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Zoning, methods of protection and equipment marking in hazardous areas

Prior to reading this document we suggest you read our e-training document "The explosion risk in hazardous areas".

ATEX95 and ATEX137

The DSEAR (the Dangerous Substances and Explosive Atmospheres Regulations) came into force in the UK in December 2002 and are intended to protect people from fires and explosions arising from dangerous substances in the workplace. In DSEAR the focus is on substances that are either flammable or explosive. The European ATEX legislation for electrical and mechanical equipment in hazardous areas came into force at the end of June 2003.

These were 99/92/EC (better known as ATEX137 or the User Directive) and 94/9/EC (ATEX 95 or the Manufacturers' Directive). ATEX 137 gives the minimum requirements for protection of workers from the risks associated with explosive atmospheres at work. DSEAR implements ATEX 137 in the UK. ATEX 95 was implemented in the UK via the "Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996".

The manufacturer (e.g. K Controls) is responsible for ensuring that the equipment is safe when it leaves its factory (ATEX95). The end user is responsible for installing, maintaining and operating the equipment in hazardous areas (ATEX 137).

The deadline for implementing the ATEX137 User Directive in all existing workplaces was 30th June 2006.

There are many companies that are now subject to ATEX regulations for the first time, due to the inclusion of dust laden atmospheres. Fires caused by dust can be equally as devastating as those caused by explosive gases and vapours. The previous regulations for explosive atmospheres did not account for the risk of explosion created by dust.

The end users responsibilities fall into the following areas:

Workers need to be trained and authorised when working in hazardous areas.
The employer must take all reasonable steps to prevent an explosion and minimise the effects of an explosion should one occur.

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The employer needs to ensure that all existing Ex protected equipment meets legislative requirements. The employer must carry out a risk assessment of any potentially explosive atmospheres and prepare an explosion protection document. The employer must classify the plant into zones and a suitable warning sign must be displayed. The employer must select ATEX compliant equipment according to the intended zone of use.

Photo: A dust explosion

The safety or plant manager is personally responsible for explosion safety.

We will now cover the following subjects in detail:

The Ignition Triangle
Area Classification
Gas Groups
Temperature Classification
Methods of Protection
Product Labeling
Flameproof (Ex d)
Increased Safety (Ex e)
Flameproof / Increased Safety (Ex ed)
Intrinsic Safety (Ex ia or Ex ib)
Flammable dusts
The ATEX Directives

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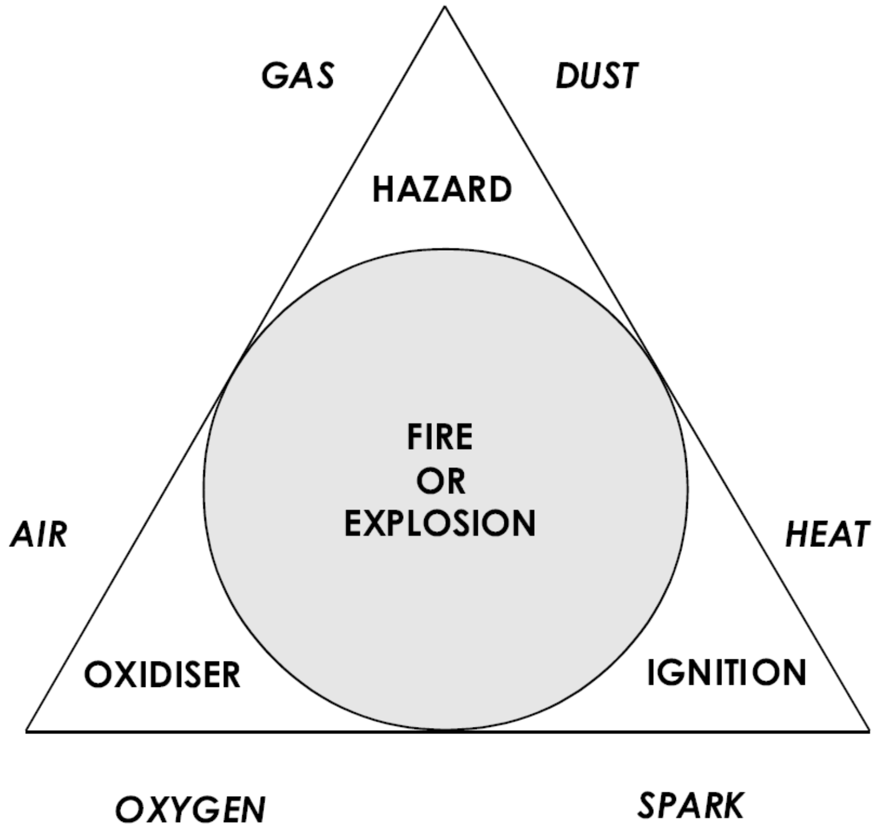
The Ignition Triangle

Fig. 1



For there to be fire or explosion there would need to be a hazard which could be either a flammable dust or gas, an oxidiser which could be either air or pure oxygen and a source of ignition which could either be heat or a spark. If these three elements are present at the same time and in the right proportions then there will be a fire or an explosion. See Figure 1.

