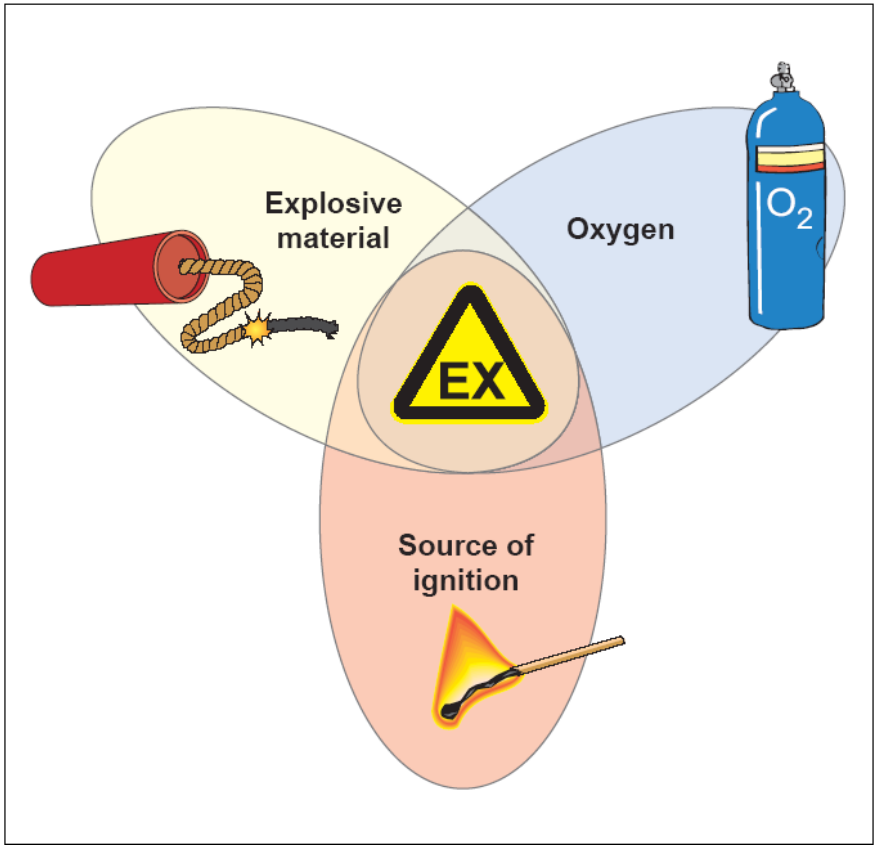
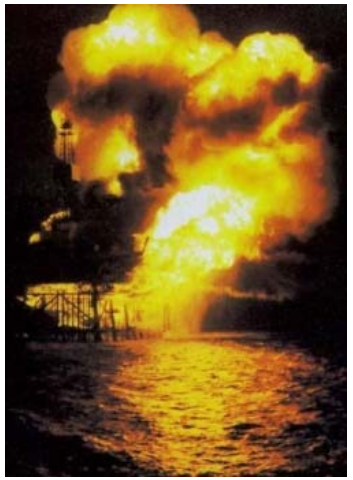
Session 2 – Explosion Protection Fundamentals

The Explosion Triangle

In order to have an explosion, all three legs of the triangle need to be present…
Our objective is to remove one or more of the legs of the triangle when we apply electrical equipment in a potentially hazardous flammable atmosphere…

All the protection concepts that are currently used in the world today address one or more legs of this triangle





Sources of Ignition in Hazardous Areas

Electrical Sparks

To ignite a flammable mixture of hydrogen and air requires only 20 micro Joules, the energy produced as a result of a break of 0.1 mS duration in a circuit carrying 20mA in 10V. Flammable gases and vapors are more readily ignited at high voltages than of low voltages, and is basically why IS circuits are seldom designed from use above 30V.

