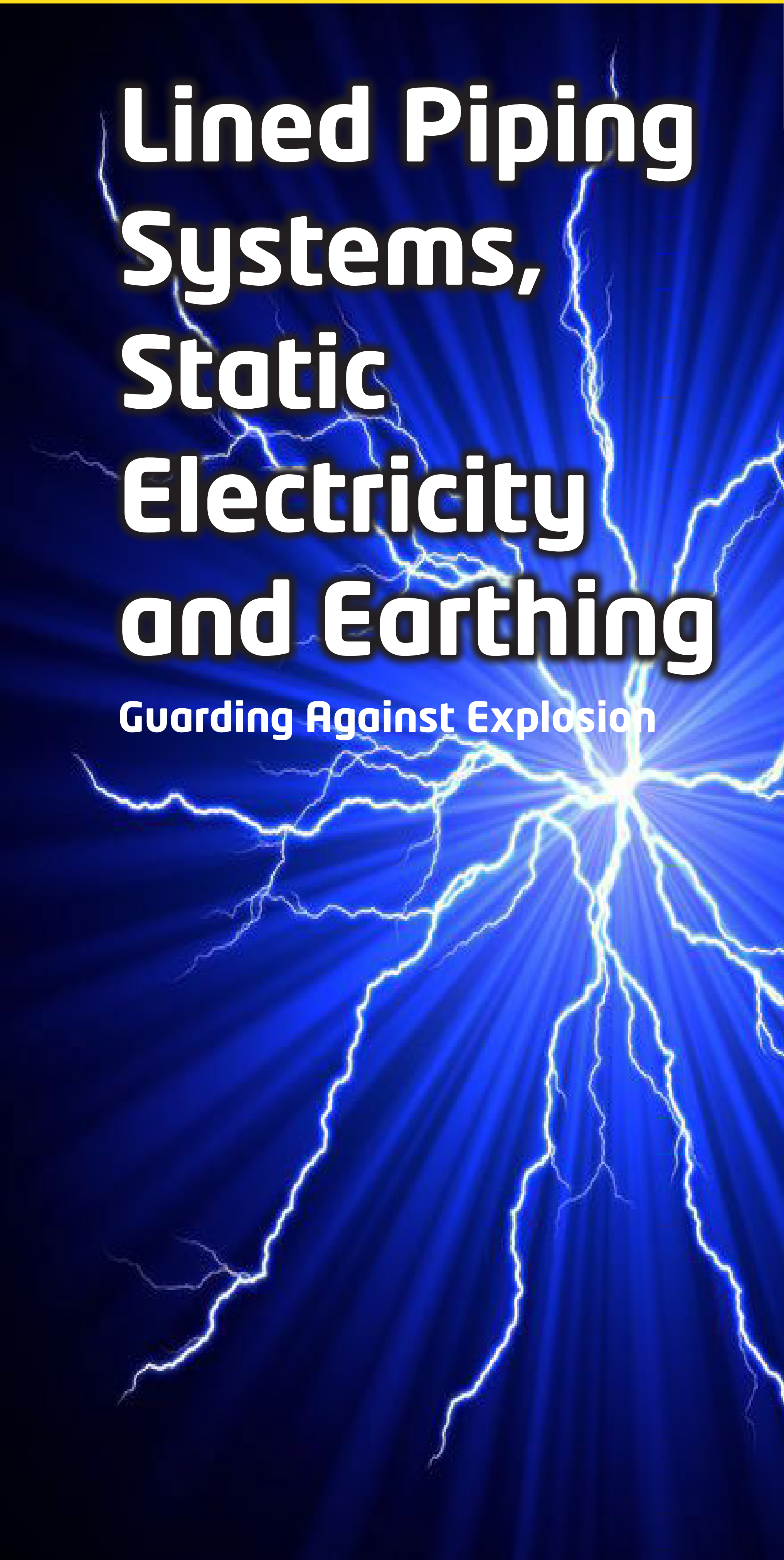

# Lined Piping Systems, Static Electricity and Earthing

## Guarding Against Explosion

crp

the corrosion expert

Every year there are unfortunate chemical plant accidents caused through the ignition of flammable chemicals. One of the key triggers is the discharge of an electrical spark generated through static charging.

