARDS IN POWDER HANDLING AND PROCESSING: THE CHANGES AHEAD

*By Pieter Zeeuwen  
Chilworth Technology Ltd, Beta House, Chilworth Science Park, Southampton, SO16 7NS, UK*

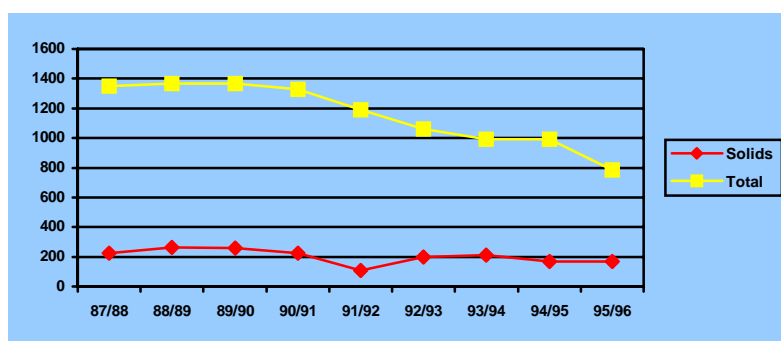
### 1. INTRODUCTION

Most solids handled in industry are flammable and, when dispersed as a dust cloud in air, can cause a dust explosion. Experience from testing a large number of materials, over many years, suggests that about 70% of all dusts handled are “flammable”, i.e. they are capable of exploding as a dust cloud (Figure 1).



**Figure 1:** 70% of the dusts handled in industry are flammable.

The number of dust explosions occurring in powder handling and processing is relatively low, especially considering the number of installations with explosion hazards, showing that many installations are designed and operated with the appropriate measures in place. On the other hand, Figure 2 (based on HSE data<sup>1</sup>) shows that while the number of fires and explosions in general has declined over the years, the number of fires and explosions involving solids has remained virtually constant.



**Figure 2:** Statistics for fires and explosions in the UK based on HSE data (reference 1).

In spite of the relatively low incidence of dust explosions, we often find that improvements would be needed to comply with statutory requirements and to operate a plant at a level of risk that is as low as reasonably practicable. Shortcomings often arise because the explosion hazards issue is considered too late in the design process, making it more difficult to implement the necessary changes. In many cases, the assumption is that adequate design and operation is possible without having proper and relevant material safety data. After an incident we often find that “assumed” material properties were not representative of the material actually handled and frequently this means that they did not err on the side of safety. It is also our experience that dust explosion issues are often considered less important than gas and vapour explosion issues. A signal of the latter is a plant where they handle flammable dusts virtually everywhere, but where the few rooms handling flammable solvents are designated the “flameproof rooms” or “Ex rooms”.

Changes in Health and Safety legislation have already led to an increased requirement for risk assessments of installations. The Machine Directive requires that all machines conform to the essential safety requirements in the Directive. It is often overlooked that the hazards to consider also include explosion hazards!

Within the next few years additional European Directives will come in force that specifically address explosion hazards. One Directive, often called the “ATEX 100a” Directive, or “ATEX equipment” Directive, considers equipment (not just “machines”) and protective systems for use in potentially explosive atmospheres. Gas and dust explosion hazards are both included and addressed in similar ways. All potential ignition sources (and not just electrical ones as has historically been the case) are treated equally.

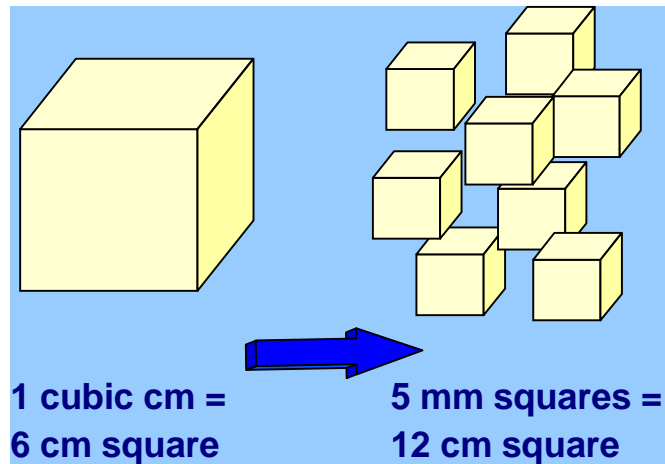
The changes brought about by the ATEX 100a Directive, bringing a new system of requirements and certification for a wider range of equipment, are considerable. However, the impact of the “ATEX 137” or “ATEX work place” Directive will be greater for the operator of facilities, both new and existing.

After describing dust explosions and explosion prevention and protection measures, these new Directives and their implications will be highlighted.

## **2. FLAMMABLE SOLIDS**

Dust explosions only occur with flammable dusts. Many solids are flammable and are recognised as such. Typical examples are fuels such as coal and wood. However, many other products such as grain, starch, milk powder, sugar, resins, polymers, metal powders, fine chemical and pharmaceutical powders, are equally flammable. Provided the particles are small enough, the majority of solids will be able to cause a dust explosion. In testing it is found that the vast majority of all dusts tested are classified as “flammable”. This is true even for dusts that can hardly be ignited as a dust layer (or not at all).