Hot Surfaces

The flow of current through, for example the windings of an electric motor invariably produces heat which will raise the surface temperature of the motor. If the motor is excessively overloaded and the thermal overload device is incorrectly set, the surface temperature of the motor may well exceed it's T-rating.

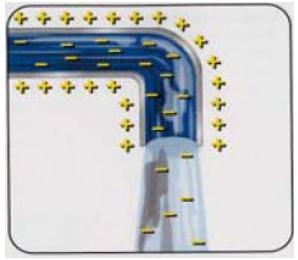
Batteries

Batteries are a potential source of ignition as they will produce incendive sparks if their terminals are short-circuited. Current of the order of 1000A can be generated if the terminals of a car battery are short-circuited. The certification of portable equipment may only allow their use in hazardous areas if powered by low-power batteries.

Sources of Ignition in Hazardous Areas

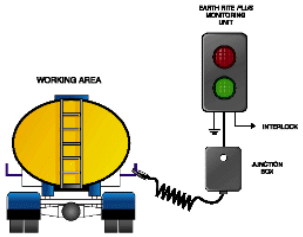
Friction

The abrasive wheels of portable grinding machines are more capable of producing incendive sparks, and hot surfaces locally at the point of contact by the abrasive wheel. Power tools unless certified shall not be used in hazardous areas.



Lightning

Lighting strikes will be readily discharged to earth by the normal metal construction of installation, but flammable gases or vapors can be ignited by lightning.



Impact

The combination of rusty iron or steel, aluminum and impact between the two is a likely source of ignition, known as thermite action, which can produce sparks capable of igniting a flammable gas or vapor. Aluminum ladders are typically not used in hazardous areas due to this fact.

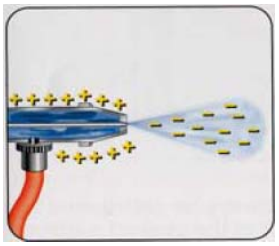
Radio Frequency

The energy transmitted by a mobile phone if used in a Zone 1 area, could be picked up by the metalwork in the area, which acting as a aerial, could produce a spark of sufficient energy to ignite the petrol vapor.

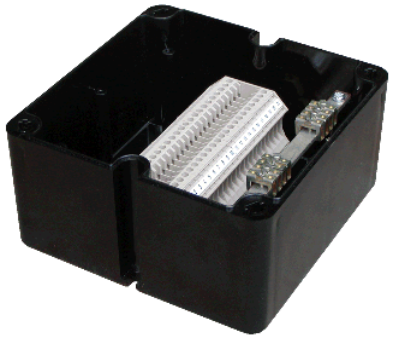
Sources of Ignition in Hazardous Areas

Static Electricity

Typical applications involve the transfer of fluids within a process plant. Up to 5000V can be generated at the nozzle of an aerosol canister. Similarly, 1000V or more can be generated at the nozzle of high pressure cleaning equipment. Bonding and earthing of aircraft or tankers during refueling prevents the buildup of electrostatic charges which otherwise might cause the fuel to ignite. Plastic enclosures normally carry the warning that they should be cleaned using a damp cloth to avoid generation of static electricity.



Excerpt from Maintenance Information on Ex e GRP enclosure



"Static Hazard

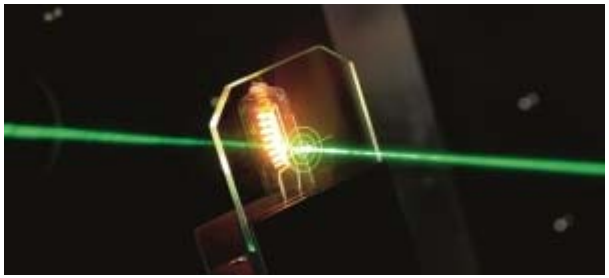
Glass Reinforced Polyester has a surface resistance of 10E9 ohms. They can present a hazard from static electricity and should only be cleaned with a damp cloth.

Carbon loaded glass reinforced, identified with the suffix "C" have a surface resistance of between 10E6 and 10E9 Ohms. They do not present a hazard from static electricity."