The aims of this document are:

- To explain how static electricity can be generated, in particular in relation to PTFE lined pipework.
- To explain why static electricity needs to be considered due to its ability to cause potentially catastrophic explosions.
- To explain how to protect PTFE lined piping systems against the dangers of static electricity, and the role that static dissipating (antistatic) PTFE can play.
- To outline the regulatory framework for dealing with static electricity.

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# Static Electricity Generation

In its simplest form, static electricity is the accumulation of an electrical charge on an object where that charge cannot be dissipated. Charge can build up either because the item being charged is an insulator and the charge cannot flow along it to earth, or because the item is insulated from all earth paths that would allow the charge to dissipate.

The two most common ways that electrostatic charging can occur are "tribo-charging" and "induction charging".

## 1. Tribo-charging

This type of electrostatic charging is probably the best known type and is typified in terms of a child rubbing a balloon on its head to create a static charge to allow the balloon to stick to the ceiling. In more technical terms, it occurs when two dissimilar materials are brought into contact with one another. When this happens, electrons will move from one object to the other. If both materials are good conductors, all of the excess charge will flow back through the last point of contact when the two items are separated. If at least one of the two materials is a poor conductor, at least some of the charge will remain on the objects. Nb. In this circumstance, if one of the items is a good conductor, and it is earthed, the excess charge on it will almost instantly be lost to earth.

The amount of charge that will be generated through tribo-charging is dependent upon several factors, including:

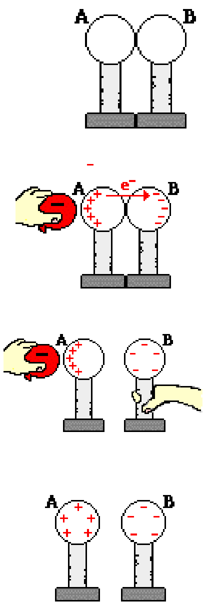
- types of material in contact.
- surface resistivity of the materials.
- ambient humidity in the environment.
- speed of contact.
- contact surface area.

Importantly, in general terms, the more energetic the contact, the greater the charge generated.

## 2. Induction Charging

When an object is exposed to an electric field, there is a tendency for charges in the item to separate, either being attracted to, or repelled from, the electric field. If the charges at one end of the item are then temporarily earthed while the item is in the electric field, this will leave a net charge on the item when it is removed from the electric field. This type of charging is illustrated in the diagram below:

Charging by Induction:




Two metal spheres are mounted on insulating stands. The spheres are in contact with each other.

A negatively charged item is brought near to sphere 'A'. This causes negative charge to flow from sphere 'A' to sphere 'B'.

Keeping the negatively charged item near to sphere 'A', the two spheres are separated.

The negatively charged item is removed from the proximity of sphere 'A', leaving a negative charge on sphere 'B' and a positive charge on sphere 'A'.

# Why it is Important to Consider Static Electricity

Due consideration should be given to static electricity because if an item that has become statically charged comes into close proximity with an item that is differently charged/earthed, this can cause a spark to jump between the two items. If such a spark were to occur in an explosive atmosphere, as can be present on many pharmaceutical and chemical plants, this could lead to an explosion.

To put this in context, on average there is one static electricity related incident or accident reported every day in Europe. In the UK there are about 50 incidents each year. The impact of these incidents can range from minor business interruption to destruction of complete manufacturing facilities with major loss of life.

In order to ascertain whether a static charge will be dangerous in any particular situation, several factors need to be taken into consideration:

- The electrical potential that the static charging can generate. These can be very high, and voltages in the range of 10kV – 30kV are far from uncommon.
- The capacitance of the item being charged (i.e. the amount of charge that it can hold). In general, the larger the object, the greater its capacitance. In this circumstance, capacitance is measured in picoFarads (pF)).
- The minimum ignition energy (MIE) of the explosive atmosphere that is present at the time of discharge (measured in millijoules (mJ)).