For a dust explosion, one needs “dust”. In this context, particles smaller than about 0.5 mm diameter are generally classified as dust. The smaller the particle size, the larger the surface area and the faster the explosion will be because the explosion reaction occurs near the particle surface (Figure 3). Unfortunately, even coarse powders usually contain at least a fraction of fine material, either because of the way they were produced or because of the handling of the material.

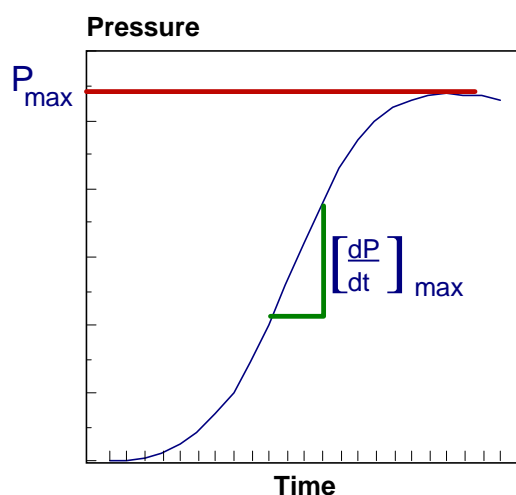


*Figure 3: Effect of particle size on the surface area of dust.*

### 3. WHAT IS A DUST EXPLOSION

A dust explosion resembles a gas explosion in many respects and is essentially a very rapid burning of the fuel. The difference is that the fuel is not a flammable gas but a fine flammable dust. In both cases the fuel burns very rapidly, the speed being caused by the fact that the fuel and air are mixed prior to ignition. Because the fuel and air are mixed, the explosion will consume the whole mixture once it has been ignited.

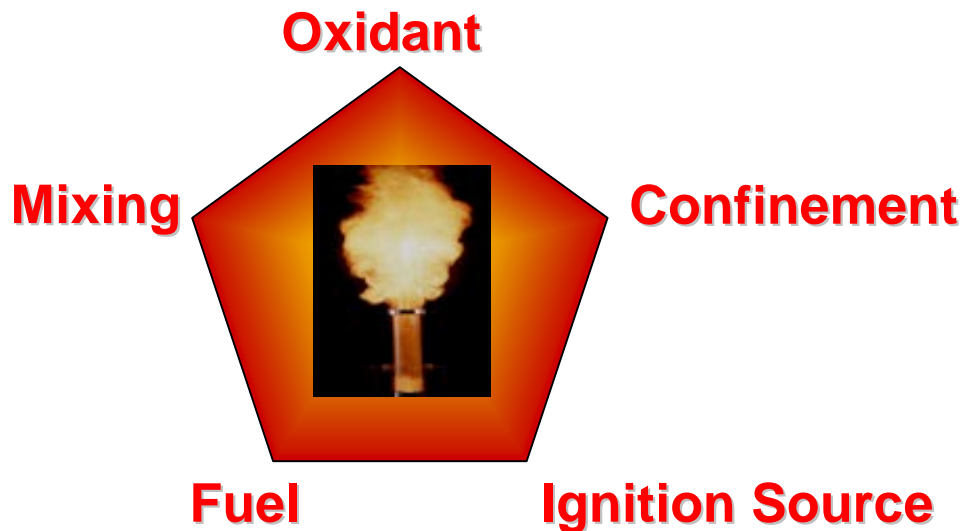
The burning of the fuel causes a large volume of hot combustion products. In an open space, this will lead to an expanding fireball. The maximum size of the fireball will be about 8 to 10 times the size of the initial dust cloud. In a closed vessel, however, expansion is not possible and the pressure will rise to about 8 - 10 times the initial pressure (see Figure 4). The time taken to reach that pressure depends on the type of dust, the dust concentration, the turbulence conditions in the cloud and the volume of the vessel. Typically, a dust explosion will take a few hundred milliseconds. This time, albeit short, provides the basis for some protective measures. The fact that the time is so short means that there is little room for correction of any mistakes.



*Figure 4: Pressure-time history of a dust explosion.*

The conditions for a dust explosion can be summarised as in Figure 5: one needs fuel (dust) mixed with an oxidant (usually air), (these three factors constitute a flammable

mixture), an ignition source and confinement. Without confinement there will be no pressure build-up and therefore no explosion, but a flash fire.



*Figure 5: Conditions for a dust explosion: the Explosion Pentagon.*

### 3.1 Flame Propagation and Detonations

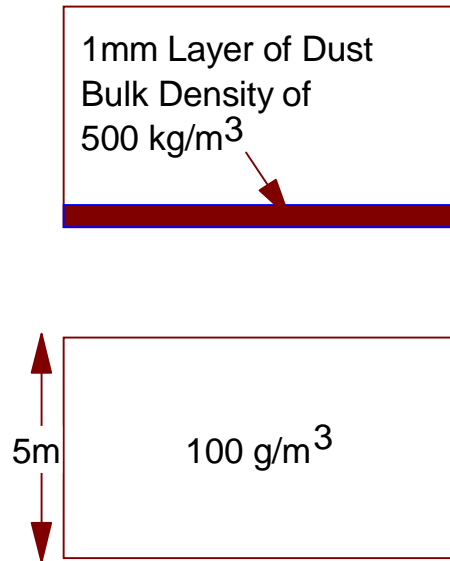
A situation that must be considered separately is an explosion propagating in a long duct. In this case the expansion of the combustion products causes a flow in the dust which increases the level of turbulence. Since turbulence enhances the combustion rate, the explosion will accelerate continuously until a different type of explosion propagation is reached: a detonation.

