Health & Safety Forum

agricultural industries confederation

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CONTROL OF FIRE AND EXPLOSION RISKS IN ANIMAL FEED MANUFACTURING PLANTS AND PROCESSES

November 2020

Tilbury Port Explosion Photo sourced from Tony Agg/Twitter

Author:
Stephen Pope
Independent Consultant
steve@safety-management.co.uk

Co-Authors:

Jeffery Marston
Jeffery.Marston@abagri.com

Grace McLoughlin
grace.mcloughlin@thompson.co.uk

Julia Harvey
julia.harvey@carrs-billington.com

Mike Fletcher
mike@safety-management.co.uk

Chris Smith
chris.smith@molevalleyfarmers.com

Nigel Hillyer
Nigel.Hillyer@carrs-billington.com

In conjunction with and thanks to the
AIC Health & Safety Feed Sector Forum:

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Foreword

This guide has been written to assist the operators and designers of animal feed manufacturing plants and processes in preventing fires and explosions and to comply with their legal duties under the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).

The guide builds on and is designed to replace previous AIC guidance. The guide is based on the knowledge and experience of the members of the working party formed by the AIC in 2017 following a desire to standardise the procedures and precautions needed and in effect to produce a level playing field.

The DSEAR Regulations are aimed solely at preventing injury to personnel, they are not concerned with reducing damage to plant and equipment nor about the effective and efficient running of an animal feed mill. Accordingly, there are minimum standards of operation and design which must be implemented, so far as is reasonably practicable, to prevent injury to personnel. There are however a series of extra measures which go above and beyond the minimum legal requirement and as a result, reduce the risk of damage to plant and equipment and interruptions to production. The implementation of these extra measures becomes an economic decision for the operator of the mill in question and will be of some interest to the operator's insurance company.

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Introduction

In the UK feed industry catastrophic dust explosions are, fortunately, rare. However there have been dust explosions in the last 20 years which had the potential to cause multiple fatalities and it is only largely a matter of luck that no one has been injured.

Across the world there are recent examples of very significant dust explosions in the grain and milling industry. Examples include;

- **11 people killed when 28 concrete grain silos were destroyed at Blaye in France in 1998**
- **one person killed and 5 injured as well as extensive damage caused to a feed mill at Rockmart USA in 2016**
- **five killed and 12 seriously injured at the Didion Plant in Wisconsin in 2017**

There are also examples within the UK in industries with similar risk profiles to animal feed having fatal dust explosions, the most recent being at Bosley near Macclesfield in 2015.

A substantial number of fires and minor explosions are also reported, and no doubt some go unreported. The potential for personal injury or loss of facilities is thus significant.

This guide can, therefore, form the basis for risk assessment and necessary control measures in both existing and new plant design and/or modification.

The guide does not consider the safety aspects surrounding fuels for boilers and vehicles (natural gas, LPG, diesel or kerosene) and the use of flammable liquids used in product laboratory testing facilities, engineering maintenance and in printers where the precautions are well known (published HSE Guidance).

1 A Background to Dust Explosions

All plant-based material will burn and therefore produce combustible dusts, which given the right conditions, can explode.

For a fire to occur three conditions are required (the fire triangle)

1. **Air (oxygen)**
2. **A source of ignition (heat)**
3. **A suitable fuel (taking into account dust concentration, particle size and moisture content)**

For an explosion to occur two further conditions are required (the explosion pentagon)

1. **Dispersion of the dust into a dense cloud**
2. **Confinement of the dust in a vessel or building**

When the fuel is in the form of large particles e.g. whole grain, or a heap of dust, the rate of combustion will be slow and will be limited by the rate at which air is supplied to the fire. The result is smouldering or a low intensity fire. The hot gases (smoke) released disperse gently.

If fine dust is raised into the air to form a dense dust cloud, the flame can spread through this cloud extremely rapidly (many metres a second) giving rise to the rapid production of hot gases and a rise in pressure (in short, an explosion). If these gases are confined within a piece of plant or a building, the rapid rise in pressure can damage the plant or building if it is not designed to withstand it. Depending on the degree of confinement, pressures in the order of 9 Bar (135psi) are achievable. To give some context, this is the working pressure of a typical mill's compressed air system. An overpressure of only 10psi can severely damage if not destroy reinforced concrete buildings.

Flash fire hazards which, while not as damaging to the plant, still have the potential to cause harm and even death to persons in the immediate vicinity.

1.1. Factors Affecting the Explosibility Of Combustible Dusts

There are several factors which affect how explosive a dust is. (Barton, 2002).

1.1.1. Concentration

The concentration of the fuel (dust) in air is critical; the range is defined by upper and lower explosion limits.

At concentrations below the lower limit there is insufficient fuel to sustain burning. The lower limit for most grain type products is typically of the order of 50-100 g/m3, which forms a cloud too dense to see through. It appears almost solid and is so dense that it is not possible to breathe in it. Anecdotally, these clouds have been described as so dense that a car headlight is not visible at 2m.

1.1.2. Particle Size

The size of the dust particles is also critical. The smaller the particles, the greater the likelihood of an explosion occurring and it being of increasing severity. It is accepted that dust particles of a size greater than 500 microns will not explode. The HSE accepts in HSG 103 (HSE, 2003) that explosions are unlikely to occur where the mean particle size is greater than 200 microns. An examination of published explosion and combustibility test results on the GESTIS-Dust-Ex database produced by the Institute for Occupational Safety and Health of the German Social Accident Insurance show that materials commonly used within the animal feed industry do not explode when the particle size is greater than 100 microns.

Within the industry dusts are not homogeneous and will not have a constant size distribution. The greater the percentage of larger particles the less risk there is that the material as a whole is potentially explosive. This is important when considering processes within machinery and storage bins. Many meals for instance will not be explosive so it can be well worth looking at the particle size distribution.

Where there is dust with mixed particle sizes, it is likely that finer fractions will stay airborne, travel further and may be deposited at high level, possibly out of sight. These deposits may be disturbed by a primary explosion, forming a dense cloud of relatively low particle size and causing a far more damaging secondary explosion.

1.1.3. Moisture Content

The higher the moisture content of dusts, the lower the risk. HSG 103 (HSE, 2003) concludes that moisture contents above 16% reduce the risk very significantly. The moisture contents of many of the imported materials within the animal feed industry will typically lie in the region 12-15% i.e. towards the lower risk end of the spectrum. It has been suggested this is one of the reasons why dust explosions within the UK animal feed industry are relatively infrequent and relatively weak when compared to the continent and midwestern states in the USA.

1.2 Dust and Explosibility Testing

Materials are often submitted to test facilities to determine their combustibility and explosive characteristics. These tests are conducted under various standards which are beyond the scope of this guidance. Typically, a submitted sample should be tested as submitted. If it does not explode further tests should be carried out after drying and if necessary, grinding (to produce a finer material). It is important for the organisation that submits the material for testing to understand the various results that may be produced.

The parameters normally supplied following tests for the ignitability, flammability and explosibility of dusts are described below. The parameters are generally used for determining and designing explosion protection measures and will be of use to equipment suppliers.

1.2.1 Kst.

This is the maximum rate of pressure rise (during the explosion test) and in simple terms is a measure of the violence of the explosion. Dusts are divided into various explosion classes on the basis of their Kst values. Dusts which are classified as non-explosive are classified ST 0. Dusts with a Kst between 0 and 200 are classified as ST 1. There are further classifications of ST 2 and ST 3 which apply to strongly or very strongly explosive dusts, however these classifications do not apply to the majority of feed materials used within the feed industry. A small number of micro ingredients can fall into the ST 2 classification and operators must ensure appropriate assessments are in place to identify these.

Kst is an important parameter to consider in the design of explosion protection systems such as relief vents.

1.2.2 Pmax

This is a measure of the highest pressure reached during the explosion testing and is carried out at the optimum dust concentration. It is indicative of the highest pressure likely to be achieved within a piece of plant should there be an explosion.

In principle, if an enclosure is or can sensibly be designed to withstand Pmax then an explosion can be contained; if Pmax exceeds the capacity of the enclosure then protection may be need to ensure that the internal pressure (Pred) during an explosion is within the capability of the enclosure to contain it and avoid a dangerous / catastrophic failure leading to harm.

1.2.3 Explosion Concentration Limits

This is a measure of the lowest and highest concentrations of dust which will support an explosion. For practical purposes only, the minimum limit known as the lower explosion limit (LEL) is of interest to plant designers and operators.

1.2.4 Minimum Ignition Energy (MIE)

This is the minimum energy stored in a capacitor which will just ignite the most ignitable dust air mixtures following the discharge of a spark. It is a measure of how sensitive the dust is to static electrical ignition. The minimum ignition energy required to ignite a dust cloud is significantly increased by increasing moisture content.

The MIE is also relevant to other ignition sources including electrical equipment.

1.2.5 Minimum Ignition Temperature (MIT)

This is the lowest temperature at which a hot surface can ignite a combustible dust cloud.

1.2.6 Layer Ignition Temperature

This is the lowest temperature at which a layer of dust of specific thickness (usually 5 mm) ignites on a heated surface and should be taken into consideration when specifying equipment. Whilst this may only produce a smouldering fire if disturbed it is a ready ignition source within a potentially combustible cloud. If thicker layers are allowed to accumulate then ignition may occur at a lower temperature.

1.3 Typical Dust Parameters

Within an animal feed manufacturing process, it will not be possible on a day-to-day basis to determine what the explosion characteristics of individual dusts in individual pieces of plant will be. The plant may have upwards of 50 different ingredients, the characteristics of which will vary depending on the supplier as well as prevailing weather conditions during transport and delivery. The plant will then mix these according to recipes which may well number in the hundreds. It is thus not reasonably practicable to carry out individual tests on individual recipes due to the lack of homogeneity of the various materials. Insofar as combustible dusts within animal feed manufacturing plants are concerned, a generic figure can be used to assist in the design of the equipment, erring on the side of caution. Typical figures which could be used are set out in table 1.

Table 1: Generic Dangerous Substance Properties

	Explosion Severity		Ignition Sensitivity			Limits
	Kst bar ms^{-1}	Pmax (bar)	Minimum Ignition Temperature (MIT) (°C)	Layer Ignition Temperature (°C)	Minimum Ignition Energy (MIE) mJ	Minimum Explosible Concentration g/m^3
Generic Cereal Dusts	130	8.0	> 400	> 300	> 100	50

These are typical figures

There is one note of caution when using generic figures because there are a few substances which do carry a higher risk particularly of static ignition e.g. maize starch. There are also a number of manufactured ingredients e.g. methionine which can carry an explosion risk. If they are only stored or used in small quantities there is little additional hazard however, if delivered in bulk and stored in larger bins and silos, the hazard should be considered separately.

When making use of processed ingredients in the form of fine powders it is sensible to obtain the explosion data from the supplier to confirm the properties are not significantly greater than those of the assumed generic figures. If following a DSEAR assessment, there is a change in the intake material, then there should be a review of the risk assessment.

1.4 Secondary Dust Explosions

The initial dust explosion, often referred to as the primary dust explosion, is often quite small, but a common characteristic of dust explosions is that this initial explosion can generate a series of larger and very violent secondary explosions. Almost all dust explosions start inside the process plant, but if this then fails, or there are openings into the building e.g. explosion relief panels, a shockwave will emerge which will raise any dust in the vicinity. Immediately following the shockwave, burning material will be ejected from the primary explosion source which will then ignite the newly raised dust. Dust lying on the floor, tops of pieces of plant, building structural members etc. can all provide sources of dust for this secondary explosion. There does not need to be much dust to give rise to the risk, 1 kg of dust sufficiently well dispersed can give rise to an explosive cloud of up to $20m^3$.