The following tables give several practical examples of the energy that can be stored on items found on chemical plants, and the energy required to cause an explosion in some typical explosive atmospheres that may be present.

| Object | Capacitance (pF) | Stored Energy at 10kV (mJ) | Stored Energy at 30kV (mJ) |
|---|---|---|---|
| 4" NB Flange | 10 | 0.5 | 4.5 |
| Steel Bucket | 20 | 1 | 9 |
| Person | 200 | 10 | 90 |

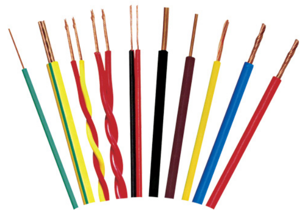
| Vapour | MIE (mJ) | Dust (in suspension) | MIE (mJ) |
|---|---|---|---|
| Methanol | 0.14 | Zirconium | 5 |
| Methane | 0.28 | Aluminium | 10 |
| Propanol | 0.65 | Wheat Flour | 50 |

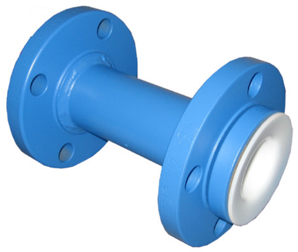
Nb. For both the vapour and dust clouds to be explosive, they need to be present in the correct concentrations. Typically, if concentrations are either too high or too low, they will cease to be explosive.

As can clearly be seen from the data above, the potential energy stored in a statically charged item of chemical plant, is easily capable of causing an explosion, should it be discharged under the right circumstances.

# Static Charging and PTFE Lined Piping

PTFE is one of the best insulators in the world, and is widely used for this purpose on electrical wiring. Due to its outstanding corrosion resisting properties, it is also widely used in the pharmaceutical and fine chemical industries as a pipe lining material.





However, if it is being used as a pipe liner on pipework that is carrying non-conducting fluids (such as many solvents), these two properties of PTFE can come into conflict. It is necessary to provide a barrier to corrosion, but the result is that, due to tribo-charging, both the PTFE and the contained fluid can become statically charged to levels that can sometimes be many kilovolts in magnitude.

## Preventing PTFE Lined Piping from causing Static Electricity Problems

As has already been stated, PTFE is an excellent insulator, and if a non-conducting fluid is flowing through PTFE lined pipework, the potential for static build up exists.

The problem of static build up splits into two sub-issues that both need to be addressed if the risk of explosion is to be minimised. The first sub-issue is dissipating any static charge that builds up on both the PTFE and within the contained fluid to the steel housing that surrounds the PTFE. The second issue is getting the static charge from the steel pipework safely to earth.

### Common Beliefs:

The inexperienced often confuse the two issues and assume that if they have dealt with the static charge in the pipework then grounding is less of an issue, or alternatively that if the plant is grounded, they do not need to worry about static generation in the piping. Neither of these assumptions is true.

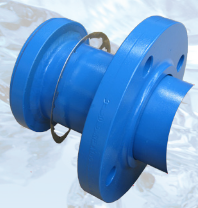
Over the years, several approaches to dealing with static build up within PTFE lined pipework have been used.

**1. Static Charge Dissipation from within Pipework**

- Design
- Earthing Spades
- Static Dissipating Materials

**2. Static Dissipation from Pipework to Ground**

- Earth studs/lugs
- Fixed Flanges and Star Washers
- CRP Spikies™



* For more information on Spikies Earth Continuity Rings, please refer to the CRP Spikies brochure.

# Preventing PTFE Lined Piping from causing Static Electricity Problems

## 1. Static Charge Dissipation from within Pipework

- ### Design

The traditional approach to the problem has been to keep flow speeds to very low levels (0.8m/s is often seen as a good rule of thumb, but each individual case needs to be considered upon its merits). In many situations this approach has been found to work well, although it results in larger bore pipework than would otherwise be necessary, and problems can arise if the contained fluid has suspended solids that are prone to fall out of suspension.