A detonation typically runs at 2 km/s (much faster than the speed of sound in the unburned mixture), has a peak pressure of about 20 bar and is more devastating and more difficult to control than a normal dust explosion. Luckily, detonations in dust-air mixtures are relatively rare - they are more common in pipelines containing a flammable gas mixture. The initial process of flame acceleration, however, is certainly very relevant because this may cause a much stronger explosion in any vessel connected to the duct.

### 3.2 Secondary Dust Explosions

Another feature commonly encountered in the handling of solids is the presence of dust outside the equipment. Even moderate amounts of dusts in the plant can, when raised to a dust cloud, create a flammable atmosphere. The force to raise the dust can be provided by the blast of a minor explosion in some equipment. The following, so-called secondary, dust explosion in the plant is often responsible for the collapse of whole buildings.

The quantity of dust needed for a secondary dust explosion is very small. For most dusts, a concentration of 100 g/m<sup>3</sup> is well within the flammable range. This means that, for example, 500 grams of dust on every square meter of a floor would be sufficient to generate a flammable cloud of 5 m high, if all dust were suspended uniformly. This height would be enough to fill most plant areas. However, 500 grams of dust would only form a layer of about 1 mm thick on the floor (Figure 6). Additional dust available for secondary dust explosions is often found on top of equipment, and on ridges, ledges and pipelines. This dust is often the finest and driest dust in the plant!



**Figure 6:** Secondary dust explosions: the flammable dust cloud that can be formed from a thin dust layer on the floor.

The issue of secondary dust explosions explains why good housekeeping must always be emphasised.

### 3.3 Hybrid Explosions

Hybrid explosions are explosions involving two different types of fuel: dust, gas, vapour and/or mist. In practice, the term is most commonly used for the explosion of a dust cloud where some flammable gas or vapour, often below the lower explosion limit of the gas or vapour, is present. Hybrid explosions have some special characteristics that must be taken into account in the hazard assessment and in the design of preventive and protective measures.

There are many sources for the gaseous fuel in hybrid explosions. Often it is present as part of the process, for example because solvent is used in the manufacture of the solid and the product is still solvent wet. Sometimes the solvent is still unintentionally present because it has not been removed as planned. In some cases, the gaseous fuel comes from an unrelated source – a situation that can be particularly difficult to predict.

Finally, many products release large quantities of flammable gases when they decompose. If these gases accumulate in plant, they can either be involved in a gas explosion or in a hybrid explosion.

Gas explosions and hybrid explosions will not be addressed explicitly further in this paper, but they must be considered wherever they could occur.

## 4 . DUST EXPLOSION CHARACTERISTICS

A range of standard tests has been developed over the years in order to determine relevant characteristics of dusts. Using standard tests has the advantage that dusts can be compared and that the data can be used when applying guidelines for preventive and protective measures.

Because the dust explosion characteristics depend strongly on the particle size, shape, moisture content and contaminants, published data can only be used with great care. Besides, it is not always clear which standard has been used for the tests. This limits the

applicability of the data even further as most data have been determined some time ago or in another geographical area. Consequently, in order to obtain the necessary data, tests are often necessary.

The **explosion severity** can be characterised by the maximum explosion pressure generated in a closed vessel and the maximum rate at which the pressure increases in the explosion ( $P_{\max}$  and  $(dP/dt)_{\max}$  in Figure 4). In order to find the maximum values, a range of dust concentrations must be tested. It is common practice to consider only the maximum values. Even if it is likely that the dust concentration will not be at the optimum value, it is virtually impossible to be sure of this because deposited dust inside the equipment can always be re-suspended in the incident.

Because the maximum rate of pressure rise is volume dependent, it is common to convert that value into a volume independent parameter,  $K_{St}$ . Using the  $K_{St}$  value, dusts can be divided for convenience into so-called dust explosion classes: St 1 (includes most bulk materials and "agricultural" products), St 2 (includes many "man-made" products) and St 3 (typically metals like aluminium).

The **explosion sensitivity** of a dust can be different for different types of ignition source. Therefore different parameters must be determined to determine the sensitivity. The most common ones are the Minimum Ignition Energy (MIE) for spark ignition of a dust cloud, the Minimum Ignition Temperature (MIT) of a dust cloud (comparable to the auto-ignition temperature for gases and vapours) and the Layer Ignition Temperature (LIT) for ignition of a thin dust layer by hot surfaces.

The ignition of thick deposits or bulk material by high temperatures is subject to separate tests, where the exact conditions, especially air availability, must be tailored to represent the plant conditions as well as possible.

There are more characteristics that can be determined, like the Limiting Oxygen Concentration or the Minimum Explosible Concentration, but the need for these data must be judged case by case.

## 5. PREVENTING DUST EXPLOSIONS

For a dust explosion to occur, a flammable dust-air mixture is needed. Most dust handling equipment is filled with air, so the only way to prevent the flammable mixture is to avoid the dust. Depending on the type of material, a large amount of fine dust can be present at any time. Even granular material will contain some fines in most cases. During pneumatic transfer, the fines may well remain suspended long after the granules have fallen down, so that the dust concentration in the head space of the receiving vessel can be much higher than expected on the basis of the average dust content of the product.