A dust layer of only 2 mm thickness over an extensive area is sufficient to give rise to a risk of secondary explosions in most circumstances. Of particular risk is the dust on the highest surfaces, as this tends to be the finest fraction, and will stay in suspension longest once disturbed.

Secondary explosions can also occur during a fire where the air currents are sufficient to raise any laid dust.

The only solution to the risk of secondary dust explosions is to ensure that the plant is kept sufficiently clean.

It is vital that the plant must be kept free of accumulations of fine combustible dust.

2 The DSEAR Assessment Process

The DSEAR assessment process should be relatively straightforward in animal feed plants although many people try to make it very much more complicated than it needs to be. It can be broken down into a series of stages which if followed through logically will ensure that the plant or process under consideration is compliant and safe to operate.

2.1 An Example DSEAR Assessment Process

Stage I

The first stage in the assessment process is to determine whether there are in fact any dangerous substances on site. Within the animal feed manufacturing industry the answer to this question will almost certainly be yes, even if only present as small quantities of combustible dust produced as a by-product of moving grain and similar materials.

Stage 2

The next stage is to analyse the plant and processes which occur. To do this it is useful to have a schematic of the plant showing the relevant process machinery and where the material flows. In effect a simplified piping and instrumentation diagram (P & I) is needed (to use the chemical industry term). For those mills with computerised control systems, mimics assembled for the purposes of programming and operating the plant can be used provided that they consider relevant plant and show all process streams including waste, by-products and aspiration.

Stage 3

For each of the items on the process flow diagram, be it intake hopper, elevators, silo and bins, grinders, dust collectors, cyclones, mixers, intermediate bins hoppers, pellet presses, coolers etc., a determination needs to be made as to whether it contains a combustible atmosphere at any stage during the process. There also needs to be a consideration of the process area itself. A consideration of unusual conditions also needs to be included within this; such as what if liquid additions aren't added or the wrong material is imported. If the presence of a combustible atmosphere can be ruled out, then that piece of plant can be eliminated from the remaining part of the risk assessment process.

When considering whether there is a combustible cloud, consider the size particle distribution of the material and the likely concentration.

There are two rules of thumb:

1. **If only a very small proportion of the contents (of the order of 10%) has a particle size below 150 µm it can be assumed that there is not an explosive concentration**
2. **If the dust cloud is so dense that you cannot see a metre or so across the piece of plant you can safely assume it is potentially explosive. (Barton, 2002)**

One of the easiest methods is to look into the piece of plant (with due regard to safety) during a series of representative 'normal' and 'worse case' situations. Do not rely on one observation.

If it is considered that a combustible atmosphere would or could exist, the interior part of that piece of plant is classified as containing a potentially combustible atmosphere. An explanation of a possible way of classifying plant and areas within Mills is described within section 2.2 of this guide.

Stage 4

Once a piece of plant or area of the mill has been classified or zoned a consideration needs to be made of the potential ignition sources which may be present and ignite the combustible cloud when it is present. Typically sources of ignition are included within section 3.2.

Stage 5

Once the potential sources of ignition have been identified (if there are any) then a determination of likelihood of an explosion can be made. There are again several methods which can be used for this which are both time-consuming and involve significant costs especially if using external consultants. Examples include Failure Modes and Effects Analysis (FMEA), Hazard and Operability studies (HAZOP) to name but two. This guide advocates a simpler process, which is to conclude that if there is a potential combustible cloud present and a source of ignition then measures are required to prevent injury to personnel and others.

One of the methods used to prevent explosions from occurring is to eliminate sources of ignition. Certainly, ignition sources should not be ignored and the likelihood of their presence should be reduced to a level which is as low as is reasonably practicable. However, eliminating ignition sources is difficult to guarantee.

Stage 6

Once it has been identified where potential explosions may occur, the assessment process moves on to determining the actions that are needed to be taken to prevent injury to personnel, taking into account any existing safeguards. If there is no risk of injury to personnel, it is then optional under DSEAR if action is taken to protect plant and equipment from damage. For new plant this then forms part of the design specification. For existing plant, a plan needs to be made as to when and how any necessary improvements are implemented. Obviously, plant and equipment which contain explosive atmospheres, ready sources of ignition and which could cause injury need to be tackled quickly.

In addition to your site it may be necessary to consider risks relating to the neighbouring premises. In particular how a potential fire or explosion in your premises will affect the safety of others off site and how an incident at a neighbour i.e. fire or explosion might affect you. Possible issues could be the external venting of explosion relief panels affecting a neighbour's premises or public space.

2.2 Classification of areas under BS EN 60079-10-2 2015

This harmonised standard deals with the classification of areas where combustible dusts may be present. The zones refer to locations that plant and equipment will be installed and inform equipment suppliers as to the type of safeguards and precautions that they should put in place designing and building the equipment.

The standard recognises **three types of zone** the definition of which are:

Zone 20

Defined as 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.

Put simply this is a location where there will be a combustible cloud. Typically, this will include the internal volumes of grinders, collection hoppers below grinders, the dirty side of some dust collectors, pneumatic transfer cyclones, bucket elevators carrying fine, loose and dusty materials, pneumatically filled meal bins and silos, the transfer points on high-volume high-speed conveying systems which are enclosed etc.

Zone 21

Defined as 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.

Typically, this will include the internal volumes of bucket elevators taking coarse materials which will have a potential fines content, the dirty side of dust collectors associated with local exhaust ventilation or fugitive dust emission systems, mixers if filled with powders from a large hopper fitted with bomb doors.

Zone 22

Defined as 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.

This will include the internal volumes of bucket elevators transporting coarse meals, aspiration systems which are not kept clean and have deposits of dust within the ducts. **It will also include, most importantly, external production and operational areas of the mill building where there is sufficient dust deposited on the floor and elsewhere which if raised would cause a combustible cloud.** It can also apply to areas where there is the potential for dust to be released by plant e.g. open discharges from dust collectors or where a positive pressure pneumatic transfer line could fail.

Once a location is classified, all plant and equipment used within it will need to be suitable for that zone. This is commonly known as ATEX rated equipment.

3 Preventive Measures

The original three fire factors - air, fuel, heat source (plus the two extra factors for explosions - dispersion of dust and confinement of dust) all need to be present to support fire and explosions. It follows that exclusion of any one will prevent fire or explosion occurring or will extinguish it. In practical terms there is thus the need to exclude the fuel (and particularly finely ground and dispersed material) or the source of heat, since air will certainly be present.

3.1 Elimination of Dust Clouds

Within animal feed plants and processes virtually all the ingredients apart from minerals (which are non-combustible) can produce dusts that may give rise to a dust explosion risk. To reduce if not prevent this, materials with little or no dust content can be used and / or processes adapted so that they do not agitate and aerate the dust into a dense cloud.

Dust is usually present in incoming raw materials, and if it is removed before storage, the risk in subsequent handling is reduced. This may be done by ensuring imported materials are cleaned of excessive fines by; screening during the intake process, installing dust extraction equipment at intakes (often necessary as part of environmental controls to prevent fugitive emissions), and extracting air from intake elevators and conveyors.

Removal of fine materials cannot be achieved with many of the by-product materials used within the industry such as loose wheat feed, distillers grains, soya hulls and similar meal products. A significant reduction in risk can be achieved if these fine materials are imported in a pellet form.

The second method to prevent raising combustible clouds of dust is to prevent agitation and air entrainment by choosing appropriate methods of transport. Typically, slow moving augers, screw conveyors and chain and flight conveyors do not generate a combustible cloud within them. Bucket elevators because of their faster speeds as well as significant air entrainment within them will frequently generate explosive atmospheres if they are transporting materials which are fine and dusty.

Belt conveyor systems can generate clouds of dust at transfer points where material falls from one belt to another and there is enclosure without aspiration.

Dust extraction systems providing aspiration on plant or local exhaust ventilation installed to control occupational health risks, rarely if ever carry sufficient dust to sustain an explosion. However, it is important that duct work is kept clean and dust is not allowed to settle within it. If it is the dust can cause a secondary explosion which can then propagate into other plant. Therefore, extraction systems should be subject to regular inspection and maintenance to ensure that transport velocities are maintained to avoid dust settlement.

Aspiration and local exhaust ventilation dust filters do not generally have an explosive atmosphere within them except during reverse jet filter cleaning or mechanical shakedown.

Cyclones used to clean cooling air will generally have an explosive atmosphere within a small part of the cone where the dust is being concentrated below the vortex finder. Cyclones which are used to remove fine powders from positive pressure pneumatic transport systems will have very high concentrations of dust in most of the cone which will be above the explosive concentration except during start up and shutdown.

Vacuum cleaners will almost certainly have an explosive dust concentration within the hose and filter. Consequently, they should be designed and used in a safe manner and further guidance on this is contained within section 7.11.

Pneumatic conveying systems will typically carry too much dust to transmit an explosion but may carry burning clumps of material short distances. During start up and shutdown, however, a cloud within the explosive range may be formed.

Bins and silos that are filled by gravity from augers, screw conveyors and chain and flight conveyors do not generally have an explosive concentration of dust within them even when being filled with relatively fine meals. Silos and bins which are filled pneumatically almost certainly will have a combustible cloud within them if there is a significant fines content in the material being filled.

The properties of the materials are a significant factor. Raw material handling and processing usually produces dust which if in sufficient quantity will be explosive, whereas pellets of finished product release little dust.

The potential for a secondary explosion when dust layers within plant are disturbed has already been noted. The dust which collects at floor level is likely to be coarse compared with that which collects at a higher level and in less accessible places. The removal of dust deposits in mill buildings is a key activity in eliminating fuel sources for secondary explosions.

3.2 Elimination of Ignition Sources

When dust explosions are investigated, it is often not possible to establish with certainty the source of ignition. Nevertheless, the main sources of ignition within feed manufacturing plants are understood and include, for example:

- **Sparks created by metal striking metal or metal striking other hard materials e.g. flint**
- **Mechanical friction (bearing failure, belts miss tracking and rubbing on plant)**
- **Hot work, such as angle grinding or welding**
- **Fires**
- **Static electricity**
- **Smoking/matches/vaping**
- **Unsuitable/overloaded/faulty electrical equipment**
- **Self-heating (spontaneous combustion) rare within the animal feed manufacturing process environment unless materials are left within bins for excessive lengths of time**
- **Smouldering product (e.g. from presses)**
- **Vehicles (very unlikely within the animal feed industry)**

The probability of these ignition sources being present can be greatly reduced by specifying and maintaining plant correctly, management controls and safe systems of work. Common methods within the animal feed industry are described below.

3.2.1 Mechanical Sparks

These are caused when metal strikes metal or other hard inanimate objects such as sandstone, flints etc. Magnets can greatly assist in the removal of tramp steel and iron. They should be placed as early as possible within the intake system and certainly immediately before any grinders. Ideally ex-farm materials should at least pass through a de-stoner or equivalent either at the plant intake or intermediate grain store.

The speed of movement of the plant is also significant. The slower the speed the less likelihood of spark generation. It is generally accepted that dangerous sparking or hot surfaces will not arise in most situations when the relative speed of the moving parts is at or below 1.0m/s. The speed of movement is also a significant element in the generation of dust clouds.