The safest way to prevent a fire or explosion is to remove the source of the hazard. However, if this cannot be done then the process engineer has three alternatives: Remove the source of ignition, prevent the source of ignition reaching the hazard or ensure that there is no oxidiser present.

As it is not always possible to remove all hazards, the risk of a fire or explosion occurring will remain. The process engineer will examine his plant and divide it into a number of Zones. This needs to be done in order to match the method of protection used with the Zone and then design the plant accordingly. It is not possible to completely remove all risk, however, it is possible to reduce the probability of an accident happening. Process engineers are also constrained by costs. If they were to use the most expensive method of protection available, in all areas of the plant, the capital outlay would be prohibitive and plant would become uncompetitive.

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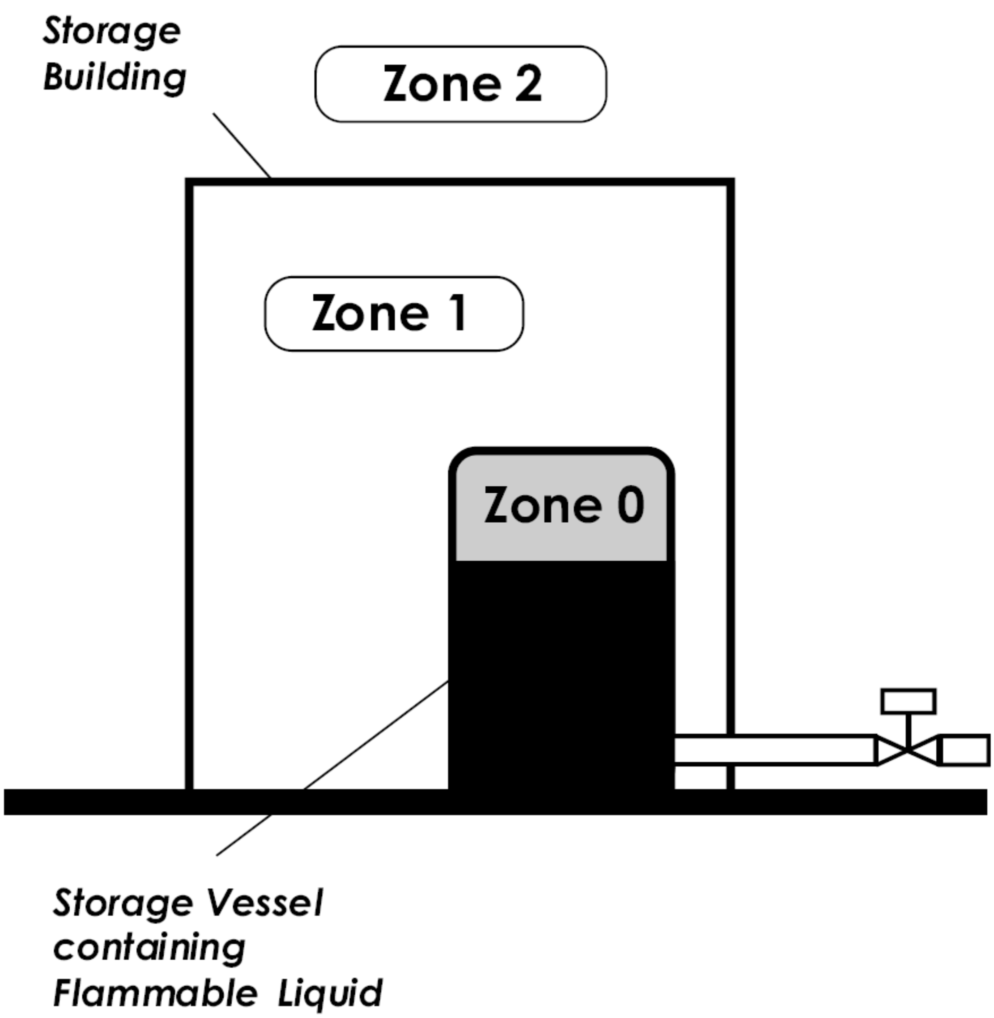
Area Classification

Fig. 2



Consider the liquid propane gas loading terminal represented in Figure 2.
Road tankers enter the terminal, fill up with liquid propane and then depart. The liquid propane is stored in a tank within a storage building. The pipe passes from the storage vessel via the wall of the storage building to the tanker loading area.