Even if this does not happen, flammable concentrations may occur occasionally. For example, at the end of a charge, all collected fines may be fed into a silo in a short period of time. Alternatively, dust sticking to the vessel walls can be dislodged by a disturbance. A collapsing "bridge" may create flow conditions totally different from those occurring in normal operation.

So, unless the oxygen is removed from the equipment (i.e. the equipment is inerted using an inert gas instead of air), a flammable dust cloud will be present in most dust handling equipment at some point in the operation.

The other requirement for a dust explosion is the presence of an ignition source. Some 13 different types of ignition source have been identified. The most common ignition sources for dust explosions are:

- naked flames (fire)
- welding and cutting
- electrical equipment
- mechanical friction and mechanical sparks
- static electricity
- hot surfaces
- self heating, self ignition.

**Naked flames** (including smoking), **welding** and **cutting** are powerful potential ignition sources that must be controlled by company procedures. In some cases they can ignite a dust explosion directly, e.g. when welding on the outside of dust handling equipment. In other cases they occur indirectly because sparks or burning material enters the equipment either with the product or through openings.

**Electrical equipment**, when suitably selected in accordance with the hazardous area classification, and installed and maintained according to the appropriate standards, should not pose any risks. The number of ignitions by electrical equipment is consequently not very high. Unsuitable equipment or wrong use of equipment, however, still leads to incidents. Examples are the use of hand-held lamps in silos, where they can be either damaged by impact against the wall or they can be buried in the product with overheating as a consequence.

**Mechanical sparks** are often identified as the ignition source in a dust explosion. Further analysis of the data shows that in many cases the power of the mechanical sparks would not have been sufficient to ignite the dust, but the friction that generated the sparks will also generate a very hot surface that is definitely capable of igniting the dust cloud. In many vessels there should be no source of frictional heating or sparking. But again, often the ignition source is introduced with the product.

**Static electricity** occurs whenever materials are rubbed together and then separated. This means that in most solids handling, a lot of static electricity is generated. When all material is conducting and earthed, however, the static charge will not be apparent. When the product is non-conducting it will become charged even in metal plant. Similarly, even conducting product will become charged if it flows through non-conducting piping.

When the charge can accumulate and then discharge, a static ignition hazard arises. There are several forms of electrostatic discharge, ranging from a "spark" from a charged isolated conductor to "cone discharges" on the surface of bulked material in a silo. The igniting power of the various discharge types must be compared to the minimum ignition energy of the product to assess the potential hazard.

Depending on the type of powder handling, the product handled and the conditions in the plant, electrostatic ignition sources can be very important. In some cases the hazards are so intrinsic to the process, that it is impossible to prevent them and either inerting or protective measures are necessary.

**Hot surfaces** can arise in many ways and it is clear that they must be controlled in all places where either a dust cloud can be in contact with them or where a dust deposit can occur.

**Self-heating** and **self-ignition** are treacherous because they do not need any input from outside. If the material is likely to self heat in some conditions of storage temperature, moisture content and storage time, there is no way to stop it. The only prevention is to recognise the hazard and avoid the conditions altogether. Examples are reduced storage time, use of smaller silos (more heat losses) etc.

Ignition sources must always be prevented, even if the plant is protected, because the frequency of explosions must be kept as low as possible. In some cases, an additional measure can be used to reduce the frequency of ignitions: spark detection and extinguishing. Where mechanical sparks or hot particles are generated in one place (plant machinery), but the most likely location for the explosion is elsewhere (silo), it is sometimes possible to extinguish the sparks before they enter the silo. It must be noted, however, that such a system is not designed to stop an explosion; just one or more sparks.

## 6. EXPLOSION PROTECTION

If it is identified that an explosion could occur in plant, and that it is not possible to limit the probability to an acceptably low level, explosion protection measures are needed to control the effects of an explosion.

When considering equipment like silos, it must be recognised that the volume tends to be large. This means that any explosion will have severe consequences. This may influence the hazard assessment; if the consequences are simply unacceptable, protection is necessary even if the probability is low. On the other hand, even “small” explosions in smaller vessels have the potential of injuring or killing workers in the vicinity.

To protect plant against dust explosions, there are several options. The detailed design of protection methods is very much specialist work. Even where national or international standards are available, experience shows that the application is rarely straightforward.

The options for explosion protection are:

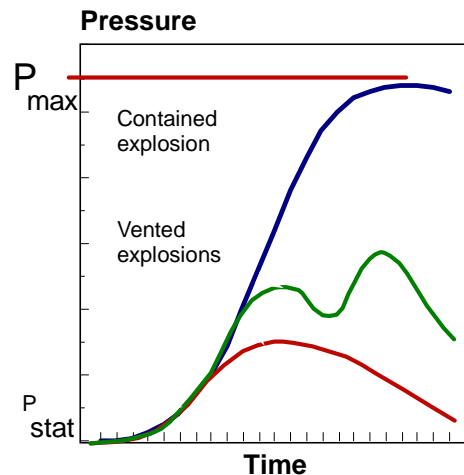
- explosion containment,
- explosion venting, and
- explosion suppression.

In all cases, it is necessary to prevent propagation of the explosion from one plant item to the next ("isolation"), not only to minimise the damage, but also to prevent pressure piling and flame jet ignition effects.