Plant inspection and maintenance is also critical in the prevention of spark generation. At its simplest this is a visual and audible examination of plant to detect for plant failure undertaken on a daily basis.

3.2.2 Mechanical Friction

The generation of hot surfaces through friction is usually as a result of some form of failure. This can be bearings, misaligned belts (both conveyors and bucket elevators) and belts slipping on a seized pulley. The issue can be minimised again by good standards of maintenance and installation as well as remote monitoring devices such as belt tracking, belt slip, and bearing temperature/vibration sensors. Again, at its simplest, daily visual and audible checks will go some way to detect these issues if they are carried out diligently and by someone who is familiar with the plant when it is performing normally.

3.2.3 Hot Work

This has been a cause of a significant number of fires as well as explosions and includes welding and similar activities as well as grinding. So far as is possible hot work within the mill in proximity to combustible materials should be eliminated. Where it cannot be eliminated a comprehensive hot work procedure needs to be implemented. As a minimum this should include a thorough clean of the hot work area both inside and outside of the plant. If this cannot be achieved, then thorough damping down may be an alternative. Measures for firefighting need to be close by and after the cessation of hot work a close eye should be kept on the affected area for a minimum of an hour to detect for any signs of smouldering.

3.2.4 Fires

Obviously, a fire within the plant is a ready ignition source if a dust cloud is raised. If a fire is allowed to develop and there is loose dust about, it can cause a secondary explosion. Fires obviously need to be avoided and tackled early. Training employees in basic firefighting techniques from a position of safety can be useful. The reduction of fire risk is a subject in itself and should be considered within the fire risk assessment process.

One area that should be considered within a DSEAR assessment is cooler fires, which are not uncommon. These can give rise to burning material being transported within the aspiration system which has in the past given rise to explosions within the dust filtration system downstream (see section 7.6 for suggested controls).

3.2.5 Static Electricity

Static electricity is a problem where air and particles move against each other and fixed pieces of plant. The higher the speed the more likely there is to be the generation of a static electrical charge. When this meets an earthed piece of equipment or the resistance holding the charge breaks down a spark with sufficient energy to ignite a combustible cloud can be generated.

The risks within the animal feed manufacturing process industry are generally relatively low because most of the plant used is steel and has a good earth conductivity as well as being driven by electrical equipment which is also separately earthed. This allows static charges to dissipate easily. Additionally, materials used within the industry are not particularly sensitive to ignition partially due to their relatively high moisture content and size distribution.

There are however some potential problem areas which need considering. These include the potential for static build up on:

- **dust filter bags if they are not specified appropriately**
- **pneumatic transfer lines or vacuum cleaning systems which use nonconductive hoses or pipes**
- **metallic pneumatic transfer pipes if there is no earth continuity across the joints**

Static charges can also be generated within powders which are tipped into mixers. The solution in these situations is to only add relatively small batches not more than 25 kg at a time.

To control the risk of static electricity generation plant should be satisfactorily earthed. A maximum of 10 ohms resistance on the earth path is permissible and this should be confirmed during the periodic electrical inspections, typically three years for fixed plant. The earthing on higher risk equipment such as blow lines and hoses which are more likely to be damaged should be checked more frequently, at least annually.

3.2.6 Smoking/Vaping/Matches

Historically this was a significant issue but is becoming less as fewer people smoke at work and the controls are much tighter. It can still be an issue with visiting drivers and contractors if they are not properly informed and supervised. The main problem is the disposal of cigarette butts which can make their way into plant. The only way to control this is by having management controls in place.

3.2.7 Unsuitable/Defective/Overloaded Electrical Equipment

If electrical equipment is poorly specified it can provide ignition sources simply by allowing dust to enter the electrical equipment. Thus electrical equipment should be designed to be dust tight, IP5X minimum. Incorrectly specified electrical equipment can heat up so that the surface could reach a temperature that will give rise to smouldering. Electrical equipment would be very unlikely to reach a temperature sufficient to ignite dust immediately unless there was a fault condition. Overloaded electrical equipment can also generate very hot temperatures and cause electrical fires. Physically damaged electrical equipment can cause sparks and high temperatures as well as permit dust to enter.

The controls that need to be implemented to prevent the above will include ensuring that electrical equipment is appropriately specified and in the case of electrical equipment installed within zoned areas comply with the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations (EPS). This is more commonly known as ATEX rated equipment.

Outside of zoned areas electrical systems should comply with BS 7671 (also known as the IET Wiring Regulations).

Electrical systems should be maintained and inspected regularly in accordance with guidance published by the HSE (HSG 85 and HSG 107) and wiring regulations.

3.2.8 Vehicles

There is a perceived risk of an ignition if a combustible dust cloud is drawn into a vehicle air intake or contacts the hot parts of an exhaust system or catalytic converter. Overall it is felt that this is a theoretical possibility and need not be considered except in particular situations where vehicles are handling very fine powders in large quantities.

As part of the risk assessment the generation of fine clouds of dust should be considered. Observations carried out within blending operations, which are perhaps the dustier parts of the industry where vehicles move frequently, indicate that there is not an explosive dust concentration close to vehicles when in operation. Vehicle fires do however occur and if not controlled could cause explosions if allowed to develop. Vehicle fires can be prevented by ensuring any vehicles are maintained and kept clean. Radiators and engines should be regularly cleaned to prevent accumulations of dust.

3.2.9 Spontaneous Combustion

Organic materials if left for a time will oxidise and potentially ferment. These processes give out heat which if not allowed to dissipate will cause a rise in temperature which further accelerates the process. Left unchecked the temperatures can rise to a level that can ignite the material. If this material is allowed to enter the milling process it could give rise to an ignition. Damp organic materials will be more prone to the issue which has been known to occur within fish meals, brewers grains and milk powders.

Generally, within the animal feed manufacturing industry it is not thought that this is an issue because materials are generally not left within storage bays, bins and silos long enough. However, if a bin were to be left with materials for a significant time a recognition of the risk by mill management is needed. Any organic material with moisture contents above 15% should be considered a potential risk. The solution to spontaneous combustion is to monitor the internal temperatures and ensure that the rise in temperature is prevented either by blowing cooling air through the product in question or regularly turning materials in heaps or bays.

4 Explosion Controls

If during the DSEAR assessment process it has been determined that there is likely to be a combustible cloud of dust and an ignition source present, then a decision has to be made on how this risk should be controlled.

It is notoriously difficult to control ALL ignition sources with sufficient reliability as to consider this the ultimate basis of safety and when the enclosed volume / consequences of ignition are significant then measures to mitigate explosions (relief / suppression) will normally be required.

Generally, controls fall into three categories:

1. Explosion mitigation
2. Explosion containment
3. Explosion suppression

1. Explosion mitigation involves designing the plant in such a way as to allow an explosion to occur but without creating a hazard to personnel by allowing the excess pressure and flame to vent to a safe area.

2. Explosion containment involves designing plant and equipment to be strong enough to withstand the results of an explosion within it without failing.

3. Explosion suppression involves a system which detects the early signs of an explosion and extinguishes it by the injection of an inert material.

There is also a method known as inerting where an inert gas, usually nitrogen, is injected continually under pressure into a process vessel thereby excluding oxygen. This is not a method which is thought practicable within the animal feed industry.

4.1 Explosion Mitigation or Venting

This is perhaps the commonest method of controlling the risk. It is considered generally to be a lower cost solution and requires less in the way of maintenance and inspection than other methods. In feed manufacturing plants, vents are normally found on plant that will regularly contain a dust cloud. Typically, this will be elevators (most significant), dust filters, some cyclones, hoppers immediately below grinding units and pneumatically filled bins. There has been a move more recently on new installations to fit explosion relief on all new bins. The basis for this is that at some point they might contain an explosive atmosphere. It does give flexibility for future use but, it is not in the AIC's opinion necessary in all circumstances especially when there are no likely sources of ignition present.

A great deal of research has gone into determining the area of explosion vent to be specified and it is an area for specialist suppliers who will design and specify the explosion relief needed. They will however require information on the explosion properties of the products to be handled (see section 1.3) as well as the likely strength of the piece of plant under consideration.

Historically explosion venting involved several different methods. These included loose relatively lightweight lids fitted to vessels (often wood) and lightweight panels which were secured in place by spring fixings or weakened fixings (nylon bolts or weakened mild steel bolts). Whilst these have proved to be effective if properly maintained, they are not accepted on new plant and equipment installed after 2002. Since the introduction of the ATEX Directive only type approved explosion relief panels should be fitted.

On older plant the traditional explosion relief methods are still permitted provided they are maintained in an effective state. The latter is not always the case and it is often found that loose lids have been secured or weighed down to stop them lifting when the bin is being filled (to prevent dust emerging). Those panels with weakened fixtures are again found with non-weakened or home-made securing devices and it is not known what pressure the panel will lift at.

For explosion venting to be a viable option several criteria must be met. These include:

- **The explosion relief panel should vent to a safe area preferably outside. If venting externally, any ducting between the outside and the vessel should not add restrictions on to the explosion relief system. Typically, any ducting needs to be strong enough to withstand the explosion pressures, be of a cross-sectional area greater than the vent and ideally not contain any bends and be less than 3m in length**
- **In many older mills venting externally is impossible. In these circumstances the proximity to personnel needs to be considered. To remove the risk of injury various solutions could be considered including re-siting the panel, removing personnel from the vicinity or the fitting of flameless vents. Deflector plates and vents have been accepted in the past but these are no longer favoured by the enforcing authorities however in existing installations they may still be effective**
- **The toxicity of the materials which might be emitted need to be considered, although is not thought to be an issue within the animal feed manufacturing process industry**
- **The vessel must be capable of withstanding the slightly elevated pressure (known as P reduced) that will be attained before the explosion relief becomes effective**
- **The vessel must be capable of being fitted with the necessary sized explosion relief panel(s)**

It has been the experience of the animal feed manufacturing process industry that where explosion relief has been fitted it is generally effective even if it has perhaps been undersized when compared with that required by the modern methods of calculation.

With some bins and silos particularly, those made from reinforced concrete and which are tall with a relatively small cross-section, it is not possible to put in place explosion relief meeting the current calculated standards. Wooden topped bins, where the top is also used as an access floor, are also a problem when designing explosion vents because there are so many unknown factors with regard their strength. Where it is not possible to build in explosion relief, then explosion suppression should be considered.

Most buildings are not designed to withstand significant overpressures, and serious structural damage may result from comparatively low overpressures. Quite low internal pressures in the event of an explosion may cause a major collapse. Tests on small brick buildings showed that cracking started at 0.05 bar and was extensive at 0.15 bar. Tall structures are weaker. This is particularly likely with traditional brick load-bearing walls, as the ceiling and roof may collapse in the event of a small displacement of the walls. The preferred method of construction is lightly clad steel frame. A number of mills place grinders within a block and brick structure as much for noise abatement than anything else. The venting of these enclosures needs to be considered if the explosion relief from the grinder vents internally.

Bucket elevators generate dust clouds inside them and there are a significant number of potential ignition sources present. Bucket elevators together with dust filters and grinders are the most common pieces of plant involved in explosions. Historically bucket elevators were vented close to the delivery with a single vent flap. This is no longer acceptable because the explosion can travel all the way round the elevator. Details on explosion venting for bucket elevators is contained within section 7.2.