The engineer has classified the hazardous areas of the terminal area into three zones:

Zone 0 is the area above the liquid but within the storage vessel, Zone 1 is the area outside of the storage vessel but within the storage building and Zone 2 is the area immediately surrounding the storage building. Some distance from the storage building will be the non hazardous or safe area.

As a rule of thumb Zones are defined in terms of the number of hours per year that a hazard is likely to be present - In Zone 0 the hazard is likely to be present for more than a 1000 hours a year, in Zone 1 the hazard is likely to be present for between 10 and 1000 hours a year and in Zone 2 the hazard is likely to be present for less than 10 hours a year.

Gas Groupings

A process engineer classifies hazardous gases according to their ignition energy. Please return for a moment to the Ignition Triangle. Figure 1. In the bottom right hand corner you will see that ignition can be caused either by a spark or by heat. Another way to think of a spark is as ignition energy. A very small spark will be enough to ignite one type of gas but a very large spark may be needed to ignite another.

Please review the Gas Groupings in Figure 3.

Gas Groups

Fig. 3

Typical gas	Gas Group
Hydrogen	IIC
Ethylene	IIB
Propane	IIA

Defines Ignition Energy

IIC More easily ignited

IIB ↓

IIA Less easily ignited

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Temperature Classification

Unfortunately gases react in very different ways when they are exposed to hot surfaces as opposed to a source of ignition energy. For example Hydrogen can be very easily ignited with a small amount of ignition energy (20 micro joules) whereas it would need to be exposed to a very hot surface (approximately 560 degrees C) before it would ignite. For this reason gases also need to be classified by their auto ignition temperatures. Apparatus is also defined by its maximum surface temperature under certain conditions.

The higher the T Class the better the apparatus, (i.e.T6 is best). See Figure 4.
The auto ignition temperature of a gas is sometimes confused with flash point; flash point is the temperature at which sufficient vapour is given off for ignition to take place if a source of ignition is provided. Auto ignition temperature on the other hand is the temperature at which the substance will self ignite (ignition without a spark).

Fig. 4

Max surface temp*	T Class
450 C	T1
300 C	T2
200 C	T3
135 C	T4
100 C	T5
85 C	T6

* Normally assumes an ambient temperature range of -20 C to +40 C in the area where the apparatus is installed.

Methods of protection

Figure 5 gives an overview of the methods of protection that can be used in particular zones. (Please return to Figure 2 to remind yourself of the three hazardous zones). The key point to remember is that some methods of protection are not considered safe for use in certain zones. For example Ex ia which is a particularly fault tolerant form of intrinsic safety is the only method of protection that can (if ATEX category 1 certified) be used in Zone 0, this method of protection can therefore, also be used in Zones 1 and 2. Ex d or Ex e can only be used in Zones 1 or 2 and not in Zone 0.

Fig. 5

Zone	Method	Ex Class
0	Intrinsic Safety	Ex ia
1	Intrinsic Safety	Ex ia/ib
	Flameproofing	Ex d
	Increased Safety	Ex e
	Pressurisation	Ex p
	Special Protection	Ex s
2	Type N	Ex N

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Figure 6 shows the three methods of protection used with K Controls products :

Fig. 6

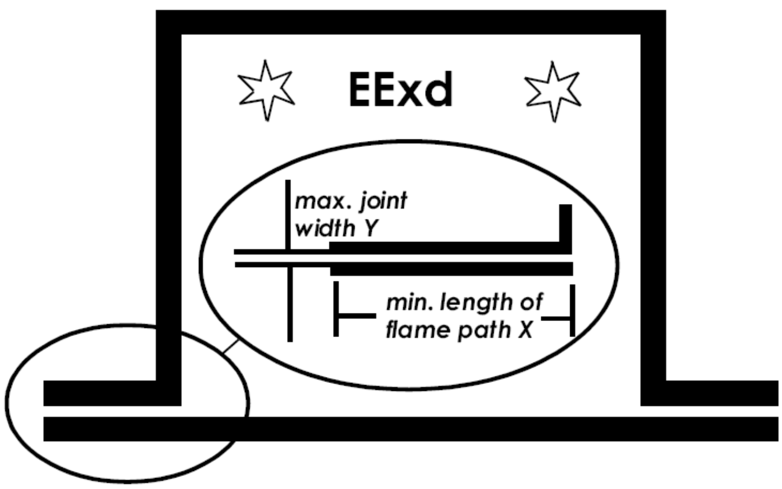
Zone	Method	Ex Class
1	Intrinsic Safety	Ex ia
	Intrinsic Safety	Ex ib
	Flameproofing	Ex d
	Increased Safety	Ex e

Flameproof Exd

Returning to the "Ignition Triangle", Figure 1, all three components, namely a hazard, an oxidiser and a source of ignition can be present within an Ex d flameproof enclosure. An internal explosion could therefore occur and the enclosure must be designed to be sufficiently robust to contain it. The internal fire or explosion is likely to be over quickly because the volume of hazardous gas and oxidiser is limited.