- ### Earthing Spades

A second approach, which is prevalent in the USA, has been to insert earthing spades made of either an exotic metal (such as hastelloy) or of conductive PTFE at pipe joints. Typically, these earthing spades would be electrically connected to the surrounding pipework. These spades function by allowing static charge in the contained fluid to, at least partially, discharge at pipe joints to the surrounding pipework, thus reducing the overall charge levels in the system. The downside of metallic spades is the potential for ion pickup from the metals and with all types of spade the introduction of an additional leak path. CRP can supply earthing spades in both exotic alloys and conductive PTFE.

- ### Static Dissipating Materials

The third approach, which is widely adopted in the UK and the European mainland, is to use static dissipating or otherwise generally referred to as antistatic PTFE. This is PTFE that contains a small percentage of carbon (less than 5%), which reduces the electrical resistance of the PTFE material to levels where any static charge that builds up on the inside of the pipe, next to the contained fluid, can flow through the PTFE to the surrounding steel pipework.

CRP can supply a full range of pipe and fittings lined in antistatic PTFE/PFA. It should be noted that while the antistatic PTFE used is FDA compliant, the antistatic PFA is not FDA compliant, since at present such a material does not exist. There is a section at the end of this document briefly outlining the CRP range of static dissipating piping materials.

Earthing Spade

## 2. Static Dissipation from Pipework to Ground

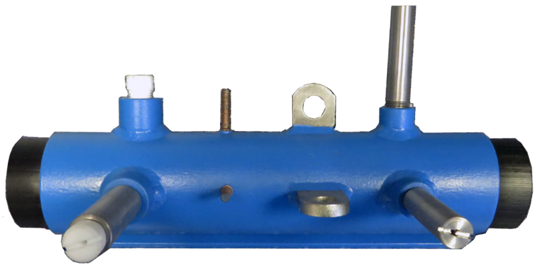
The approaches described previously only pass the static charge from the bore of the PTFE lining to the outside steel pipework. If no further action were taken, static discharges could still take place between the pipework and other items on the plant at a different electrical potential. Therefore, it is also critically important to ensure that pipework is suitably earthed.

The generally accepted value of resistance to avoid problems with static build up is that there should never be more than 10Ω resistance between any point on a plant and ground. To achieve this companies adopt several different approaches:

### • Earth studs/lugs

Earth studs or lugs are welded onto each end of pipe spools/fittings, and onto any loose flanges. Once assembled, copper earth straps are then joined onto every earth stud/lug to provide a low resistance route to earth across each pipe joint.  This system has the drawback that earth studs/lugs are open to being accidentally knocked off during fitting or operation.

CRP pipe spools and fittings can be provided with earthing studs if required for the connection of earth straps between components.  These can be fitted to both fixed and rotating components if required.  Standard component M6 x 25mm.  Other earthing connections including stud and lug configurations can be supplied to specific customer requirements.



### • Fixed flanges and star washers

The use of welded on fixed flanges ensures good earth continuity from pipe to flange on spools and fittings. To ensure good earth continuity across pipe joints, studs and star washers are employed on these joints.  The star washers serve to bite into the metal of the flanges and nuts to provide earth continuity between the two, and the threads on the nuts and studs have a sufficiently large contact area to ensure good continuity between the two.

Thus good earth continuity across the joints can be achieved. The use of fixed flanges however has the drawback that on long pipe runs accumulated minor errors in the rotational position of flanges when joints are assembled together can lead to misalignment errors at elbows/tees/valves.

# Preventing PTFE Lined Piping from causing Static Electricity Problems

- **CRP Spikies™**

Spikies are fitted between rotating flanges and stub ends on pipes and fittings and serve the same function as star washers, namely they bite into the front face of the flange and the back face of the stub end to provide earth continuity between the two items.

These are then used in conjunction with studbolts and star washers across the pipe joint. Thus, this simple system allows the user the benefits of the robustness of star washers and studs, combined with the ease of assembly of pipework with rotating flanges.

## Important Notes

In all of the aforementioned scenarios, it is critical that the entire plant is regularly joined to earth through the use of appropriate earth bonding systems.

If antistatic PTFE is being used to line pipework, this does provide a "conductive" pathway from spool to spool. As the resistance of the antistatic PTFE/PFA is many times too high to provide an earth path of less than 10Ω to ground, and therefore the use of one of the earthing systems described above is essential.