For those who are carrying out a DSEAR assessment on existing plant a question arises what should be done when the plant does not comply with current standards. The answer depends upon the level of risk.

Most buildings are not designed to withstand significant overpressures, and serious structural damage may result from comparatively low overpressures.

Existing plant

If the risk assessment shows that a piece of plant presents a risk of injury to persons if an explosion occurs and there is no explosion relief (or other safeguard) in place a plan should be made to protect personnel urgently. At its simplest this could involve excluding personnel from the danger area when the risk is present.

A longer-term solution may need to be sought which would involve the fitting of explosion relief or suppression. To do this the plant will need to be modified and specialist advice sought.

If a piece of plant is already fitted with explosion relief and that complied with the relevant guidance issued at the time the plant was installed, then it is reasonably safe to assume the plant can be accepted as adequately protected. Even when the plant has been fitted with only nominal explosion relief it has been the experience within the animal feed industry that this is enough to protect the plant against catastrophic failure albeit some damage and structural deformation occurs. In this circumstance it is often satisfactory to accept the current arrangements albeit deficient if the risk to personnel is low.

Where explosion relief panels have been fitted but relieve onto occupied areas there are various solutions that can be adopted. These include excluding personnel, altering the ducts to vent externally and the fitting of flameless vents. Flameless vents can assist but they too have an exclusion zone although this is less than an unprotected vent. Historically, deflector plates and angled ducting were used to protect personnel from explosion relief panels but these are on longer considered good practice.

Where loose lids are used as an explosion vent such as older bins lids should be restrained by a substantial chain or hinges in order to prevent the lid becoming a missile.

To contain an explosion safely the plant must be built to be able to withstand the pressures that may be generated during an explosion.

4.2 Explosion Containment

To contain an explosion safely the plant must be built to be able to withstand the pressures that may be generated during an explosion. Within the animal feed manufacturing process industry this is normally impracticable with perhaps the exception of hammer mills and mixers. In the case of grinders, they often discharge into collection hopper/bin with explosion relief and a dust collector, again fitted with explosion relief. Overall it is thought that explosion containment is not generally a viable method of protection within the animal feed industry with the exception of the above two examples.

If explosion containment is chosen as a means for control, periodic inspection will be necessary to ensure that the strength of the plant is not compromised as it wears through use. Information from the supplier should be sought as to the maximum wear permissible.

4.3 Explosion Suppression

These systems detect the early signs of an explosion with a transducer (either flame or pressure) and then via a control system trigger an injection of an inert material into the vessel at high pressure. This renders the overall atmosphere noncombustible, hence quenching the explosion. The systems are relatively expensive and require frequent maintenance and checking. They are however effective and can be useful where other measures to control the risks from explosions are not feasible.

There can be an issue with false activations through faults, poor maintenance, or the incorrect specification of detectors. This can result in contamination of batches, leading to increasing waste. The systems will need to be isolated or disarmed whenever personnel are working on the plant and this should be controlled by permit to work procedures.

The design and fitting of these systems together with the maintenance is a specialist area beyond the scope of this guidance and if the decision is made during the assessment process to explore this route specialist suppliers should be consulted.

5 Preventing Spread of Fire and Explosions

If there is a fire or an explosion in one piece of plant it can propagate and cause explosions elsewhere as burning material is moved through the plant.

Examples include:

- **an ignition within an elevator which can allow burning material to progress further into the system**
- **a pellet press igniting materials which smoulder but then develop into very significant fire in the coolers and possibly further downstream within the finished product line, causing an explosion within the cooler cyclone**

Specific safeguards relating to pieces of plant are described further in section 7 but in generality one of the most important safeguards is to stop transport machinery immediately downstream of any discovered fire or ignition.

Explosions can also propagate through plant if there is dust present and an open aperture. If there is a solid barrier formed from either feed material or a valve, the explosion progress can be arrested. Where high risk pieces of plant such as grinders and elevators are directly connected to bins or other pieces of plant which contain combustible clouds the fitting of a choke should be considered. This will ensure that an explosion cannot progress from the grinder/elevator to the bin(s) by placing a physical barrier between them. There are several methods such as:

- **rotary valves**
- **augers inclined at approximately 45° which self-choke**
- **scroll conveyors with a missing section of scroll and a baffle above**

The latter present significant problems because they leave a plug of material which can contaminate subsequent batches and the technique is generally not favoured.

Where high risk pieces of plant such as grinders and elevators are directly connected to bins or other pieces of plant which contain combustible clouds the fitting of a choke should be considered.

6 Process Controls

Well-designed process controls are an important means of reducing the risk of dust escaping from plant as well as potential dust explosion. Many of these controls may be needed for efficient operation, but if they also serve a safety function it is important that the actions to be taken in the event of a processing problem are well understood by those operating the mill, and that staffing levels are adequate to implement them promptly.

Examples of how process controls can contribute to safety are given below:

- Level gauges on bins, and silos designed to prevent overfilling will help prevent the uncontrolled escape of dust
- Pressure or flow sensors at appropriate points may identify blockages in a transfer system. Where a blockage occurs, dust trapped in moving machinery may overheat and catch fire
- Temperature sensors are normally provided on drying or cooling processes and will help prevent overheating, but they may not pick up localised hot spots. If that is a significant risk, extra temperature measurement points will be needed, or other means of identifying smouldering ignition may be fitted
- Where large quantities of dust could escape because of a simple failure, controls may be needed to ensure such a failure is identified quickly. Examples might be a damaged dust filter bag, failure of a blow line or a flexible coupling tearing on a connection to a vibrating sieve
- Pneumatic conveying systems may need controls to prevent over-pressurisation of the system. Any pressure relief device should be located where it cannot become blocked with dust. Generally pneumatic conveying systems should be operated on a vacuum principle rather than a positive pressure principle so that any leaks or breaks in the system will not fill external areas with clouds of dust
- Interlocking of slide valves on the inlet to a set of storage bins so that only one is open at a time may prevent burning material spreading from one bin to the next in the event of an explosion
- Automated controls can reduce the need for access to areas that may put operators at risk in the event of an explosion. This particularly applies to bin tops, where access should be avoided while the bin is being filled
- Fitting aspiration to place plant under negative pressure and reduce dust concentrations. This is particularly important for bucket elevators, but chain and flight and screw conveyors can also benefit. Aspiration is also vital on any pneumatically filled bins and needs to be sized so that it is not overwhelmed by the blowing system
- There are also systems available to detect and suppress sparks, hot bodies and other similar potential sources of ignition which may be intercepted/extinguished before they reach items containing larger volumes of combustible dust atmospheres e.g. dust filtration equipment, silos etc. These systems can be variously designed to inject an extinguishing medium (often water) to cool/extinguish the object and prevent ignition and/or to divert the flame front away from the items containing significant dust volumes

In many cases, a fire develops before burning material ignites a dust cloud. If fire is suspected, all conveying equipment should be stopped promptly. This will not extinguish the fire, but dust clouds will settle quickly, and the risk of an explosion is much reduced.

For new plant the above safeguards should be designed in. For existing plant, the risk assessment should consider whether it is reasonably practicable to implement them.

7 Operations

Most feed manufacturing plants will have the following operations, and the precautions to prevent fire and explosion hazards are discussed in the following sub-sections. A summary of the likely zone a process will fall into and the likely necessary precautions are set out in Table 2.

7.1 Raw Material Intake

Procedures should be in place to avoid the intake of overheated or smouldering materials by inspection before tipping. Ideally raw materials should have had contaminants like stone, and metals, removed by use of rubble and magnetic separators before tipping however this is not always feasible. As such the intake grid should have a gap size as small as possible whilst allowing enough intake rate. The grid will serve to remove large lumps of (potentially) foreign material. A magnet should be placed within the product stream to remove tramp ferrous metal as soon as is practicable after the intake preferably before the intake elevator but immediately afterwards at the latest.

Pneumatic delivery pipe work and vehicles must be earthed when blowing combustible materials.

Intake pipes should be capped when not in use to prevent ingress of foreign materials and precautions taken to ensure that materials are delivered to the correct destination. Blowing pressures must be controlled to prevent bins being over pressured or creating dust clouds inside buildings if the capacity of the aspiration system is exceeded. The dust filter unit must be of adequate size to take both the normal blowing pressure/flow rate and the conditions at the end of discharge.

7.2 Elevating and Conveying systems

All new elevating and conveying systems should be to a common standard. In the case of bucket elevators transporting combustible materials and which have been zoned they should comply with the requirements of a European technical report CEN/TR 16829:2016. This has not been transposed into a European harmonised standard and is thus guidance. Overall it is expected that elevators will have:

- **Enclosed motors which should be kept clean, especially any cooling fins**
- **Rotation sensors to detect drive failure or belt slip. These must be mandatory on elevators which have been Zoned. On other elevators it is desirable if only to prevent damage and fires**

Figure 1 Elevator boot fitted with rotation sensor

- **Belt alignment monitoring. This must be mandatory on horizontal conveyors and Elevators which have been zoned internally as 20 or 21. On other elevators it is desirable if only to prevent damage and fires**
- **Explosion venting if zoned internally. For materials with a KST of less than 130 it is expected that bucket elevators will have an explosion relief panel equivalent to the cross-sectional area of the leg in both legs as close as is possible to the discharge and boot (not more than 6m away). The opening pressure should be less than 0.1 bar. The uppermost panel should also be interlocked to prevent burning material potentially being transported further into the plant. On taller elevators intermediate explosion relief panels should also be fitted so that the maximum spacing between consecutive panels is 12m. If materials have a KST of greater than 130, which would be unusual, the spacing between consecutive explosion relief panels should be reduced to 6m**
- **Explosion relief panels that have been fitted since 2002 should be type approved and tested and be marked with the CE and EX Mark. As such they should be purchased from specialist manufacturers**

- Explosion relief panels installed prior to 2002 do not have to be replaced if they are still effective. Replacement membrane material with a similar performance characteristic to 'ATEX rated' panels is still available
- Explosion relief panels should vent into a safe area. Ideally this is outside any building but can be vented internally to a safe area. Ideally vents should be at least 2m above head height. If they are below this flameless vents are advised and an exclusion zone should be set dependent upon manufacturers recommendations. Advice should be sought in the design of these to avoid reducing the effectiveness of the original explosion relief panel. As a general point explosion relief panels should not have any direct obstructions within 3m. Anything within this area is likely to suffer damage and if it is within a metre or so could reduce the effectiveness of the vent

Figure 2 Typical explosion panel on belt & bucket elevator

Figure 3 Example of flameless venting on belt & bucket elevators

- Explosion suppression can be used as an alternative to explosion relief and if it is chosen it should be designed and supplied by specialist suppliers
- Metal buckets are preferable, while plastic buckets can also be used bucket failure can generate small particles of plastic which then contaminate the process material and are virtually impossible to detect and remove. Plastic buckets also have the effect of increasing explosion pressures and can present an increased fire risk

All conveying systems should include:

- Overfeed and overflow detection
- Belt tension should be maintained correctly to minimise belt slip
- Bearing overheat sensors may be useful on conveyor and main elevator bearings particularly those which are zone 20 or zone 21
- Electrical switch gear should be IP5X (IP6X if located in a Zone 21 area) or be located in a clean environment
- Enclosed conveying systems should be aspirated to keep them under a small negative pressure typically via a dust filter unit which will cater for air displacement and prevent leaks of fine dust to atmosphere. Higher speed belt conveying systems will need significant aspiration at conveyor transport points to avoid the generation of flammable dust clouds
- Daily visual and audible checks should be carried out by a person familiar with the plant to detect the early signs of failure
- Process control / control of over-ride for the various sensors need to be used with care and controlled with permits to work or their equivalent

7.3 Grinding

The grinder is a source of ignition risk which is likely to appear as fire/explosion in downstream plant and pneumatic systems. Temperature sensing on the grinder (bearing over temperature) should be installed to detect overheating due to blockage or failing bearings, with appropriate alarms in the control room or similar location. Feed to the grinder should be shut off in the event of any overheating being detected. Grinder bearing vibration sensing is also advisable.