**Containment** means building the plant to be explosion resistant, i.e. so strongly that it will resist the internal pressure of the explosion. For most equipment this means strength of around 10 bar, but the actual design pressure must be determined taking into account all relevant parameters (initial pressure, temperature, etc.). Obviously, such a high design pressure is rarely an option for large silos, but for smaller hoppers it may well be feasible. Because the full explosion pressure is contained, the maximum force is generated for propagation to connected equipment, so isolation is of the utmost importance.

Two options have been developed over the years: explosion pressure resistant and explosion pressure *shock* resistant. The latter makes better use of the strength of the construction. This is deemed acceptable because an explosion is a one-off event of short duration. Obviously, the probability that some deformation of the equipment occurs is increased.

**Explosion venting** is sometimes called the "natural" explosion protection. This is because without any protection, the equipment would fail and the explosion would be vented. Because of the venting, the maximum pressure during the explosion would be reduced (see Figure 7). To apply explosion venting in a controlled manner, however, is not as simple as this analogy suggests. It is imperative that a vent opening of sufficient size is available at the right time. Because of the short duration of the explosion, there is no time to overcome the inertia of heavy covers. In many explosions where "vent covers" were designed in the wrong manner, the explosion pressure increased so fast that the vessel ruptured before the vent was even opened!



**Figure 7:** Pressure-time history during a vented dust explosion.  $P_{stat}$  is the opening pressure of the venting device,  $P_{max}$  the maximum pressure that would be obtained in a closed vessel without explosion vents fitted.

For large silos the necessary vent area is large and there may be problems to accommodate the vent on the silo roof, especially if the roof is not free of obstructions. Many silos are elongated and this must be taken into account in the design of the vent area; in the extreme a silo can resemble a duct, and what that means for the explosion process inside has been explained before.

Venting is in reality nothing more than displacing the explosion to another location; when the vent opens, both unburned and burnt dust is expelled from the vent and this creates a huge flame jet or fireball outside the vent opening. The size of this flame is often underestimated and the safe area is either too small or lacking altogether. Also the pressure is vented from the vessel and that can cause some damage to the surroundings.

Because of the external effects, any equipment located indoors can only be vented safely via a duct to a safe location outside. The vent duct, however, will reduce the efficiency of the venting and either the vent must be significantly enlarged or the vessel must be built stronger. For smaller vessels nowadays some special "flameless venting devices" are available that allow venting indoors.

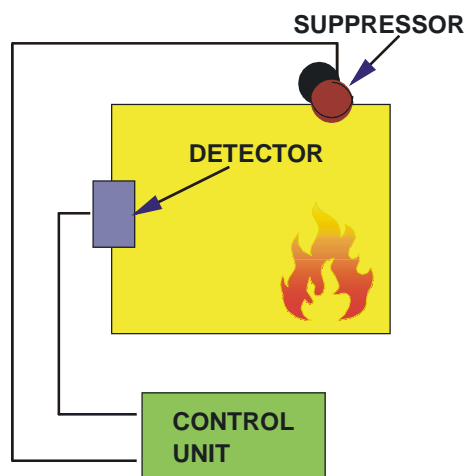
Explosion venting does not stop the explosion. Therefore, even if a vent is present close to the ignition location, the explosion will propagate throughout the equipment. This can be seen in Figure 8, taken during a test at the Health & Safety Laboratories in Buxton: with explosion vents located along the length of this bucket elevator, the explosion still propagates the length of the elevator. This explosion behaviour has implications for

elongated equipment such as bucket elevators, where it may be difficult to find suitable safe areas especially near the lower parts of the elevator.



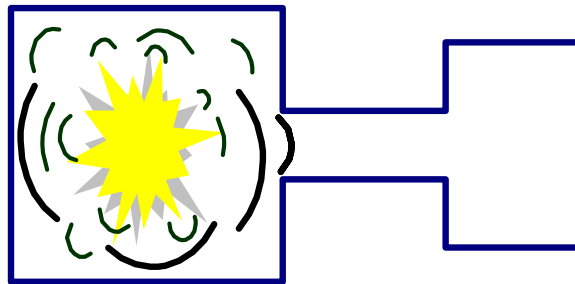
**Figure 8:** *Explosion test in a bucket elevator, showing how the explosion propagates the length of the elevator in spite of the explosion vents (photo courtesy of the Health & Safety Laboratories).*

**Explosion suppression** relies on the detection of the incipient explosion and the injection of a suitable suppressant from one or more suppressors (see Figure 9). This effectively extinguishes the explosion and so limits the pressure rise to a value that the vessel can withstand. Suppression systems must be designed to work effectively in the time available and the design is therefore dependent on the hardware of the particular supplier. Especially on large volumes like silos, the investment can be considerable. Suppression of large silos is therefore very much limited to those cases where venting is not permissible (e.g. for environmental reasons), and inerting (as a preventive measure) or containment are not feasible. For smaller vessels the range of application is much wider.