Flameproof (Ex d)

Fig. 7



Internal fire or explosion must be "contained" such that it does not ignite the surrounding hazardous atmosphere.

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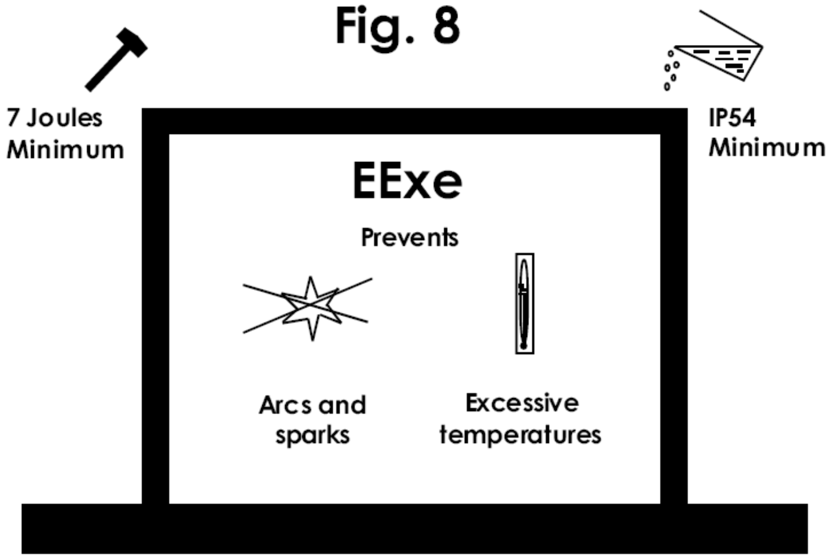
As a cover is needed to gain access to the internals a flanged joint is sometimes permitted. As it is not possible to machine the faces to produce a perfect join, a gap or "flamepath" is designed into the product. The "X" and "Y" dimensions shown in Figure 7 are a function of gas group (see Figure 3) and the volume of the enclosure. These dimensions have to be tightly controlled both during production and subsequent on site maintenance. If these dimensions are not exceeded the probability that a flame will reach the surrounding hazardous area is extremely small.

Please remember that Ex d equipment can only be installed in Zones 1 or 2.
It cannot be installed in Zone 0. (See Figure 5).

Increased Safety (Ex e)

Fig. 8



A "refined mechanical design" removes possible sources of ignition.

Increased Safety Exe

Returning to the "Ignition Triangle", Figure 1, two of the three components, namely a hazard and an oxidiser can be present within an Ex e increased safety enclosure. However, a source of ignition is not permitted. Safety is achieved by ensuring that the device is non-sparking in normal operation and under certain fault conditions.
As the enclosure does not have to withstand an internal explosion it is usually lighter, more compact and more easily sealed than an Ex d equivalent. Exe equipment must withstand defined levels of impact and ingress by dust and water. Excessive temperatures are not permitted and special terminals must be fitted to ensure there are no shorts between circuits or between a circuit and the enclosure. (See Figure 8).

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Combining two methods of protection: Flameproof / Increased safety (Ex ed)

Safety is achieved by mixing the protection concepts Ex e and Ex d. The M6 versions of K Controls 007 Switchbox and 007T Switch Terminal Box are Ex ed approved. Ex d switches are terminated via an Ex e terminal strip in an Exe enclosure. Ex ed product have no external flamepaths to maintain and although strong they are generally lighter and more compact than their Ex d equivalents. Please remember that Ex e or Ex ed equipment cannot be installed in Zone 0. (See Figure 5).

Intrinsic Safety (Ex ia or Ex ib)