For all of the above earthing systems, it is highly recommended that the user regularly checks that earth continuity is being maintained across the whole plant.

CRP can supply pipes and fittings fitted with any of the earthing systems described previously.

# Regulatory Framework for Static Control

As with all matters relating to employee safety, the overarching piece of legislation in the UK governing this area is the Health and Safety at Work Act 1974 which requires employers to ensure, so far as is reasonably practicable, the health, safety and welfare at work of his employees.

This is governed by the so called "six-pack" of legislation. This comprises the following:

- Management of Health and Safety at Work Regulations 1999
- Provision and Use of Work Equipment Regulations 1998
- Manual Handling Operations Regulations 1992
- Workplace (Health, Safety and Welfare) Regulations 1992
- Personal Protective Equipment at Work Regulations 1992
- Health and Safety (Display Screen Equipment) Regulations 1992

These regulations have introduced the concept of risk assessment, and the requirement for the employer to undertake risk assessments on all of the activities he undertakes.

## ATEX

More recently still, on the 1st of July 2003 two EU Directives, known as the ATEX directives came into force across the EU.

- The Explosive Atmospheres Directive (2014/34/EU). This covers health and safety protection of workers. It places duties on the employer, and it is intended to ensure that workers enjoy a minimum level of protection throughout the EU. It was incorporated into UK law as part of the "Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)". Amongst other things, it defines how hazardous areas should be classified (see below) and therefore to what equipment may be used in these areas.

- Directive 94/9/EC - Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres. This covers products intended for use in hazardous areas. Duties are placed upon the manufacturer/supplier of product. It is intended to facilitate the free movement of goods within the EU. It was incorporated into UK law as "The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 (SI 1996/192)".

## Hazardous Area Classifications:

Hazardous areas are classified in terms of "Zones" on the basis of the frequency and duration of the occurrence of an explosive atmosphere. This classification determines what sort of equipment may be used in a particular location.

### Gases, Vapours and Mists

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

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

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

### Combustible Dust

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.

Notes:
1. Layers, deposits and heaps of combustible dust must be considered as any other source which can form an explosive atmosphere.

2. "Normal operation" means the situation when installations are used within their design parameters.

## Equipment Classification:

### Equipment Group I

This covers equipment intended for use in underground parts of mines, and to other area endangered by firedamp and/or combustible dust. This equipment group is split into 3 equipment categories, namely M1, M2 and M3, but discussion of this type of equipment it outside the scope of this document.

### Equipment Group II

This covers equipment intended for use in places other than those covered by Equipment Group I liable to be endangered by explosive atmospheres. This equipment group is split into 3 equipment categories:

Category 1: Equipment in this category is intended for use in Zones 0 and 20, and provides a very high level of safety. It must be able to cope with "rare incidents" relating to it. It must be protected with either 2 independent means of protection, or, be able to cope with 2 independently occurring faults.
Equipment surface temperature must not exceed its stated maximum even in the most unfavourable circumstances. Temperature rises caused by heat build-ups and chemical reactions must also be taken into account.
For equipment that can be opened (i.e. ignition source be exposed), this may only happen when it is safe. Where this is not possible, it must have a warning label. Additional interlocking equipment may be necessary.

Category 2: Equipment in this category is intended for use in Zones 1 and 21, and provides a high level of safety. It must be able to cope with frequently occurring disturbances or equipment operating faults, which normally have to be taken into account.
Equipment surface temperature must not exceed its stated maximum even in the case of abnormal situations anticipated by the manufacturer.
For equipment that can be opened (i.e. ignition source be exposed), this may only happen when it is safe. Where this is not possible, it must have a warning label. Additional interlocking equipment may be necessary.