Sources of Ignition in Hazardous Areas

Optical Radiation

The use of optical fibres in particular opens up many fields of application. This technique offers in fact numerous advantages, however, the effect of the energy source "light" as a potential ignition source in explosive atmospheres must be given consideration.



Chemical Reaction

Mixing chemicals that have different chemical reactions can and does create significant potentially explosive environments.

Ultrasound

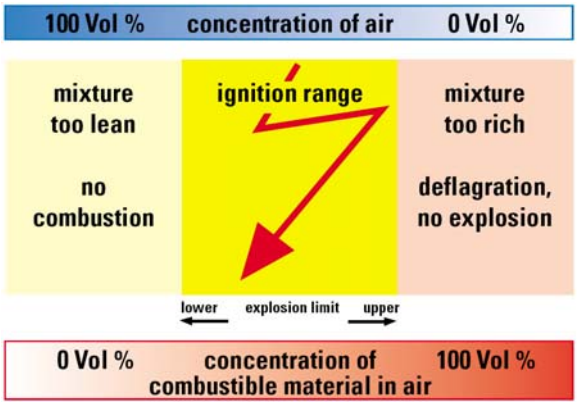
Chemical solvents may introduce a fire or explosion hazard especially if exposed directly to ultrasound. Electrical hazards are also present and should be considered especially where any liquids are involved (e.g. sonicating water baths).

Upper and Lower Flammable Limits for flammable gases and vapors

Just like your automobile, the mixture needs to be in the proper range for an explosion to occur…

GAS	LEL - UEL	INGITION ENERGY (µJ)	GAS GROUP
Acetylene	1.50% to 100%	19	IIC
Hydrogen	4.00% to 75%	85	IIC
Ethylene	2.70% to 34%	19	IIB
Methanol	6.70% to 36%	290	IIA
Propane	2.00% to 9.50%	260	IIA

Most gases fall in the 2%-10% range while Acetylene and Hydrogen have much larger ranges, hence one reason they are grouped very similar…



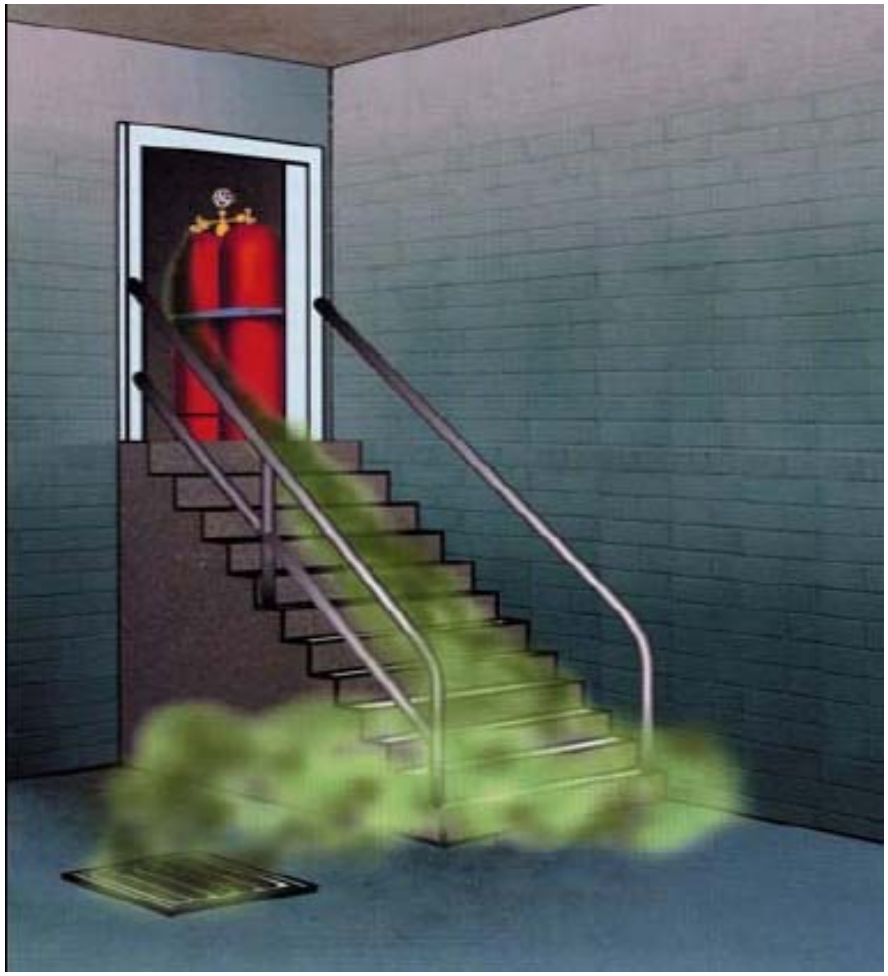
Specific Density of Flammable gases and vapors