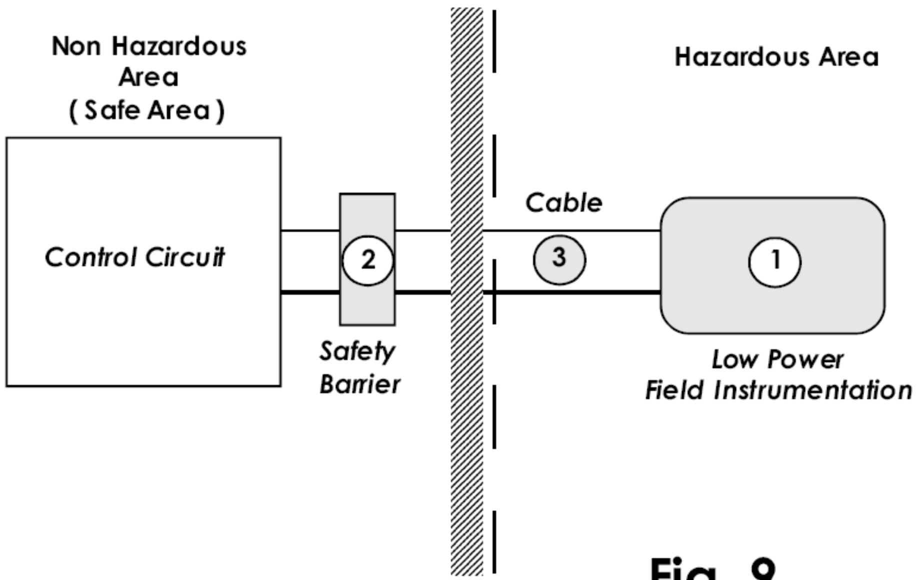

Fig. 9

Intrinsically safe system = (1) + (2) + (3)

"Energy limiting technique". Electrical energy is limited to less than the ignition energy level of the hazard.

Returning to the "Ignition Triangle", Figure 1, two of the three components, namely a hazard and an oxidiser can be present within an EEx i enclosure (see item 1 in Figure 9) however a source of ignition will not exist because the electrical energy that passes from the safe to the hazardous area is limited by a safety barrier (see item 2 in Figure 9).

A typical Zener Safety Barrier is shown in Figure 10. Current is limited by the resistors and voltage by the Zener Diodes. The electrical energy that can pass from the safe to the hazardous areas = maximum current x maximum voltage. (The fuse is included to define the maximum current and therefore the rating of the Zener Diodes. It is assumed that the barrier could be connected to the mains supply in error.) Ex ia equipment must be capable of safe operation with two faults present and Ex ib equipment with one fault present. The Safety Barrier shown in Figure 10 is Ex ib, for it to be Ex ia a further Zener Diode and a further resistor would need to be added to the circuit.

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Galvanically (electrically) isolated interface units (also known as transformer isolated or amplifier barriers) are now often used in place of Zener barriers. They have the advantage of not requiring an intrinsically safe earth and they often contain additional electronics to perform other functions e.g. converting a 0 -10v dc to a 4-20mA signal.

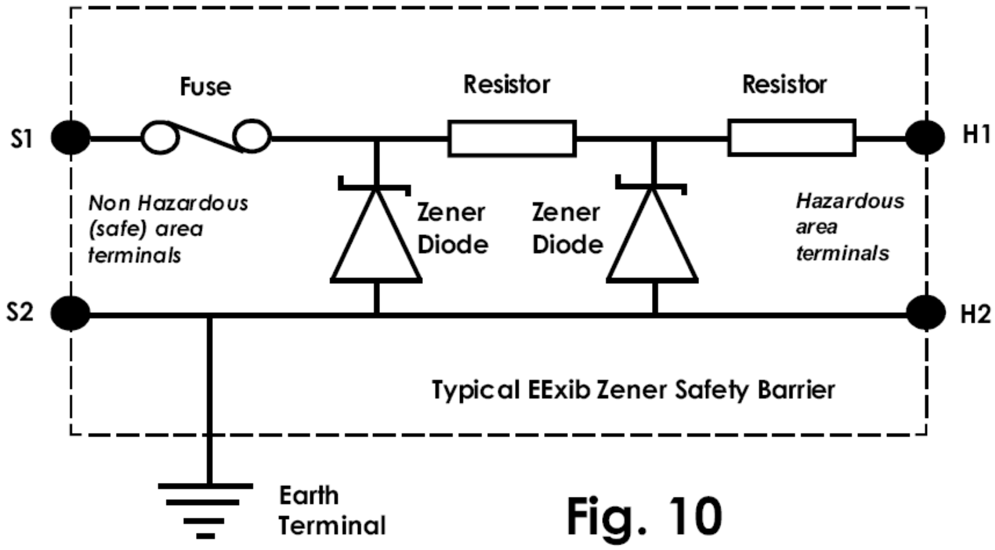

Fig. 10

"Energy limiting technique". The safety barrier limits the power (voltage x current) that can pass from the safe to hazardous area.

Unfortunately the electrical energy passing from the safe to the hazardous area can be modified by energy stored (capacitance) or induced (inductance) by the field equipment (item 1, Figure 9) and or the interconnecting cable (item 3, Figure 9). Figure 11 and Figure 12 attempt to explain capacitance and inductance.

In Figure 11 an electrical capacitor is represented by a tank of water, the electrical connection to the capacitor by a pipe with a valve in it and the connection from the capacitor by the open ended pipe at the base of the tank. The water represents the current flowing through the system. In this example when the valve is closed (the current is switched off), water (current) will continue to flow out of the tank for some time due to the capacity of the tank (capacitance of the system.) If the power to the field equipment is switched off energy could continue to be stored either within the equipment or within the cable. This must be considered when selecting a suitable safety barrier.