Explosion relief should be incorporated in the under hopper and dust filter. If the dust filter and under hopper are together a single explosion relief panel may be used if of a suitable size. Similar to other explosion relief panels they should be ideally vented externally otherwise to a safe place. Flameless venting can be used to assist in this if fitted internally.

Figure 5 Grinder under hopper fitted with a flameless vent

Where a grinder is located within a separate brick or block structure any explosion relief should vent outside of this structure or the structure itself be fitted with sufficient relief to avoid failure in the event of an explosion within.

If grinders discharge directly into a screw conveyor, this and the grinder must be sufficiently well built to withstand any explosion within it.

There should also be enough restriction after the grinder under hopper to prevent an explosion propagating from this area into downstream plant.

Magnetic protection ahead of the grinder should be provided to reduce the likelihood of damage to the screens but will only be effective if the units are inspected regularly. Records of these inspections should be kept. The magnet should be removed from the product stream when inspecting to avoid loss of collected material into the product. Where electromagnets are employed there must be an indication that they are activated. Whilst effective against magnetic ferrous materials, these magnets will not protect against stones and non-ferrous metals.

If reasonably practicable, the company should provide some means e.g. pneumatic or sieve separators, airleg or similar, to remove stones ahead of the grinder. Admix entering the grinder can lead to ignition within the equipment and the risk that smouldering material will pass forward in the process and possibly lead to an explosion downstream. Whilst these controls are desirable they are not mandatory.

More recently grinder manufacturers and designers have reduced the actual tip speed of hammer mills from 3000rpm to 1500rpm and now advocate that there is no requirement for a grinder to be housed in a separate building. Likewise the use of roller grinders is becoming a more popular technique with a much reduced requirement for dust filtration systems to be employed to provide a forced airflow to enable material to be extracted from the grinder chamber. Roller grinders carry a much lower explosion risk.

Grinder under hoppers and meal elevators would normally be zoned internally as 20 or 21 and be protected by explosion venting or in some cases suppression. They should also be fitted with belt alignment and rotation sensors.

Explosions within grinders can be prevented from propagating upstream using a natural choke caused by the materials. The material upstream of the grinder is generally too coarse to allow an explosion to propagate through it.

7.4 Raw Material Storage (Bins & Silos)

Raw material bins which have been zoned should incorporate explosion relief. Bins that have not been zoned because of the nature of the material they contain combined with the method of filling do not. For new bins the required vent area can be calculated. Historically HSE recommended a ventilation area of $1m^2$ for every $6m^3$ of volume where the bin capacity was up to $30m^3$. For plant with over $300m^3$ capacity a vent area of $1\ m^2/25m^3$ was recommended (HS (G) 103 first edition). Within the UK animal feed sector there has been virtually no reported examples of bin failure following an explosion within where there has been some form of explosion relief.

Figure 6 Example of bin top explosion relief panels – to right of barrier.

If bins have been zoned but access to the top areas are required, for example for inspection, cleaning and bin dipping, it should only be done when the conveying plant is either shut down or transporting low risk materials to minimise the risk from an explosion in the bins.

In the case of pre-grind mills where coarse materials are ground prior to mixing the risk of an explosive atmosphere developing within the meal bins is higher than in a post grind mill where the addition of liquids, fats etc. dampen the production of dust. It is most likely that any meal bins in a pre-grind mill will need to be zoned internally as a 22 if gravity filled and 21 if pneumatically filled. The latter will need extra safeguards in the form of explosion mitigation or a purpose designed choke to prevent an explosion propagating into them.

Electrical equipment within bins should be eliminated. If inspection lighting is fitted it should be external and fitted with a shatterproof clear window between it and the bin. Where portable lights are necessary within a bin they should be of explosion protected design. Powerful LED torches can now replace the historic 12 V inspection lamps relatively easily. Bin dipping should ideally be by remote sensing of material level. If physical bin dipping is undertaken non-metallic weights, tapes etc. should be used. Automatic temperature monitoring should be installed in bins and flat storage containing stocks liable to self-heating.

Nested bins can be found in some feed manufacturing plants. An issue can also arise if bins are connected to a common aspiration system, or air passes from bin to bin along the row during filling. In all these cases there is a risk of an explosion spreading throughout the system. Where an explosion spreads from one bin to another the severity of the explosion is likely to be greater than the initial explosion. Wherever possible this arrangement should be avoided. If nested bins cannot be segregated, then care needs to be exercised to ensure that they are kept clean and do not store materials which can give rise to combustible dust clouds. When filling bins only one bin inlet should be open at any one time. The ductwork in aspiration systems also need to be kept clean to prevent explosions propagating through them.

As an alternative to the above a dust extraction unit on the conveying system filling the bin will reduce the likelihood of any explosion propagating or an explosion barrier device (choke) could be used.

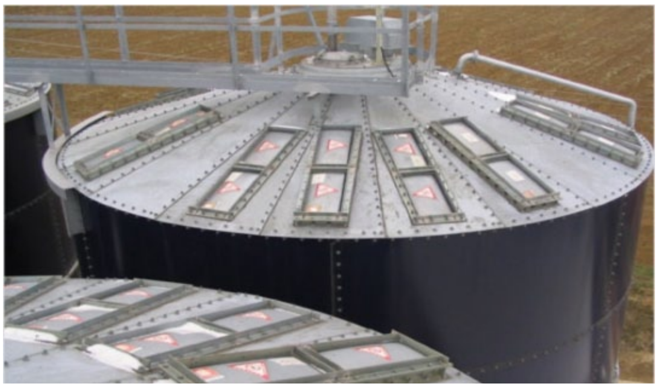

Figure 7 Example of explosion relief panels fitted to storage silo

7.5 Mixing and Blending Units

Mixers generally do not have an explosive atmosphere within them other than when they are being filled with dry fine materials. In the case of post grind mills where mixing takes place before grinding, the risk can be discounted as the materials are generally too coarse with insufficient fines to generate an explosible cloud. In pre-grind mills where materials are ground and then mixed the risk is higher but again very low. Where liquids are added this further reduces if not eliminates the chances of a dust cloud being generated either within the mixer or downstream plant. Because of the slow speed of the mixing paddles/ribbon the mixed material behaves very much like a fluid and observation over many years has shown that the ullage space does not contain a combustible concentration even when mixing fine powders.

There is however a risk of creating an explosive atmosphere in a mixer if either a single ground material or an unground fine dusty material is discharged into the empty mixer in isolation, in which case a dust cloud may be created within either a paddle or ribbon mixer. The risk can be mitigated by not running the mixer during the initial fill and starting in partly loaded which reduces the dust cloud, although this may not be practical in many plants because of the high starting load it creates. In addition, mitigation is improved by ensuring that the air balance pipes between the mixer top hopper and the mixer, and between the mixer and the mixer bottom hopper are completely clear. This will enable any dust cloud created when the mixer is being filled to be displaced safely.

In blends plants any fine dry dusty materials should either be added first when the mixer is not running or if this is not possible because of the starting load thus created they should added after the addition of coarse materials. This will reduce the possibility of an explosive atmosphere arising. Where manual additions are made precautions need to be taken to avoid creating an explosive cloud and static ignition. Adding these materials in small amounts (maximum 25 kg) and ensuring any container used is earthed will reduce the risk.

7.6 Pressing/Cooling

These two steps are considered together since the most common cause of fire in a cooler is the introduction of smouldering material from die burn-ups. Means to divert such material away from the cooler should be provided e.g. quick-dump chutes.

In the event of a die burn-up care should be taken not only to remove all overheated material from the press but also to check the cooler. This is to ensure that any dormant smouldering material has not entered the cooler prior to detecting the burn-up.

Early detection of fire in coolers is essential in view of the air flow through the bed of material. This can be achieved through smoke or flame detection, or by monitoring the rate of increase of temperature in the exhaust ducting. Specification of actual temperature levels may not be possible as products cool at different temperatures and in different ambient conditions. Any tripping/alarm devices should automatically shut down the exhaust fans when an alarm condition arises. If there is a significant height difference between the cooler and discharge point of the cooling air there can be a significant natural ventilation pressure in which case a damper may also need to be incorporated as part of the shutdown system.

It is also sensible to fit a manually operated water drench system to extinguish the fire within the cooler. This should be operated from a safe location well away from the cooler, possibly outside, and can be a simple lever valve.

The event of a fire within the cooler, in addition to shutting down the aspiration system, the discharge mechanism should also be stopped to prevent the potential spread of burning materials downstream. Likewise, the press feeder should also be disabled to prevent further material entering the cooler.

Figure 8 Fire damper system installed in cooler fan duct upstream of filtration system

7.7 Finished Product Bins

Dust levels associated with extruded or pelleted products are very low, and consequently there will be no explosion risk. Some mills produce meals. The majority of these contain some liquids which will ensure that a combustible cloud of dust cannot be created. However, some dry meals may contain enough fines to produce combustible clouds. In these circumstances the conveying equipment and bins may need to be zoned with safeguards similar to those on the raw material side.

7.8 Fats Handling

The hazards associated with fat handling and storage arise principally from the leakage of fat into lagging on tanks or pipes. Ignition may be caused by trace heating or tank heating in contact with this contaminated lagging, or it may ignite spontaneously due to the large surface area of mineral wool materials, even at room temperature. Fat tanks and pipe work should be constructed of stainless steel, insulated with closed cell lagging (rather than mineral wool) for this reason, and enclosed within a fat-proof cladding. Tanks should be sealed at the top with the overflow directed away from the tank itself. Manhole covers should be bolted down and sealed. The tank contents should be checked by external means, not by manual dipping, to avoid fat spills.

Tank heating should ideally be by external hot water coils. (Internal steam coils are not recommended due to the risk of contamination of boiler feed water). If electrical trace heating has already been fitted it should be confirmed that any electrical failure will not overheat the fats to a temperature which is likely to cause an ignition.

Note that fats handling throughout the mill, including pipe work, day tanks and fat coaters poses a fire risk. Any contaminated lagging should be removed (especially if it is of the mineral wool type) with care when exposure to air occurs and replaced with a closed cell material. It should be wetted thoroughly whilst awaiting disposal. Fat suppliers issue useful guidance on fat handling.

7.9 Blends and Coarse Mix Plants

Blends and coarse mix plants, may also need to take into account the requirements of DSEAR. These plants vary significantly from the very simple to the sophisticated. At their simplest a blends plant will consist of an enclosed building subdivided into a number of bays in which various animal feed raw materials are tipped from large goods vehicles or farm trailers.

Materials are then drawn according to a recipe from the bays using some form of loading shovel which are tipped into some form of mixer; often a modified agricultural trailer mixer or its equivalent. Liquid additions can be added but are not always. The addition of liquids will reduce the dustiness of the material in its subsequent handling. Machinery used for moving materials should avoid so far as is possible lifting and dropping it so equipment such as grain throwers should not be used.