Density ration gases to air:

Some gases are generally denser than air (propane) and have a tendency to creep over long distances and potentially ignite when exposed to an arc.

Other gases have the same density as air (acetylene, ethylene) and there is little tendency for these gases to sink or move around.

Still other gases have a density lighter than air (methane, hydrogen) and have a tendency to disperse unless contained by a container or structure.

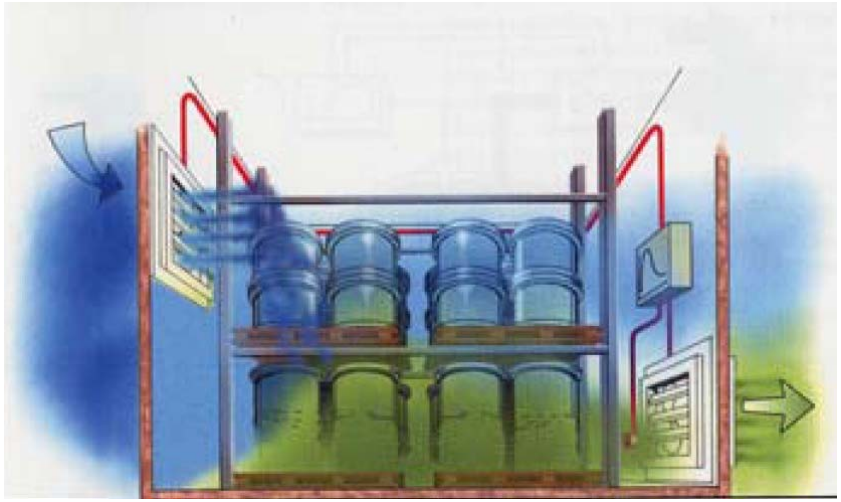


General Rules of Thumb in determining hazardous area

A continuous volume of 10 liters of explosive gases in a confined room is always considered to be a hazardous area irrespective of the size of the room…

A simple calculation is that if the volume of hazardous gas is 1/10,000ths of the volume of the room or greater, a potential for explosion can occur. This does not mean that the entire room would be classified as a hazardous area, but possibly only a part.

Where explosive pressures can rupture the vessel containing the material, much smaller volumes of gas should be considered as hazardous due to rupture from other surrounding items.

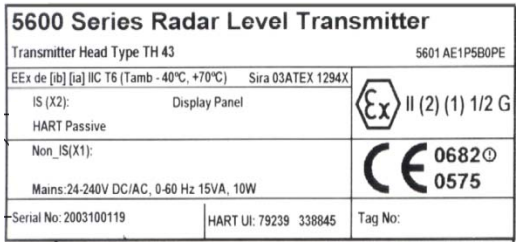


Example of proper ventilation of a contained room with heavier than air mixtures.