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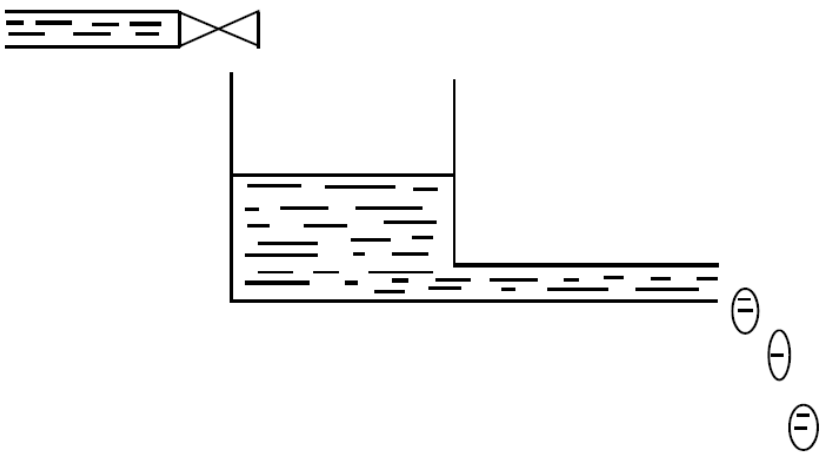
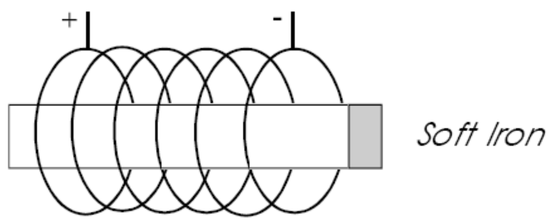
Fig. 11 Capacitance



"The property of a system that enables it to store electrostatic charge"

In Figure 12 a coil of wire surrounds a bar of soft iron. If a current is applied to the coil a magnetic flux is induced in the soft iron. If the current is then switched off then a current will be induced back into the coil. As additional energy could be induced via the field equipment and or the cable, the total inductance of the system must also be considered when selecting a suitable safety barrier.

Fig. 12 Inductance



"Relationship between magnetic flux and the current that causes it"

Field devices that can store or induce energy include solid state inductive proximity switches (e.g. K Controls types P2 and P3) and solenoid valves. As a rule of thumb the inductance and capacitance of the interconnecting cable can be ignored unless the run in the hazardous area exceeds 1000 metres.

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In order to check that a system is safe the process engineer will add the inductance and capacitance of the field device to the inductance and capacitance of the inter-connecting cable and check that the totals do not exceed the limits stated on the safety barrier.

Simple Apparatus

Simple apparatus is an electrical component of simple construction with well defined electrical parameters which is compatible with the intrinsic safety of the circuit in which it is used. Simple apparatus must not generate or store energy beyond the limits defined in the standards. A passive component such as a micro-switch is considered to be simple apparatus. Such items can to be used in intrinsically safe systems without certification but, post ATEX, the trend is now to certify products that contain simple apparatus.

Benefits of Intrinsic Safety

Intrinsic safety is the only method of protection that can be used in Zone 0. (See Figure 5). Standard instrument cable can be used. (Heavily sheathed or armoured cables are needed with Exd or Exe installations.) Live maintenance is permitted. (Not the case with Ex d or Ex e). Low power levels present no danger to personnel. (Not always the case with Ex d or Ex e). (A wide range of products from K Controls are suitable for use in intrinsically safe systems, please refer to the latest product selector.)

Applying Instrinsic Safety to Mechanical or Proximity Switch Circuits

Fig.13 shows how intrinsic safety can be applied to mechanical or proximity switch circuits. Fig. 13a shows a mechanical switch circuit. Gold plated contacts are recommended because corrosion of silver contact switches could create high resistance contact faults at the low voltages and currents used in intrinsically safe circuits. A simple Zener barrier is all that is required at the interface between the safe and hazardous areas because no additional electronics are required to perform the switching function.

In order to understand how a proximity switch can be applied it is necessary first to look at the proximity switch in a safe area installation. Fig 13c. The electronics within a proximity switch consist of an "oscillator" to sense the target, an "amplifier" to switch the current and in the case of AC switches only "a thyristor" to handle the power. In an intrinsically safe circuit, Fig 13b, it is necessary to limit the inductance and capacitance within the field device. This is done by removing the amplifer and transferring it to the safety barrier. Only the oscillator remains. This operates at nominally 8v dc and the current varies between 1 and 3 mA. The amplifier monitors this changing current and switches at a pre-determined value.