**Figure 9:** *Schematic of an explosion suppression system fitted to a vessel.*

**Explosion isolation** is, as mentioned before, needed to prevent propagation of an explosion from one vessel to the next. This is not just necessary to limit the damage, but also because explosions become more difficult to protect against as they propagate. Two effects are important here: flame acceleration and pressure piling. Consider the situation in Figure 10 of two interconnected vessels. When the explosion starts in one vessel, the pressure will increase in the other vessel before the ignition propagates into the second vessel. Thus the explosion will occur at an elevated initial pressure, and the explosion pressure will be proportionally higher. If the pressure in the second vessel is only 1 bar g at the time of ignition, the maximum pressure in this vessel will already be about 19 bar instead of 9 bar (10 times the absolute initial pressure)!



**Figure 10:** *Pressure piling in interconnected vessels: the pressure from the explosion in the primary vessel (left) will increase the pressure at which the explosion starts in the secondary vessel (right).*

Additionally, the flow of the gases from the primary vessel to the secondary vessel will increase the level of turbulence there (which will increase the severity of the explosion as mentioned earlier) and the ignition source will be a large flame jet instead of the usual point source.

A range of measures is available that can be implemented. The best, in terms of value for money, are those that do not need additional investment. The first of this kind is to simply avoid any connections between vessels that are not absolutely necessary. The second is the use of an explosion proof rotary valve instead of a standard one. Such rotary valves are stronger than normal and have smaller gaps (which stop the flame). Rotary valves need to be stopped in case of an explosion, because otherwise burning material may be transferred to the next vessel.

Other options are the use of special valves to stop the explosion in a duct, a diverter (local venting arrangements on a duct) and advance inerting barriers. Each option has its advantages and disadvantages.

## 7. THE ATEX DIRECTIVES

The above basics about dust explosions and explosion prevention and protection have been well established for many years. What is changing at the moment is that new legislation is being introduced in Europe as a consequence of two new Directives specifically aimed at “potentially explosive atmospheres”, hence the title “ATEX” from the French “Atmosphères Explosives”. Directive 94/9/EC on equipment and protective systems<sup>2</sup> and Directive 1999/92/EC on the protection of workers<sup>3</sup> are both concerned with potentially explosive atmospheres (“explosive” is the term used in these official documents for what is commonly called “flammable” in English), but from different perspectives.

## 7.1 What is in a Name?

There is a lot of confusion about the common names of these Directives, and different names are used. It is common practice in EU circles to designate Directives by the number of the article of the Treaty establishing the European Community that is referred to in the opening statements. So, when there were plans to prepare two Directives relating to potentially explosive atmospheres, the one that was finally published as Directive 94/9/EC was often called "ATEX 100a" and the other "ATEX 118a".

Unfortunately, these designations, although very convenient and used widely in circles such as the standardisation working groups, were never made official. The EU web site refers to Directive 94/9/EC just as "ATEX", but EN 1127-1<sup>4</sup> actually mentions "... The Council Directive (94/9/EC) ... (called ATEX-100a-Directive) ...".

The confusion was increased when, by the time Directive 1999/92/EC was published, the Treaty of Amsterdam had renumbered the various articles! So, "ATEX 118a" actually in the final version refers to article 137. This means that many people still refer to ATEX 118a, even if that article is not mentioned in the actual Directive, while others have adjusted their terminology and now call it "ATEX 137". Others have gone as far as now referring to ATEX 100a as ATEX 95, after the new number for the "free trade" article, even though that Directive does not actually refer to article 95.

The best solution is probably to refer to "ATEX equipment" and "ATEX worker protection" Directives, or similar designations, but this is almost as cumbersome as using the official designations.

## 7.2 ATEX 100a Directive

This Directive has been in force since 1996 and has been implemented into national legislation throughout the European Union. Until mid-2003 its application is optional, but after that date it is compulsory.

This Directive applies to equipment and protective systems intended for use in potentially explosive atmospheres, although some safety devices, controlling devices and regulating devices located outside the potentially explosive atmosphere can be covered as well. Essentially, it is a "free trade" Directive, and any equipment conforming to ATEX 100a must be allowed on the market in the EU.

This is a situation similar to the long-established system for "explosion proof" electrical equipment suitable for areas where a gas explosion hazard might arise. In fact, the new system replaces this old one, and very importantly, now covers *all* equipment, electrical and non-electrical, and gas (or vapour) explosions as well as dust explosions and mist explosions.

This Directive is a "New Approach" Directive, which means that only essential health and safety requirements (EHSR's) are laid down. Technical details of how compliance with these EHSR's can be achieved is laid down in European Standards, but it is not compulsory to follow these standards as long as compliance can be achieved.

In the "old" system for electrical equipment, the methods of protection were standardised in European construction standards, but the application of the equipment was subject to national selection and installation rules. This is now changing. The ATEX 100a Directive defines the levels of safety. For equipment of Group II (Group I is for gassy mines), three categories of equipment exist:

- Category 1 has a very high level of protection;
- Category 2 has a high level of protection;
- Category 3 has a normal level of protection (taking into account that the equipment is intended to be used in a potentially explosive atmosphere).

These categories obviously define where the equipment can be used, although that is not stated in the Directive that is only concerned with “placing on the market”.

### 7.3 ATEX 137 Directive

The ATEX 100a Directive has large implication for the manufacturer and for the buyer of equipment, but the ATEX 137 Directive will have a far greater impact on the actual operation of a plant.