Gas Grouping per IEC 60079-12

Material	Ignition Temperature °C	Temperature Class	Explosion Group
1,2-Dichloroethane	440	T2	IIA
Acetaldehyde	155	T4	IIA
Acetone	535	T1	IIA
Acetylene	305	T2	IIC
Ammonium	630	T1	IIA
Petrol fuels	220-300	T3	IIA
Benzene	555	T1	IIA
Cyclohexanone	430	T2	IIA
Diesel fuels	220	T3	IIA
Acetic acid	485	T1	IIA
Acetic anhydride	330	T2	IIA
Ethane	515	T1	IIA
Ethyl ethanoate	470	T1	IIA
Ethanol	400	T2	IIB
Ethyl chloride	510	T1	IIA
Ethylene	440	T2	IIB
Ethylene oxide	435	T2	IIB
Diethyl ether	175	T4	IIB
Ethyl glycol	235	T3	IIB
Fuel oil	220-300	T3	IIA
i-Amyl acetate	380	T2	IIA
Carbon monixide	605	T1	IIA
Methane	595	T1	IIA
Methanol	440	T2	IIA
Methyl chloride	625	T1	IIA
Naphtalene	540	T1	IIA
n-Butanol	365	T2	IIA
n-Hexane	230	T3	IIB
n-Propyl alcohol	385	T2	IIB
Phenol	595	T1	IIA
Propane	470	T1	IIA
Carbon disulphide	96	T6	IIC
Hydrogen sulphide	270	T3	IIB
Toluene	535	T1	IIA
Hydrogen	560	T1	IIC

Example – Ethane has an auto-ignition temperature of 515°C which falls into suitability for equipment rated T1 or better and gas group IIA…

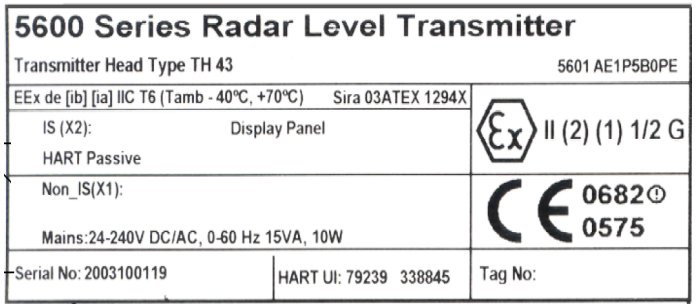


Is this product suitable areas in which Ethane is present for extended periods of time?

Yes… IIC suitability, T identification suitability and protection method suitability…

Temperature Identification Numbers

Example – Product has a marking of T6 it means that at a 40˚C ambient, the surface temperature of the product in question will never exceed 85˚C. Elevated ambient temperatures can effect the T identification number dramatically. It is best under both high and low ambient conditions to check with the manufacture to determine suitability of the product being used or considered.



Temperature Class	Max Temp limit (°C)
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85

Temperature Identification Numbers

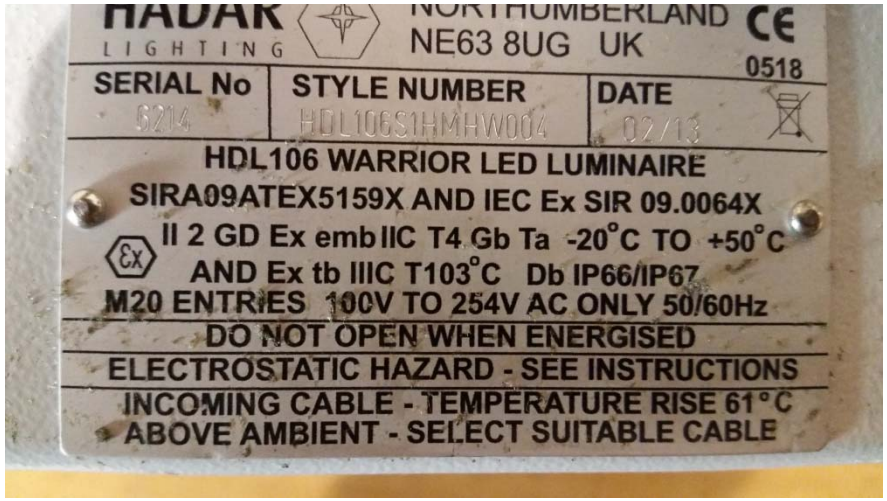
In general, if you can produce a product that is rated at T3 or better, (max. surface temperature of 200°C or cooler) you will cover approx. 90% of the flammable gases and vapors seen in the oil and gas industry…