Once mixed the blends can either be dumped onto the floor below the mixer or be transported to elsewhere within the building via conveyors, bucket elevators or augers.

The biggest issue in blends plants is cleanliness because the processes are essentially unenclosed and any movement of the ingredients and blends will generate dust which then settles. This dust could then be raised by an explosion within a piece of plant or a fire which can produce a secondary explosion. To reduce the need for cleaning, buildings and plant should be designed to reduce if not eliminate high-level horizontal surfaces that dust can settle on.

In any event there will need to be a regular cleaning regime the frequency of which depends on the quantity of dust that accumulates.

It is a good idea to enclose, so far as is possible, the tipping point into the mixer. Although the front has to be left open to allow the bucket to enter, dust emissions can be significantly reduced by using heavy duty plastic curtain fingers and or fitting some form of extraction ventilation. If an extraction system is used the dust filter must comply with the requirements set out in section 7.12 and should ideally be located outside the plant so that any ignition within it will not disturb dust within the plant.

The other significant source of dust is when tipping materials, often the final product, into a bay from a conveyor. In these circumstances, specialist chutes which are used in other industries can be used to reduce dust emissions although historically they have not been used in blending plants. Telescopic and dust suppression hoppers (DSH) are two of the examples which may be suitable. Water fogging systems can also help reduce dust but do give rise to a higher moisture content which may not be desirable.

7.10 Mobile Plant

If a blends plant is sufficiently dusty and warrants zoning as a Zone 22, significant difficulties arise with the specification of plant and equipment. Whilst there are ATEX rated motors, conveyors etc. there are very few if any large goods vehicles or farm tractors and trailers which carry this certification. Observations carried out over many years in flat stores and blend plants show that vehicle movement does not give rise to a dust cloud of a combustible concentration. Whilst the temperature of certain engine parts (mainly the exhaust system & catalytic converters) could provide an ignition source if there were a dust cloud present. The risk of the presence of a combustible dust cloud must be assessed and if it cannot be discounted then a lesser alternative exists in the form of vehicles sometimes referred to as 'enhanced safety' types. These vehicles are not certified for use in zoned areas but safety is 'enhanced' by (for example) the application of insulation to hot surfaces such as exhausts.

Fires associated with mobile plant and equipment can occur usually as a result of overheating through poor maintenance and cleaning. It is thus important that plant and equipment used in dusty atmospheres is properly specified with heavy duty dust filters and maintained so that radiators and dust filters are cleaned on a daily basis.

Some fires and minor explosions have occurred during bulk tank deliveries of fine combustible products. Product may enter the blower fan causing frictional heat or blinding of the clean air intake filter or both, resulting in ignition of filter material. Non-return valves downstream of the blower may be ineffective, particularly if the vehicle driver switches off the blower and relies on residual pressure within the bulk tank to discharge the last of the product. This may cause product to enter the blower. Drivers should be warned of the danger and instructed to keep blowers going until the discharge is fully complete.

There is also the issue of static electricity being generated on pneumatic transfer lines. The blowing pipes should be linked and earthed back to the vehicle and the vehicle earthed to the ground to prevent this.

7.11 Cleaning

Maintaining a clean plant or mill is vital in the prevention of secondary dust explosions. Routine cleaning within the mill buildings should always be by vacuum rather than brushing. Particular attention should be paid to ledges at high levels where the finest dust settles, electrical equipment that can overheat, and ventilation grilles.

Ideally a centralised vacuum plant should be fitted with connection points throughout the Mill. Alternatively, portable vacuum cleaners can be used. Vacuum cleaners need not be ATEX rated unless they are used in an internal zone 22 environment but must meet certain criteria to reduce the risk of an explosion within them. This includes that there should be twin filtration and that dirty air should not pass over the electrical motor. Ideally the vacuum hose and tools should be earthed with the machine. However, if plastic hoses and tools are used it is recognised there is little risk of sufficient static build up to give rise to an ignition. What must be avoided is the use of metal tools with plastic hoses. More detailed guidance is contained on the HSE website on such machines www.hse.gov.uk/food/dustexplosion.htm (HSE, 2013)

Regular cleaning not only reduces the likelihood of creating a fine dust in the atmosphere but also reduces the exposure of operators to dust.

When cleaning up major spillages of dust, shovels may be used. Fine dust should not be returned to process as this increases the dust explosion risk inside the plant. Care will be needed not to raise fine dust; consideration should be given to dampening the material first to decrease occupational exposure.

7.12 Dust Control Equipment

Dust extraction units tend to be bag or cartridge filters or cyclones.

Bag and cartridge filters can be open or closed. In an open bag filter the dusty air is drawn through the fan before being discharged under positive pressure through a series of filter socks. Generally these units are not suitable for use with combustible dusts because of the increased risk of ignition when the dust travels through the fan and any failure of the filter bag can lead to large quantities of dust being dispersed creating an explosive or cloud.

Closed bag filters consist of a chamber with filter cloth which is either arranged as tubes or socks or as flat panels. In either case the dirty air is drawn by a fan which may be internal or external to the filter through the filter media before passing as clean air through the fan and being discharged either internally or externally. On some older dust extractors the fan motor can be located in the dirty side of the dust collector. If it is the motor must be suitable for that zone.

To prevent the filter media becoming blocked some form of cleaning is required. In many there is a system of compressed air cleaning which involves injecting compressed air against the normal flow of dirty air which pushes filtered dust away from the bag which then drops to the bottom of the chamber where it can be removed. This is usually by gravity through a rotary valve to maintain an air seal before it drops into some form of a tote bag or bin. Alternatively, mechanical shaking devices are fitted to some smaller filters which operate when the units are shut down. Reverse air jet cleaning is far more effective in plant which is run for long periods of time.

The dust extraction system can be a route through which an explosion can travel through the plant if combustible dust settles within the ducts. This can happen if the extraction system is poorly designed or maintained. If there is the potential for this to occur then an explosion isolation valve should be fitted at the inlet to the dust filter. This slam shut device will close off the ducting and prevent any flame propagating into the ducts.

Dust collectors have a history of explosions associated with them and should always be protected with explosion mitigation, usually explosion relief but explosion suppression would also be feasible. In existing systems if no explosion mitigation is fitted the risk of injury to personnel should be examined. In small dust collectors with large aperture intakes the risk is minimal (Sack tip units and intake dust collectors). Other dust collectors should either be fitted with explosion mitigation or people should be excluded from any danger zone. To minimise the risk of explosions within dust collectors the filter medium should be of a type which dissipates the buildup of static electricity.

Cyclones are devices which draw air through them and then induce the air to spin at high speed. The air particles within the air are thus forced towards the outside of the cyclone where they fall to the base where can be collected usually through a rotary valve or other airlock arrangement. Clean air moves towards the centre of the cyclone and exits via a central duct in the top. Cyclone design is a specialist subject and specialists in this area should be sought.

Within the animal feed industry cyclones are not generally fitted with explosion relief. Explosions have been known to occur within them extremely rarely and when they do occur are relatively weak because only a small proportion of the air within the cyclone is above the explosive concentration. They also tend not to have any direct ignition sources within them.

This guide does not advise the automatic fitting of explosion relief or its equivalent to cyclones except where they are connected to plant which has a high risk of discharging burning material into them e.g. direct fired dryer or microniser and there is a substantial dust concentration within the air.

Both cyclones and dust filters should be specified by the quantity of air they are required to pass through them. The ductwork (lengths, bends, diameters) and materials, the cyclone and any exhaust ductwork will together allow a competent ventilation engineer to specify an appropriate fan. If it is feasible that any failure in the filter medium would allow a combustible dust cloud to progress through the fan the fan itself will also need to be ATEX rated and comply with BS EN 14986. If they are situated in a zoned area not just zoned internally the motor and associated electrical switch gear will also need to be ATEX rated.

In most existing systems it is not thought reasonably practicable to replace fans and motors with ATEX rated ones provided they are maintained and operated as designed. Fans and their motors are very unlikely to give rise to an explosion. This is because there must be three simultaneous failures; a combustible cloud within the air being transported, a failure in the filter mechanism and a fault in the fan giving rise to an ignition source. All are very low probability events and when combined can almost be considered so remote as to not require consideration. There is also fourth factor which is that dust collectors and fans are likely to be in a remote area which is not occupied other than occasionally. If existing equipment has to be replaced (worn out) then it should be replaced with suitably rated equipment (see section 10).

Figure 9 Example of compressed air cleaning dust filtration unit (Unit fitted with dust explosion relief)

7.13 Motors and Other Electrical Equipment

Motors and other electrical equipment which are used within a zoned area need to comply with the requirements of the Equipment Used in Potentially Explosive Atmospheres Regulations (EPS). These motors are commonly known as ATEX rated motors. There are various ratings depending upon the zone which the motor is being placed. Within the animal feed industry there should be little need to fit ATEX rated motors provided that the mill environment is clean and the risk of secondary explosions eliminated. At the very worst if electrical equipment is placed within a zone 22 environment the rating should be EX II 3D which indicates that it is suitable for zone 22 environments. Motors which are suitable for zone 2 environments would be marked EX II 3G. Some equipment is marked both G and D indicating it is suitable for both dusts and gases/vapours. Equipment which is suitable for a zone 21 environment would be marked EX II 2D. Equipment which is marked suitable for a zone 21 is automatically also suitable for a zone 22 but would be over specified.

Electrical equipment which predates the EPS regulations can still be safe to use provided it has been maintained. Typically, within the milling environment electrical equipment was installed to a standard which allowed only limited dust ingress known as IP5X or totally protected from dust ingress known as IP6X. Equipment which has been maintained to this standard remains suitable for use in a zone 22 or 21 area respectively.

Prior to the EPS regulations there were a whole series of older standards more associated with the control of risks from flammable atmospheres from gases and vapours. These included intrinsically safe and flameproof equipment. It is beyond the scope of this guide to detail the standards but if the equipment has been maintained in its original state then it continues to be safe to use.

7.14 Signage

Where there is an explosion risk the employer must place warning signs at the entrances to the area. The warning sign is shown in figure 10.

It is useful to supplement this sign with an indication of the zone be it zone 22, zone 21 or zone 20 with a similar colour and border.

Where it is only the internal volumes of plant which are zoned it is still important to notify personnel who might be working on it that it could contain a potentially combustible atmosphere. To that end it is recommended that either the EX sign is affixed to the plant at locations where personnel might access it or alternatively a floor plan showing the plant and its EX rating is posted prominently on each floor or entrance to it.

Figure 10

In addition to placing signs there is also a duty on the employer to restrict access to any designated areas to those people who are necessary for the tasks.

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7.15 Training

One of the most important requirements of DSEAR is that employees are appropriately trained. It is important that employees are aware of the potential hazards of accumulations of fine dust as well as the need to prevent fine dust being raised into a cloud, the special risk associated with fires and the need to exclude sources of ignition.

They should also have a basic understanding of the measures which the employer has put in place to protect them and maintain the effectiveness of the explosion prevention measures. This should include such things as reason for the use of magnets and their regular inspection, explosion relief panels and using appropriate tools for cleaning and clearing blockages.

In addition site maintenance personnel and contractors will also need to be made aware of the special requirements associated with plant and equipment situated in zoned areas and the need to make sure any special design features associated with ATEX rated plant or its predecessors are maintained.