Category 3: Equipment in this category is intended for use in 2 and 22, and is safe in normal operating conditions. It must be able to cope with normal operating conditions.
Equipment surface temperature must not exceed its stated maximum under intended operating conditions. Higher temperatures, in exceptional circumstances, may be allowed only if the manufacturer adopts special additional protective measures.
Equipment in both equipment groups, and in all categories within them, must be CE marked. For equipment in categories 1,2, M1 and M2 the manufacturer needs to involve an independent notified body. For equipment in categories 3 and M3 the manufacturer can self certify the equipment.

| Code | Protection Method | Equipment Category | How it works |
|---|---|---|---|
| Ex ia | Intrinsic Safety | 1 | Limit energy of sparks and surface temperature. Can cope with two faults. |
| Ex ib | Intrinsic Safety | 2 | Limit energy of sparks and surface temperature. Can cope with one fault. |
| Ex d | Flameproof (Explosion proof) Enclosure | 2 | Contain the explosion, quench the flame. |
| Ex e | Increased Safety | 2 | No arcs, sparks or hot surfaces. |
| Ex o | Oil Immersion | 2 | Keep flammable gas out. |
| Ex p | Pressurized Apparatus (Purged Apparatus) | 2 | Keep flammable gas out. |
| Ex q | Powder Filling (Sand Filling) | 2 | Contain the explosion, quench the flame. |
| Ex m | Encapsulation | 2 | Keep flammable gas out. |
| Ex n | Normally Nonsparking and/or Nonincendive Circuits | 3 | Won't spark or get too hot even in fault conditions. |

# Regulatory Framework for Static Control

## Protection Types:

Protection types denote the level of safety for the device.
Nb. Many pieces of equipment have an additional "E", e.g. EEx ia. This second "E" denotes that the equipment is certified to Cenelec standards.

## Gas Groups:

| | °F | °C |
|---|---|---|
| T1 | 842 | 450 |
| T2 | 572 | 300 |
| T3 | 392 | 200 |
| T4 | 275 | 135 |
| T5 | 212 | 100 |
| T6 | 185 | 85 |

Gas Groups classify the exact flammable nature of the material. Flammable gases, vapours and mists are classified in order of ease with which they can be ignited in a mixture with air. Equipment is grouped according to the gases it may be used in.

**Group IIC:**
For application in above ground installations where hazards due to hydrogen (this gas is most easily ignited) may exist.

**Group IIB:**
For application in above ground installations where hazards due to ethylene (this gas is less easily ignited) may exist.

**Group IIA:**
For application in above ground installation where hazards due to propane (this gas is least easily ignited) may exist.

**Group I :**
For application in below ground installations (mines) where methane (firedamp) and coal dust may be present.

## Temperature Codes:

Temperature Codes convey the maximum surface temperature of the apparatus based on 104° F (40° C) ambient. These temperature codes need to be selected carefully not to exceed the ignition temperature of the specific gas or vapor to be encountered in the application.

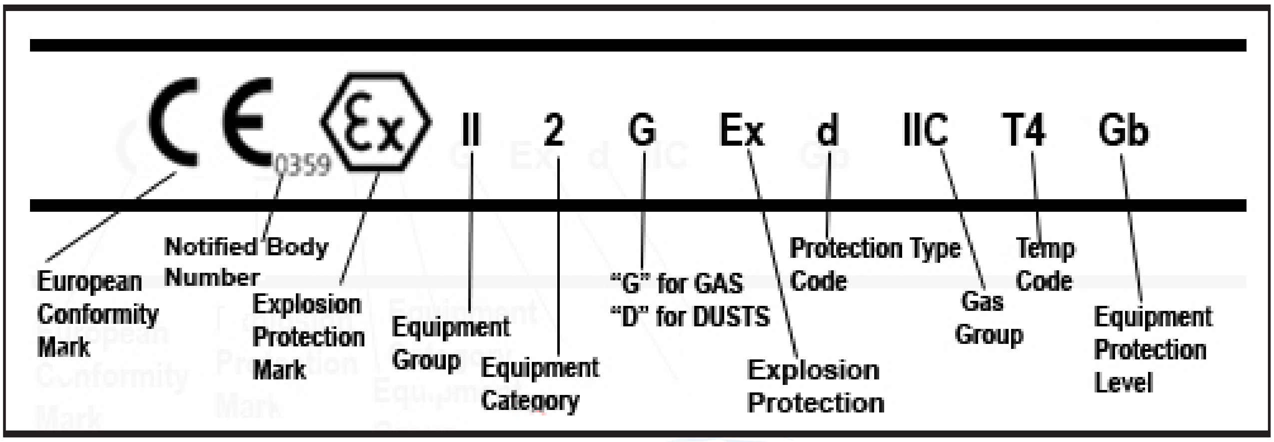
Nb. Equipment intended for use at ambient temperatures higher than 40°C is often given a dual Temperature Code, e.g. T4/T5. This means that it is rated T5 in the normal ambient of 40°C, but if the ambient temperature is raised to 85°C, the potential temperature rise in fault conditions will take it above the 100°C limit for T5, necessitating a T4 rating.