- The lower the 'T' number, the higher the temperature.
- Hottest is worst
- Coolest is best

T1 T2 T3 T4 T5 T6

SOURCE IEx

- If the marking of the electrical equipment does not include an ambient temperature range, the equipment is designed to be used within the temperature range **–20 °C to +40 °C**.
- If the marking of the electrical equipment does include an ambient temperature range, the equipment is designed to be used within this range.
- One thing that must never be allowed to happen is that the surface (internal or external) temperature of the equipment rise beyond the ignition temperature of the gas or vapour that it is located in.



Relevant International standards for Hazardous Locations

Concept	Designation	Zone suitability	European	International
General requirements	Ex	Zone 0, 1 & 2	EN 60079-0	IEC 60079-0
Increased Safety	Ex eb	Zone 1 & 2	EN 60079-7	IEC 60079-7
	Ex ec	Zone 2	EN 60079-7	IEC 60079-7
Non-arcing	Ex nA	Zone 2	EN 60079-15	IEC 60079-15
Flameproof	Ex d	Zone 1 & 2	EN 60079-1	IEC 60079-1
Powder filling	Ex q	Zone 1 & 2	EN 60079-5	IEC 60079-5
Protected facilities and components	Ex nC	Zone 2	EN 60079-15	IEC 60079-15
Intrinsic Safety (IS)	Ex ia	Zone 0, 1 & 2	EN 60079-11	IEC 60079-11
	Ex ib	Zone 1 & 2	EN 60079-11	IEC 60079-11
	Ex ic	Zone 2	EN 60079-11	IEC 60079-11
Energy-limited apparatus	Ex nL	Zone 2	EN 60079-15	IEC 60079-15
Pressurized enclosure	Ex px	Zone 1 & 2	EN 60079-2	IEC 60079-2
	Ex py	Zone 1 & 2	EN 60079-2	IEC 60079-2
	Ex pz	Zone 2	EN 60079-2	IEC 60079-2
Restricted breathing	Ex nR	Zone 2	EN 60079-15	IEC 60079-15
Encapsulation	Ex ma	Zone 0, 1 & 2	EN 60079-18	IEC 60079-18
	Ex mb	Zone 1 & 2	EN 60079-18	IEC 60079-18
	Ex mc	Zone 2	EN 60079-18	IEC 60079-18
Oil immersion	Ex o	Zone 1 & 2	EN 60079-6	IEC 60079-6

Hazardous Area Classification….
Category Concept

Gases, Vapours, Mists	Dusts	Definition explosive atmosphere is present:
Zone 0 - Category 1G	Zone 20 - Category 1D	Continously or long term or frequently
Zone 1 - Category 2G	Zone 21 - Category 2D	Occansionally
Zone 2 - Category 3G	Zone 22 - Category 3D	Infrequently or short period
G= Gases, D=Dusts		

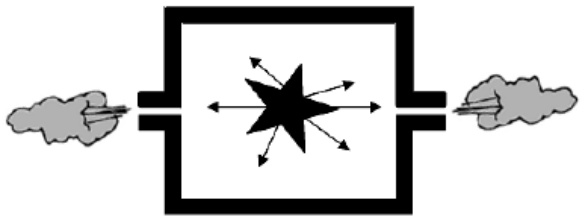
Gas Grouping for Ex ‘d’ enclosures

Explosion groups	Maximum experimental safe gap	Minimum ignition current ratio relative to methane
IIA	>0.9 mm	>0.8 mm
IIB	0.5 mm to 0.9 mm	0.45 to 0.8
IIC	<0.5mm	<0.45mm