They should also understand the need for the close control of hot work in and around any plant which may contain a combustible substance and hot work permit systems.

7.16 Management of Change

The successful control of fire and explosion is determined by the control measures installed as a result of the DSEAR risk assessment. Any change in the materials being processed, or the processes themselves can invalidate the assessment by introducing unforeseen hazards. It is thus important that whenever changes are planned or perhaps occur without planning e.g. a supplier substitute a different category of material the risk assessment is reviewed to ensure that the control measures are still effective. With new processes or lines it is likely that a new assessment for that particular part of the plant will need to be carried out. In the case of materials it will be a case of determining whether the existing safeguards continue to be suitable. It is perhaps unlikely but if a pre-pelleted or coarse material was being substituted something which was fine and dusty the plant handling may not be suitable. Before changes are made employers are advised to consider those changes involving production, engineering and safety personnel.

Table 2: Typical Safeguards for various key items of plant

The safeguards identified below presume the equipment is installed an area with little or no accumulations of combustible dust which will give rise to a secondary explosion risk and as such the plant will not need to be ATEX rated equipment. The equipment will however need to be suitable for the task being carried out which may include the development of combustible dust clouds within it. If the DSEAR risk assessment identifies that plant and equipment will be installed in location where there is the potential for a combustible dust cloud to develop the whole plant and equipment will need to be compliant with the EPS regulations and suitable for a zone 22 environment.

Equipment	Typical classification	Not zoned	Zone 22	Zone 21	Zone 20
Intake Fugitive emission dust filter	zone 21 dirty side zone 22 clean side	Not Applicable	Explosion relief on dirty side	Explosion relief or suppression. Relief may be provided by sufficiently large intake aperture	
Intake Bucket elevators	Zone 21 possibly 22 if handling only cleaned raw materials with minimal fines	No requirements	Explosion relief see section 4.1	Explosion relief see section 4.1 Slip protection belt tracking protection bearing over temperature and/or bearing vibration monitoring and aspiration	Explosion relief see section 4.1 Slip protection belt tracking protection bearing over temperature bearing vibration monitoring and aspiration
Raw materials conveying system chain and flight conveyor/screw conveyor/auger	Not Zoned	No requirements Aspiration to reduce risk of dust concentration & leaks	Aspiration to reduce risk of dust concentration & leaks	Not applicable	Not applicable
Enclosed Belt Conveyor	Not normally zoned, exception enclosed transfer points on higher speed conveyors conveying materials with a significant find content.	No requirement Aspiration to reduce risk of dust accumulation, concentration & leaks	Aspiration to reduce risk of dust accumulation, concentration & leaks	Aspiration to reduce risk of dust accumulation, concentration & leaks explosion relief on the enclosure. Bearing over heat on drive and return roller daily checks to guard against idler roller bearing collapse	Not applicable
Open Belt Conveyor (blends or coarse plants) and some final product conveyors.	Not Zoned	No requirements Aspiration to reduce risk of dust concentration & leaks	Not Applicable	Not Applicable	Not Applicable
Raw material bins	Bins containing whole grains, peas and beans and similar not zoned Bins containing meals with a fines element, gravity fed not zoned. Bins containing flour like products zone 21. Bins containing fine products pneumatically filled zone 21. Bins with substantial dust deposits on upper wall surfaces zone 22.	No requirements	Explosion relief In older bins loose lids permissible	Explosion relief or Suppression	Not applicable

Safeguards in green are thought to be desirable but not essential to ensure compliance with DSEAR.

Equipment	Typical classification	Not zoned	Zone 22	Zone 21	Zone 20
Ground Meal Bins (pre-grind Mills)	Depending on size distribution of meal and whether fines are removed probably zone 22.	No requirements	Explosion relief In older bins loose lids permissible.	Explosion relief or suppression	Not applicable
Weighers	Not zoned	No requirement	No requirement	No requirement	No requirement
Grinder and collection hopper and associated aspiration system	Zone 20	Not applicable	Not applicable	Not applicable	Explosion relief fitted to under hopper and dust filter. Tramp metal magnet at intake Stone cleaner to remove stones/ nonferrous tramp material Bearing over temperature/ vibration
Meal elevator	Zone 21/20	Not applicable	Not applicable	Explosion relief see section 4.1 Slip protection belt tracking protection Bearing over temperature and/or bearing vibration monitoring	Explosion relief see section 4.1 Slip protection belt tracking protection bearing over temperature bearing vibration monitoring
Pre-press bins	Zone 22 or not zoned depending on method of filling to be confirmed by visual observation	No requirements	Explosion relief	Not applicable	Not applicable
Conditioner	Not zoned the addition of steam and liquids means dust clouds cannot be raised	No requirement	Not applicable	Not applicable	Not applicable
Pellet press	Not zoned the addition of steam and liquids means dust clouds cannot be raised	No requirement	Not applicable	Not applicable	Not applicable
Extruder	Not zoned the addition of steam and liquids means dust clouds cannot be raised	No requirement	Not applicable	Not applicable	Not applicable
Cooler Dryer	Not zoned materials within them pellets very low percentage of fines well below explosive or concentration	The fitting of over temperature probes and trip with possible damper together with manual water sprays	Not applicable	Not applicable	Not applicable
Cooler, Dryer Cyclone/ dust collector	Zone 22/21 within cyclones there will be a small part of the internal volume with a combustible concentration of dust.		Explosion relief fitted to duct close to cyclone or cyclone itself if measures not present to prevent cooler fire.	Explosion relief fitted to duct close to cyclone or cyclone itself if measures not present to prevent cooler fire.	
Fat coater	Not zoned the addition of steam and liquids means dust clouds cannot be raised	No requirement	Not applicable	Not applicable	Not applicable
Roller mill	Zone 22	No requirement	No requirement	Not applicable	Not applicable
Open flame Radiant Microniser	Not zoned combustible dust clouds not present however risk of overheating and setting fire to material	The fitting of over temperature probes and trip	Not applicable	Not applicable	Not applicable

Safeguards in green are thought to be desirable but not essential to ensure compliance with DSEAR.

8 Maintenance

In the prevention of fire and dust explosions maintenance is of vital importance.

Plant and equipment needs to be kept in good running order to prevent mechanical failure which can lead to sparking and hotspots. Electrical systems need to be examined and maintained to prevent hotspots developing. Explosion protection measures need to be maintained to ensure that they will continue to work. Explosion relief panels and flameless vents can become blocked with accumulations of dust. Trip panels and switches can seize and over the course of time plant which has been designated strong enough to contain an explosion may wear and weaken.

Maintenance activities can also cause and give rise to fires and dust explosions if incorrect materials are used, hot work it is not controlled and equipment is not repaired or reassembled correctly. It is beyond the scope of this guide to set out more details on methods of controlling maintenance work other than to say the site should have a strong and effective permit to work system that controls hot work and the work of contractors in generality.

As has been said previously equipment which predates ATEX and indeed ATEX rated equipment will need to be maintained. When carrying out maintenance work specialist skills may be needed. Within the oil and petrochemical industry there is the CompEx scheme. The scheme assesses the competency of employees and contract staff who are working in environments with the potential risk of explosive atmospheres. The scheme was developed by the Engineering Equipment and Materials Users' Association (EEMUA) and JT Limited, the CompEx Certification Body is accredited by UKAS to ISO/IEC 17024 : 2012. Holders of CompEx units 05-06 have passed practical assessments on the installation, maintenance and inspection of electrical and instrumental systems in an environment where combustible dust may be present.

Overall in so far as the maintenance of ATEX rated equipment is concerned the replacement of like with like and seeking the advice and guidance of the original supplier is likely to be sufficient to ensure the equipment continues to function as it should. Specialist equipment should only be maintained by the suppliers accredited personnel or employees, examples of this would include explosion suppression systems.

9 Building Design and Fire Precautions

9.1 Fire Protection

Fire safety is controlled through the Regulatory Reform (Fire Safety) Order 2005 (RRFSO). These place duties on employers to carry out a fire risk assessment which should identify the fire precautions which are necessary. There are also relevant standards and controls within the Building Regulations which are intended to ensure, for new or extensively modified buildings, that:

- **there are adequate means of escape in case of fire**
- **the building will not collapse prematurely in a fire**
- **fire cannot spread easily from building to building**
- **water supplies for fire fighting are adequate; in some cases wet or dry rising mains inside the building may be required**
- **adequate access is provided for the fire brigade**

These are enforced through Building Control Officers in local authorities. Fire brigades, through a system of inspection, police general fire safety, such as fire alarm systems, provision of fire extinguishers, and emergency lighting.

At the time of writing this guide fire safety and in particular the building regulations is under review and there are likely to be significant changes going forwards. The Home Office have published guidance on fire risk assessment and basic fire precautions in the guidance document Fire safety risk assessment: factories and warehouses.

9.2 Means of Escape

The basic aim in designing adequate means of escape is to limit the distance a person needs to travel before they can reach a place of comparative safety. This is usually a door to the outside, or a fire protected corridor or staircase. Within an animal feed mill if there is only a single escape route this distance should not exceed 25m. If there is more than one means of escape the distance should not exceed 45m. Rearrangement of process plant without adequate thought may result in much extended travel distances and reduced safety. Most mill buildings will need a fire alarm system, and automatic fire detection may also be advantageous, particularly in areas that are often unoccupied. It is sensible to request that the local fire brigade familiarise themselves with the mill premises.

Building Design and Fire Precautions – it is worth clarifying that the RRFSO relates to General Fire Precautions; DSEAR may lead to additional requirements known as Process Fire Precautions; the meaning of Process Fire Precautions is less clearly defined, but in general these are precautions (including enhancements to existing general fire precautions) that are made necessary by virtue of the presence of particular substances and/or the processes operated; a simple example could be a reduction in the travel/escape distance.

9.3 Building Materials

There is a clear issue with using composite materials especially on building cladding. In older twin skin materials combustible materials have been used, the interior of which will melt/ degrade when exposed to fire, and the metal skin then quickly deforms. The interior material can also act as an agent to spread fire. Rockwool filling is recognised as satisfactory.

All plastics will melt or soften at a comparatively low temperature. If plastic is used for ducting or a bin it may allow product to escape as a dust cloud as a result of quite a small fire.

The choice of building materials and the fire risk are beyond the scope of this guidance. Suffice it to say that these form part of the planning and approval process for new buildings and alterations. Whilst building regulations are not retrospective consideration of fire risk should be considered as part of the fire risk assessment carried out under the fire reform act. The controls surrounding fire safety are currently under examination and is likely they will change in the near future.

9.4 Firewalls and Sprinklers

These can be provided within buildings to limit or delay the spread of smoke and heat. Close attention should be paid to proper sealing where cables, pipe and ducting pass through fire walls. The value of expensive protection can easily be lost if holes in fire walls are not sealed properly, and many proprietary products are available to maintain the original integrity of a wall.

Sprinkler protection is generally encouraged by insurers, and if it is to be fitted it may influence the design. The sprinkler design codes contain requirements for internal compartmentation of buildings with fire walls. If sprinklers and firewalls are fitted, then these must be installed and maintained as per manufactures/insurers instructions.