Under existing Health and Safety legislation it is already required to operate a plant safely. The new Directive now explicitly demands that the potential explosion hazards are tackled at the source whenever possible. The Directive states that the employer shall take organisational and/or technical measures, in order of priority:

- To prevent the formation of explosive atmospheres, or where the nature of the activity does not allow that,
- To avoid the ignition of explosive atmospheres, and
- Mitigate the detrimental effects of an explosion so as to ensure the health and safety of workers

Where necessary, these measures shall be combined and/or supplemented with measures to prevent the propagation of explosions.

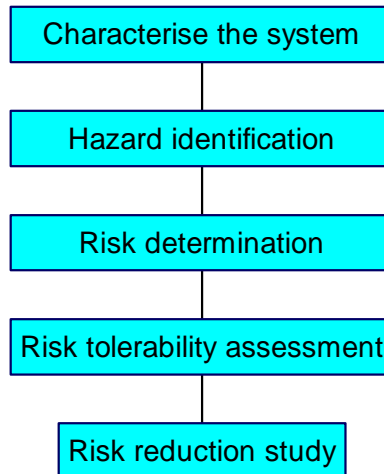
This Directive adds some new elements to the existing practices and the following stand out:

- Organisational measures (e.g. Permit to Work systems, training, maintenance plans and procedures) are as essential to safety as the technical measures (e.g. explosion venting, earthing and bonding measures).
- The first priority should always be the avoidance of the explosive atmosphere, before measures to prevent ignition or to protect plant are even considered.
- Explosion isolation is now very clearly identified as an issue and measures to prevent propagation must be included in the plant.

In line with much other recent legislation, the decisions about plant safety are taken based on a risk assessment. Specifically, the Directive requires that an explosion hazard and risk assessment is carried out, taking into account the special circumstances in the plant under consideration, which includes at least the following factors:

- 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.

Figure 11 shows the steps that need to be taken in a risk assessment. The same basic steps apply whether an assessment is made of a machine or a piece of equipment (as under the ATEX 100a Directive), or of a process. In all cases it is imperative that a good understanding of the foreseeable process conditions is obtained, including the material properties under those conditions.



*Figure 11: Steps in risk assessment of equipment and processes.*

The first factor above is very closely linked to Hazardous Area Classification, and under the Directive it will become an explicit requirement to carry out a Hazardous Area Classification. In addition, the hazardous areas must be identified in plant by displaying a prescribed sign (Figure 12).



*Figure 12: Sign prescribed by Directive 1999/92/EC to indicate hazardous areas in plant.*

With the introduction of the Directive, the hazardous areas for dust explosion hazards will be defined differently. Instead of the two-zone system in use until now (designated Zone Y and Zone Z in most countries), a three-zone system is introduced in parallel with the Zone 0 – 1 – 2 system that is used for flammable gases and vapours. The new definitions are:

- Zone 20 – a place where an explosive atmosphere in the form of a cloud of combustible dust is present continuously, or for long periods, or frequently;
- Zone 21 – a place where an explosive dust atmosphere is likely to occur occasionally in normal operation;
- Zone 22 – a place where an explosive dust atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

The results of the explosion hazard and risk assessment, as well as several other aspects, need to be documented in a so-called “Explosion Protection Document”. This document must be prepared before commencement of work and must be revised as necessary.

The ATEX 137 Directive also prescribes that, generally, equipment must conform to the ATEX 100a Directive, and states that in Zone 20 only equipment of Group II, category 1 can be used, in Zone 21 category 1 and 2, but that in Zone 22 equipment of category 1, 2 and 3 can be used. Obviously, the equipment must be suitable for the fuel that can be

present, which is another reason why the actual flammability properties of the dust must be known.

The time scale for ATEX 137 is very challenging. Even though the Directive was only published early in 2000, the start date will be 1 July 2003 for new plant or subsequently modified plant. Before that date, the Directive must be incorporated into national legislation by all Member States. For existing plant, there is a three-year period before they must comply with the minimum requirements of the Directive.

For work equipment the Directive states that it shall comply with the minimum requirements from 1 July 2003, but if it is already in use before 30 June 2003, then the above mentioned selection criteria do not apply.

#### **7.4 European Standards**

It was mentioned before that the technical guidance for compliance with the ATEX 100a Directive will be made available in harmonised European Standards. To achieve this, the European Commission has given a mandate to CEN and CENELEC to prepare the necessary standards.

In CENELEC, the Technical Committee TC31 has extended the scope of its work to include not only the revision of the existing standards for "Ex" electrical equipment, but also to prepare standards on installation, maintenance and on electrical equipment for use in dust explosion hazardous areas.