Equipment approved for use in gas environments usually has the temperature rating expressed as its T class (e.g. T6), but equipment approved for use in dust environments usually has its temperature rating expressed as an actual temperature (e.g. T85).

Some atmospheres that may be highly explosive if exposed to even a minute spark may not spontaneously ignite until quite a high temperature is reached. Similarly, some atmospheres may spontaneously ignite at quite a low temperature, but not be very susceptible to ignition from the presence of a spark.

## Product Marking:

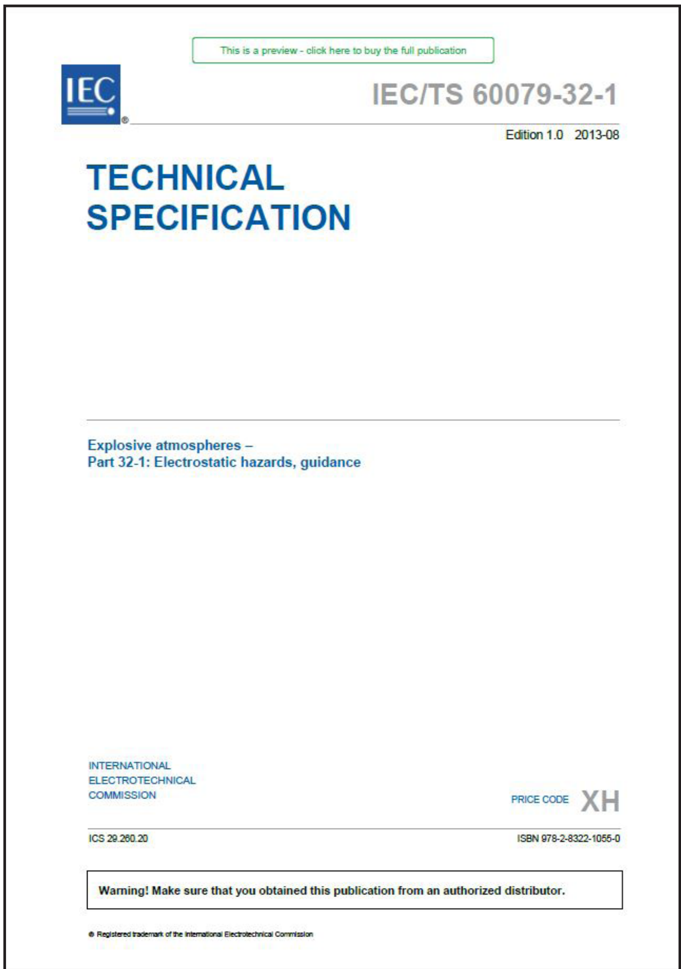
Typical markings found on an ATEX approved product would be:



# Standards Pertinent to Static

While the above provides the legal framework for dealing with hazards arising from the build up of electrical charges on process equipment "PD CLC/TR 50404:2003 Electrostatics. Code of practice for the avoidance of hazards due to static electricity. Section 4.4.2 – "Bonding of conductive items" provides practical guidance to the plant operator on how best to earth pipework and other structures.

Any advice offered in this document is CRP's understanding of the physics of static generation and methods to control it. It is up to each user to undertake their own assessment of the risks on their plant from static and decide for themselves upon the best methods to address any risks identified.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IEC/TS 60079-32-1

Edition 1.0 2013-08

TECHNICAL SPECIFICATION

Explosive atmospheres –
Part 32-1: Electrostatic hazards, guidance

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE XH

ICS 29.260.20 ISBN 978-2-8322-1055-0

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IEC/TS 60079-32-1:2013(E)
Explosive atmospheres - Part 32-1: Electrostatic hazards, guidance

IEC/TS 60079-32-1:2013(E) gives guidance about the equipment, product and process properties necessary to avoid ignition and electrostatic shock hazards arising from static electricity as well as the operational requirements needed to ensure safe use of the equipment, product or process.