10 New Plant Design Considerations

10.1 Basic Principles

It is much better to design precautions against fire and explosion risks into new plant at the outset, than to try and add on safety features once the plant is built; it is also significantly cheaper. Key design issues include:

- **Enclosing processes to the greatest practical extent to limit the release of dust hence minimising the amount and cost of cleaning**
- **Collecting any dust that is released close to the source by installing aspiration to keep the plant at a slight negative pressure**
- **Process plant needs to have features that will prevent the spread of burning material or an explosion, through the system. This is often described as explosion isolation**
- **Limiting the spread of dust around a building beyond process areas, by use of internal walls and close fitting doors**
- **Ensuring that all areas where dust may settle are reasonably accessible for cleaning and using profiles within building construction which will shed dust**
- **Plant that needs to be protected by explosion venting, should either be located outside, or where the vents can be ducted to the outside. All should vent to a safe area**
- **Where there is a dust explosion risk Buildings with concrete or masonry load bearing walls should be avoided, unless they are specially protected against explosions so that the building itself will not collapse**
- **Plant layout including access walkways needs to consider means of escape in case of fire. Fire risk assessment guidance and consideration of the Building Regulations will assist with this.**

The aim of the designer should be to ensure that the only combustible atmospheres which are likely to occur will be within pieces of plant.

10.2 Equipment Selection to Avoid Ignition Sources

The choice of process equipment is important in two areas. The first consideration is to choose equipment which will reduce the risk of combustible atmospheres developing. This generally means choosing equipment with slow rotational speeds that does not agitate the materials and aerate them. The second consideration is to choose equipment which will not give rise to ignition sources. This means specifying equipment correctly, choosing robust and reliable equipment where necessary including necessary transducers to detect faults.

10.3 New Equipment

The rules concerning new equipment have changed greatly over recent years, in response to pressures to make a single market across Europe for a great many products. Common basic safety requirements apply to machinery, electrical equipment, and equipment designed to prevent or control explosions. Machines, for instance, must be designed to avoid all risk of fire and any risk of an explosion, and the supplier should be able to tell you how this has been achieved. Often they will refer to published standards. See glossary in Annex I, and Annex II.

For the equipment supplier, the details are set out in regulations (see Annex II). Related regulations require the plant operator to ensure that new process plant installed in a production site will comply with the Essential Health and Safety Requirements. Much work equipment comes with a CE marking indicating it has been built to comply with European legislation and safety standards. As the CE marking may apply to more than one set of requirements, it is important to read the documentation carefully, to see which set of requirements has been applied. Documentation should make clear the intended use of the equipment; and it is then up to the user to see that it will be suitable for use in the process area. Documentation should also set out any installation requirements needed to ensure the equipment or machinery will be safe for use.

10.4 Certified Equipment

In addition to the CE mark (or equivalent), new electrical and other equipment intended for use in areas which are zoned should carry the symbol of explosion protection, which is Ex in a hexagon and a series of letters and numbers giving other identifying details. For dusty areas three classes of equipment have been established by the ATEX directive (see glossary-Annex I).

Category 1D may be used where dust is always present in quantity, mainly the inside of process plant i.e. a zone 20. This will have to be certified by a recognised test laboratory.

Category 2D, built to less demanding standards, will be suitable where dust clouds may often form, i.e. a zone 21. Areas where 2D equipment is needed should be quite small. Electrical equipment of this category will also have to be certified by a recognised laboratory.

Category 3D is intended for use where dust clouds may only form in the event of some unintended release (zone 22). Much of the inside of a mill or other process building where process plant is located may need equipment to this standard if it is not kept sufficiently clean.

The fact that there is a potential explosive atmosphere within the plant does not affect its ATEX certification but does require the manufacturer/supplier to put in place explosion protection measures which are discussed within this guidance document.

10.5 Equipment Selection for Zoned Areas

For most purposes there is a simple link of equipment category to zone. This applies to new equipment only. In zone 22 new equipment should be ATEX Category 3D (the D stands for dust). Older electrical equipment should be dust protected to BS6467 and have an enclosure that is dust tight to IP5X. If the area is classed as zone 21 a higher standard of new equipment, ATEX category 2D, is needed. Older electrical equipment should be dust tight to BS 6467 - the enclosure should meet IP6X - because dust clouds or deeper layers may form in normal operations.

Very little electrical equipment normally needs to be located inside the process, but if it is, and especially if it can become submerged in dust, the highest standards of equipment will be needed, i.e. category ID under ATEX.

When discussing new equipment with suppliers they should ask whether the equipment will be going into a zoned area and what sort of material it will be handling. It is for the equipment supplier/manufacturer to design and specify the equipment to be safe in these circumstances. For instance, manufacturers/suppliers will not certify the majority of plant and equipment as suitable for other than a zone 22 environment even though internally the plant will have atmospheres which may well be zone 20 or 21. The fact that there is a potential explosive atmosphere within the plant does not affect its ATEX certification but does require the manufacturer/supplier to put in place explosion protection measures which are discussed within this guidance document.

10.6 Electrical Equipment

Where dusts may be present as a cloud, or a layer, electrical equipment needs to be suitably designed. There are three particular risks to consider.

Deposits of dust may be heated by the equipment, particularly if it is high powered. They may then start to smoulder and later burst into flame if disturbed. Alternatively, a dust layer may act as insulation, causing the electrical equipment itself to overheat, causing damage or fire.

The third possibility is that dust will enter the equipment and be ignited across sparking contacts.

There is rarely the need to install electrical equipment actually inside the process, where it may be completely submerged with dust, or exposed to clouds for long periods. If this must be done, particular care in equipment selection is required.

10.7 Non-Electrical Equipment

As noted elsewhere non-electrical equipment may create hot surfaces, or when it is faulty friction sparks. Standards for non-electrical equipment for zoned areas are being written, but not much equipment with the CE and EX marks is yet available. Fans are one exception with BS EN 14986:2007 Design of Fans working in potentially Explosive Atmospheres. With other equipment manufacturers will typically fit ATEX rated motors and electrical equipment (not always needed if the motor is not actually in a zoned environment) and design the plant to avoid the risk of mechanical failure sparks by fitting heavier duty bearings, increasing clearances, avoiding the use of plastics and aluminium and other light metals.

Other considerations could be the fitting of flame-retardant V belts and using fire resistant lubricating fluids. They should also fit (although they may need to be persuaded of the need), explosion relief, bearing overheat/vibration transducers and in the case of belts tracking protection.

10.8 Old Equipment

The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 (EPS) came into force in 1996 and DSEAR in 2002. An exemption within the EPS regulations permitted equipment to be installed meeting the older standards until 30 June 2003. Thus any equipment newly installed or being substantially refurbished since 30 June 2003 should comply with the EPS regulations if it is situated within a zoned area. There is no requirement, however, to upgrade old equipment if it is still fit for purpose.

Existing electrical equipment built to the older BS 6467 standard should be suitable. This recognised two standards of equipment, built to dust-tight (IP6X) or dust-protected (IP5X) standards. Similarly, older style explosion relief panels using explosion membranes can still be replaced with new membrane material if needed.

Annex I - Glossary

ATEX: abbreviation for Atmospheres Explosive. This abbreviation relates to two European directives. These ATEX equipment directives appears as UK regulations - The Equipment Used in Potentially Explosive Atmospheres Regulations 1996 (EPS) sets out essential safety requirements for a wide range of equipment used in mills.

Dangerous and Explosive Atmospheres Regulations 2002 DSEAR protection directive brings into law the concept of hazardous area classification and other requirements. It appears in UK regulations - see Annex II (2).

Explosible: used to describe combustible dusts capable of exploding as a cloud. This is different from solid explosive materials (like TNT) which do not need air to explode.

Explosion Protection: methods used to reduce the effects of an explosion.

Explosion Pressure Resistant: plant is designed to withstand the explosion pressure without rupture but permanent deformation will most likely occur and is allowable.

Explosion: violent combustion reaction causing heat, flame and pressure.

Explosion Vent/Explosion Relief: a passive device designed to rupture (open) when the pressure within an enclosure reaches a predetermined level releasing the explosion pressure and combustion products into the atmosphere.

Hazardous area: an area or space where explosive atmospheres may form and special equipment is needed to prevent explosions.

IP rating: IP is an abbreviation for ingress protection. The term is used mainly for electrical equipment and relates to protection of the equipment by an enclosure to keep out dust or liquids.

Kst: dust specific measure of explosibility (bar ms-1). Maximum rate of pressure rise in a 1 cubic metre test vessel.

M.I.E.: Minimum Ignition Energy. This is relevant mainly to controlling risks from static electricity.

M.I.T.: Minimum Ignition Temperature. This may refer to a dust cloud ignition temperature or a dust layer ignition temperature. Usually the layer temperature is much lower. Layer ignition temperatures for most grain products exceed 250°C.

P.max = Maximum Explosion Pressure: the maximum pressure obtained during a confined explosion in accordance with standard test procedures.

Pred = Reduced Explosion Pressure: pressure generated by an explosion of a dust/air mixture in a vented vessel. This is the minimum required strength of equipment protected by venting. It is usually in the range 0.2 to 1 bar.guage.

Pstat: opening/rupture pressure of vent closure under static conditions, usually 0.1 bar.

ST. Class: Dust Explosibility Class - a way of grouping explosible dusts by KST value.

Class	Kst	Explosion Characteristics
ST 0	0	Non-Explosive
ST 1	0 - 200	Weak to moderate
ST 2	200 - 300	Strong
STB	Above 300	Very strong

Almost all agricultural products will be class ST1

T class: equipment for use in hazardous areas will normally be marked with a T class, indicating its maximum surface temperature in normal use. For example, T3 implies a maximum temperature of 200°C.

Zone definitions:

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
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
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.

Annex II - References

Legislation

1. Management of Health & Safety at Work Regulations 1999 (SI No.3242)
2. Dangerous Substances and Explosive Atmospheres Regulations 2002 (SI No. 2776)
3. Provision and Use of Work Equipment Regulations 1998 (PUWER) (SI No.2306)
4. Supply of Machinery (Safety) Regulations 2008 as amended (SI No.1597)
5. Equipment and Protective Systems intended for use in Potentially Explosive Atmospheres Regulations 1996 (SI No.192)
6. Regulatory Reform (Fire Safety) Order 2005 (SI No.1541)

Other Guidance

1. Barton, J. (2002). 'Dust Explosion Prevention and Protection a practical guide. Institution of Chemical Engineers.'

   Tel: 01788 578214

   Fax: 01788 560833

   e-mail: general@icheme.org.uk

   British Standards: for full details of titles and parts consult BSI

   Tel: 020 8996 9001

   Fax: 020 8996 7001

   e-mail: orders@bsi-global.com

2. Electrical equipment for dusty areas: BS EN 61241-10:2004
3. Non-electrical equipment for use in potentially explosive atmospheres: BS EN 13463
4. Hazardous Area Classification for dusty areas: BS EN 60079-10-2:2009
5. Explosion prevention and protection - basic principles: BS EN 1127-1:2011
6. Design of fans working in potentially explosive atmospheres: BS EN 14986
7. Electrical Apparatus with Protection by Enclosure for Use in the Presence of Combustible Dusts Part 1: Specification for Apparatus Specifies requirements for electrical apparatus based on the maximum surface temperature of the enclosure and on the restriction of dust ingress to the enclosure. BS 6467-1:1985
8. HSE. (2004). 'HSG 103 Safe handling of combustible dusts.' HSE Books.
9. HSE. (2013). 'Prevention of dust explosions in the food industry Web Edition.' HSE.
10. Fire safety risk assessment: factories and warehouse. Home Office. 2006 ISBN 9781851128167