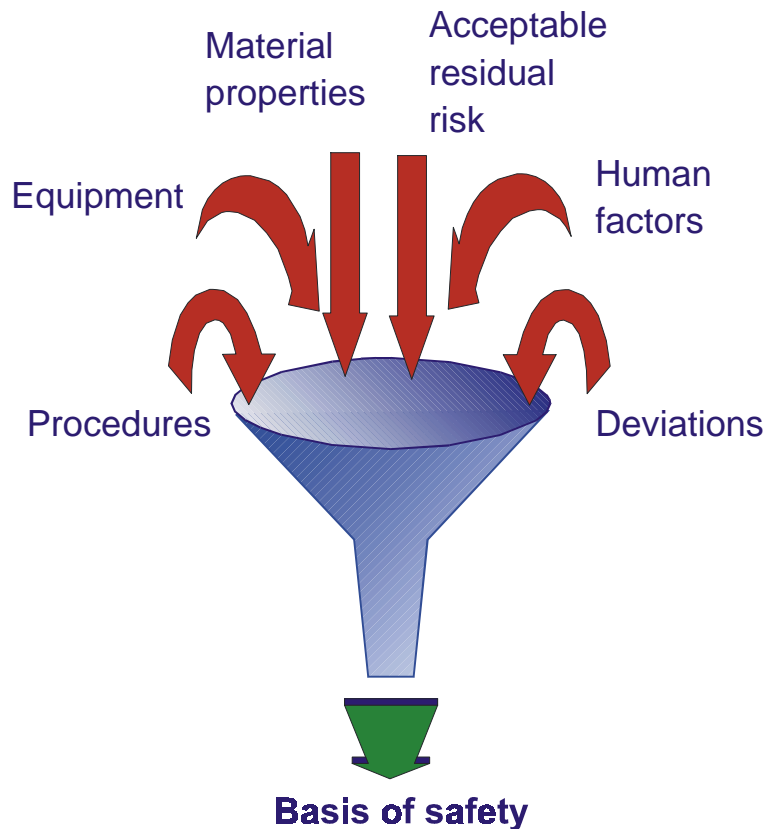
In CEN there was no central committee to oversee all work, and TC305 was especially founded for that purpose. TC305 not only considers the construction standards for non-electrical equipment, but also protective systems and, to be able to define the hazards and the protective measures, test methods to determine the explosion characteristics of gases, vapours and dusts. The scope of work in the working groups in TC305 is extremely wide, and the number of experts available to prepare these standards is very small. Progress is therefore much slower than needed and anticipated. Consequently, many standards will not be available at the time when the users need them.

Although the standards are prepared under a mandate referring to the ATEX 100a Directive, many are also applicable under ATEX 137. For example, to assess the hazards in plant, the material properties are needed, and test standards for many common parameters (explosion severity, minimum ignition energy and temperature, limiting oxygen concentration, etc.) are being prepared in CEN TC305. To assess the adequacy of explosion protection measures, the relevant standards are again needed, for example standards on the sizing and positioning of vent panels.

#### **8. CONCLUDING REMARKS**

The analysis of dust explosion hazards in a plant needs to take into account the actual plant conditions and all relevant environmental factors. Seemingly similar plants can thus have a totally different level of hazard and consequently the measures needed to minimise the risk can be different. Likewise, the selection of the most appropriate protective measure can give different results. As there is no preventive or protective measure that is ideal in all respects (product quality, investment, operating cost, environmental impact, etc.), it is important not to exclude any option too soon. In order to select the appropriate Basis of Safety for a plant, all relevant factors must be taken into account, including human factors,

the procedures that are in place and possible deviations from the normal operating conditions (see Fig. 13).



*Figure 13: Factors influencing the selection of an appropriate Basis of Safety.*

In general, if the potential dust explosion hazard is recognised before a plant is built, it is possible to improve the design to obtain a better level of safety without additional investment. Besides, any investment that is still needed will be lower than if explosion prevention and protection are only considered once the plant is built.

The new ATEX Directives provide a structure to assess the hazards and risks and to design preventive and protective measures to obtain a level of risk that is as low as is reasonably practicable. The underlying methodology of the ATEX Directives is not new, but their implementation will certainly bring about some changes in industry. Early recognition, assessment and reduction of explosion hazards has not been implemented in the past consistently in some parts of industry. These industry sectors should see benefits in terms of safety as return for the additional effort that is undoubtedly needed to comply with the ATEX Directives.

## References

1. A. Fowler and J. Hazeldean, *Fire Prevention*, **311** (1998) p22
2. *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*, Official Journal of the European Communities, L100, Volume 37, 19 April 1994
3. *Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15<sup>th</sup> individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC on the introduction of measures to encourage improvements in the safety and health of workers at work)*, Official Journal L23, 28 January 2000
4. EN 1127-1:1997, *Explosive atmospheres – Explosion prevention and protection – Part 1: Basic concepts and methodology*, CEN, March 1997

## Bibliography

There are several useful handbooks on dust explosions. Some of these are listed below. More detailed information on various aspects of dust explosions and explosion prevention and protection are published in specialist journals.

W. Bartknecht, *Dust Explosions - Course, Prevention and Protection*, Springer Verlag, 1989

W. Bartknecht, *Explosionsschutz - Grundlagen und Anwendung*, Springer Verlag, 1994

J. Cross and D. Farrer, *Dust Explosions*, Plenum Press, 1983

R.K. Eckhoff, *Dust Explosions in the Process Industries*, Butterworth-Heinemann, 2<sup>nd</sup> edition, 1997

P. Field, *Dust Explosions*, Elsevier Scientific Publishing Co., 1982

---

For further information on products and services available from Chilworth Technology please telephone or write to the Marketing Department :-

**Chilworth Technology Ltd**

Beta House, Chilworth Science Park, Southampton, SO16 7NS, UK

Tel: +44 (0)23 8076 0722 Fax: +44 (0)23 8076 7866

Web: [www.chilworth.co.uk](http://www.chilworth.co.uk) Email: [info@chilworth.co.uk](mailto:info@chilworth.co.uk)

*Explosion Hazards- The Changes Ahead (RSC).doc*