It can be used in a risk assessment of electrostatic hazards or for the preparation of product family or dedicated product standards for electrical or non-electrical machines or equipment.

The purpose of this is to provide standard recommendations for the control of static electricity, such as earthing of conductors, reduction of charging and restriction of chargeable areas of insulators. If the standard recommendations given in this document are fulfilled it can be expected that the risk of hazardous electrostatic discharges in an explosive atmosphere is at an acceptably low level.

# Piping Systems

## PTFE Fluoropolymer Lined Piping Systems:

Piping systems produced by CRP are conventionally manufactured using fully fluorinated polymers-PTFE (Polytetrafluoroethylene) and PFA (Perfluoroalkoxy).

These have the well-known characteristics that cause them to be specified for chemicals applications-resistance to almost all organic and inorganic chemicals, high temperature resistance, mechanical resistance and excellent non-stick properties.

However with a volume resistivity in excess of $10^{16}\,\Omega$cm, they are capable of resisting a conductive discharge. Therefore if static dissipation is a requirement another piping system may be required. Any charge that builds up on the bores of the liners can reach voltages that can discharge through the process media, creating a spark.

## CRP Static-Dissipating Fluoropolymer Lined Piping:

CRP manufactures lined pipe and fittings in static dissipating materials. The materials are PTFE and PFA, both containing static dissipating agents-commonly referred to as having antistatic properties.
These linings are constructed in such a way as to allow potentially dangerous electrical charges to pass from the medium being conveyed within the piping system through to a safe earth point via the metal pipe.

The chemical resistance, temperature/vacuum rating and mechanical strength are unimpaired by the changes made to the electrical properties of the lining material.

For further information on our range of PTFE/PFA fluoropolymer lined piping systems please contact our sales office at +44 (0) 1706 756 400.

# CRP Static-Dissipating Fluoropolymer Lined Piping

## Materials Approvals

There are FDA approved materials for paste extrusion in static dissipating materials - so that lined pipe and 90 and 45 degree elbows can be manufactured in these materials. However there is no FDA approved static dissipating PFA, although there are precedents for its use where there is no process alternative. The PFA will not leach as it is encapsulated, but the carbon fibres used are not approved and the percentage of carbon is higher than the allowable minimum. At present there is no likelihood of a static dissipating PFA being approved by the FDA.

## Static Dissipation Verification Tests

An independent inspection company and a specialist technical consultancy conducted the following tests and provided results.

### Resistance Test

Measured BS2050 A4.5 modified for PTFE.
Result-Measured resistance 2 x $10^4\Omega$.

### Resistivity Tests

Surface Resistivity: This is the resistance to leakage of a charge across a square area of surface.
Tested as ambient temperature and 50% relative humidity.
Result-measured value (inside liner) 1.8 x $10^4\Omega$ m.

Volume Resistivity: This is the internal resistance of an insulating material to current flow. High volume resistivity guarantees that the material acts as an insulator of conversely a conductor.
Tested at ambient temperature and 50% relative humidity.

Result-measured value 2.1 x $10^4\Omega$m

### Materials Classification

The materials are classified as static-dissipative or antistatic and far exceed the minimum requirements.

### Electrical Requirements of ICI Specification EDS.PIP.53.04A June 1989

In the absence of a universally recognised international standard the above specification has been adopted by the chemical process industry as a benchmark and requires that static dissipating (antistatic) PTFE lined pipe and fittings are subject to a resistance measurement taken from the inside surface of the lined component to any point on the metal housing. This measurement must not exceed $10^7\Omega$ when tested in accordance with paragraph 16.2.2. of the specification.

All CRP's static dissipating products are tested to this standard and the results obtained are in the order of $10^4\Omega$ - a substantially better performance.

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