It is important to remember that intrinsically safe proximity switches will only work, therefore, with amplifier safety barriers.

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Intrinsic Safety (Ex ia or Ex ib) *Continued* **Fig. 13**

Fig. 13a **Mechanical Switches**

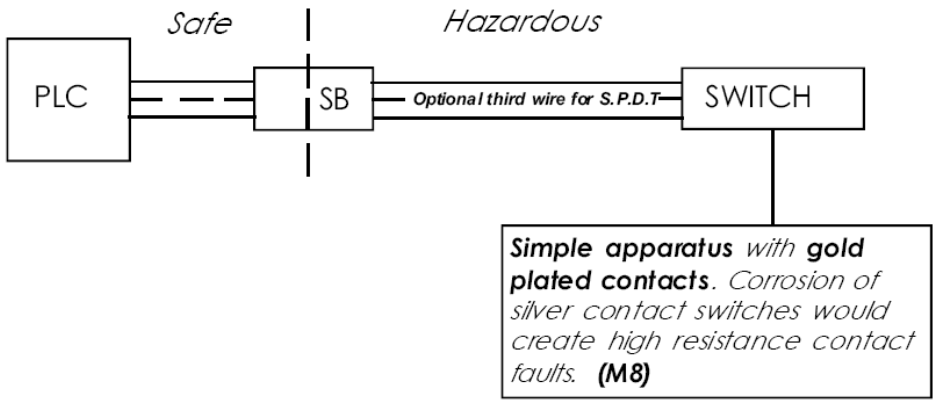


Fig. 13b **Proximity Switches**

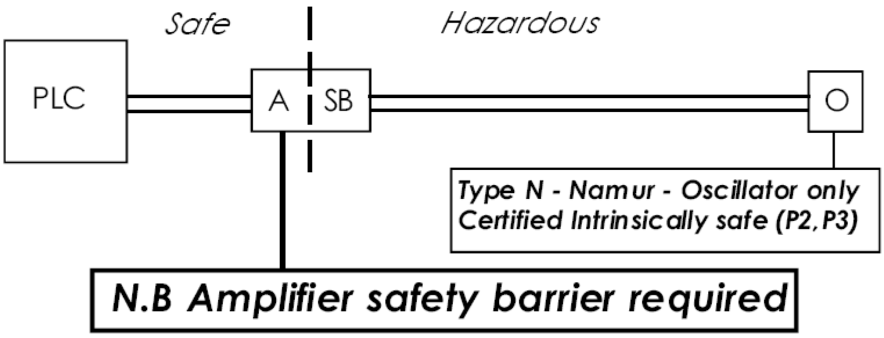
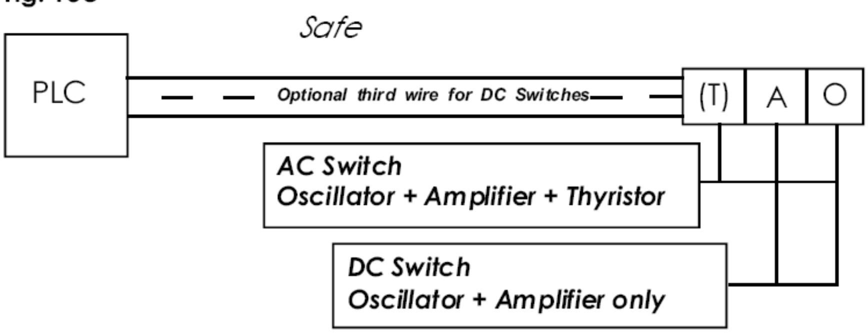


Fig. 13c



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Flammable dusts

Many materials produce flammable dust clouds that can explode if ignited. Sugar, carbon, grain, certain metals and approximately 85% of all organic powders behave in this way. Anything that can burn and which exists in a fine powdered form is a risk. Obvious examples of safe powders are sand and cement. Flammability data is much less commonly available for dusts compared to gases and vapours because factors such as particle size can affect the figures so much.

The main risk of ignition of dust hazards is from hot surfaces. Dusts may settle on surfaces and the build up can give rise to a concentration that could be ignited. Layers of combustible material will burn relatively slowly owing to the limited surface area exposed to the oxygen in the air but if you have the same solid in the form of a fine powder and you suspend it in air as a dust cloud the result will be quite different. In this case the surface area exposed to the air is much larger, and if ignition occurs, the whole of the cloud may burn very rapidly. This results in a rapid release of heat and gaseous products and in the case of a contained dust cloud will cause the pressure to rise to levels which most industrial plant is not designed to withstand. Although a cloud of flammable dust in air may explode violently, not all mixtures will do so. The concentration of dust and air must be within the upper (UEL) and lower (LEL) explosive limit of the dust in question.

Zones of Use (Dust)

Zone 20 is an area in which a potentially explosive atmosphere may occur occasionally in the form of a cloud made up of flammable dust that is part of the air permanently, over long periods of time or frequently.
Zone 21 is an area in which a potentially explosive atmosphere may occur occasionally in the form of a cloud made up of flammable dust that is part of the air.
Zone 22 is an area in which a potentially explosive atmosphere may occur in the form of a cloud made up of flammable dust that is part of the air. This does not occur normally or is only of brief duration.

Ignition temperatures of dusts

The ignition temperature of a dust is different for a cloud and a layer. For example the ignition temperature of a cloud of flour is 490 degrees C. This falls to 340 degrees C if it has settled in a layer. Please refer to the paragraph headed "Equipment Category" on the next page to learn which equipment category can be used in which dust zone.
The maximum surface temperature of the equipment as shown in the coding must not exceed the ignition temperature of the dust.

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The ATEX Directives

ATEX 95 is a term used for the European Union's Equipment Directive 94/9/EC which concerns equipment and protective systems intended for use in potentially explosive atmospheres. The purpose of the directive is to facilitate trade within the EU by aligning the laws of the Member States regarding the safety requirements for hazardous area products. This directive became mandatory on 1st July 2003. Equipment certified in accordance with the ATEX directive is CE marked. In doing so the manufacturer is also confirming compliance with other relevant directives such as the "Low Voltage Directive" or the "Electro Magnetic Compatibility Directive". In addition to complying with ATEX product certification the manufacturer has to hold a licence to manufacture equipment for use in hazardous areas. This licence is granted by a notified body such as BASEEFA and regular surveillance must take place to ensure that the manufacturer's quality management system is acceptable. ATEX 137 is a term used for the Personnel Directive 99/9/2/EC that specifies the minimum requirements for improving the health and safety protection of workers who may be at risk from exposure to explosive atmospheres. It is mandatory from Ist July 2006.

Equipment group (by industry)

Mining Equipment - Group I

Non Mining (Surface) Equipment - Group II

Equipment category

Category 1 – Very high level of protection:
(1G can be used in Gas Zone 0, 1D in Dust Zone 20)

Category 2 - High level of protection:
(2G can be used in Gas Zone 1, 2D in Dust Zone 21)

Category 3 - Normal level or protection:
(3G can be used in Gas Zone 2, 3D in Dust Zone 22)

Use in a gas atmosphere is also subject to the gas group and temperature class shown in the coding.

Use with a dust hazard is also subject to the maximum surface temperature class shown in the coding.

Category 1 equipment can be used in all Zones.
Category 2 equipment can also be used in Zones 2 and 22.

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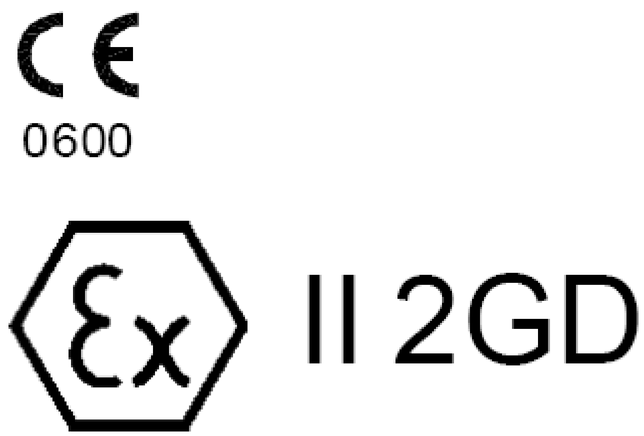
Product labelling will include the CENELEC marking however there are additional requirements :

The ambient temperature (-20C to 40C if not marked).
(Detailed after the "T rating" as "T ambient")
The CE mark and a number which indicates the notified body responsible for surveillance.
The manufacturer's type identification.
Apparatus certificate number.
Apparatus parameters.
Year of manufacture and serial number.

ATEX Group and category:

Distinctive European Community Mark + Equipment group + Equipment category + Type of explosive atmosphere G = Gas Vapour Mist D = Dust



Further reading

Further information on the UK Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) :
http://www.hse.gov.uk/fireandexplosion/dsear.htm

A guide to DSEAR for small and medium sized businesses
http://www.hse.gov.uk/pubns/indg370.pdf

Books to buy on DSEAR
http://www.hsebooks.com/books/ (Type in DSEAR in the search box)

Further information on Zoning
http://www.hse.gov.uk/fireandexplosion/zoning.pdf

E-training

K Controls designs and manufactures valve networking monitoring and control products:

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If you have any questions or comments, would like a colleague to receive this information or you would like the latest list of training documents, please use the contact details below:

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