Table 4. Minimum width of joint and maximum gap for Group IIC enclosures

Type of joint		Width of joint L	Maximum gap for volume V (cm³)			
			≤ 100	> 100 ≤ 500	> 500 ≤ 2000	> 2000
Flanged joints[1]		≥ 6 mm	0.10 mm	–	–	–
		≥ 9.5 mm	0.10 mm	0.10 mm	–	–
Spigot joints (figures 1, 2, 3)	$L = d$	≥ 6 mm	0.10 mm	0.10 mm	–	–
		≥ 12.5 mm	0.15 mm	0.15 mm	0.15 mm	–
		≥ 25 mm	0.15 mm	0.15 mm	0.15 mm	0.15 mm
		≥ 40 mm	0.20 mm	0.20 mm	0.20 mm	0.20 mm
Spigot joints (figure 4)	$c \geq 6$ mm $d_{min} = 0.5\,L$ $L = c + d$ $f \leq 1$ mm	≥ 12.5 mm	0.15 mm	0.15 mm	0.15 mm	–
		≥ 25 mm	0.18 mm[2]	0.18 mm[2]	0.18 mm[2]	0.18 mm[2]
		≥ 40 mm	0.20 mm[3]	0.20 mm[3]	0.20 mm[3]	0.20 mm[3]
Cylindrical joints		≥ 6 mm	0.10 mm	–	–	–
		≥ 9.5 mm	0.10 mm	0.10 mm	–	–
		≥ 12.5 mm	0.15 mm	0.15 mm	0.15 mm	–
		≥ 25 mm	0.15 mm	0.15 mm	0.15 mm	0.15 mm
		≥ 40 mm	0.20 mm	0.20 mm	0.20 mm	0.20 mm
Cylindrical joints for shaft glands of rotating electrical machines with rolling-element bearings		≥ 6 mm	0.15 mm	–	–	–
		≥ 9.5 mm	0.15 mm	0.15 mm	–	–
		≥ 12.5 mm	0.25 mm	0.25 mm	0.25 mm	–
		≥ 25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm
		≥ 40 mm	0.30 mm	0.30 mm	0.30 mm	0.30 mm

1) Flanged joints are not permitted for explosive mixtures of acetylene/air.
2) i_T of cylindrical part increased to 0.20 if $f \leq 0.5$.
3) i_T of cylindrical part increased to 0.25 if $f \leq 0.5$.



Relevant International standards for Dust Hazardous Locations

IEC Standard	EN Standard	Description
IEC 60079-31	EN 60079-31	Electrical apparatus for use in the presence of combustible dust - Part 1: Protection by enclosures "tD"
IEC 61241-14	EN 60069-14	Electrical apparatus for use in the presence of combustible dust - Part 1-2: Electrical apparatus protected by enclosures and surface temperature limitation - Selection, installation and maintenance
ISO/IEC 80079-20-2		Electrical apparatus for use in the presence of combustible dust - Part 2: Test methods - Section 1: Methods for determining the minimum ignition temperatures of dust
IEC 61241-10	EN 60079-10-2	Electrical apparatus for use in the presence of combustible dust - Part 3: Classification of areas where combustible dust are or may be present

Harmonization of ATEX & IECEx update (as of April 2015)

Protection Concept	Standard	Harmonization Status	Use for ATEX	Use for IECEx
Gas/Vapour General Requirements	EN50014:1997	Withdrawn	No	No
	EN 60079-0:2004 (IEC 60079-0:2004 Ed. 4	Never harmonized	No	No
	EN 60079-0:2006 (IEC 60079-0:2004 Ed 4 modified)	Contains non-technical amendments to fit the IEC standard for ATEX purposes, particularly relating to marking and instructions. Harmonisation expired June 2012	No	No
Gas/Vapour and Dusts General Requirements	EN 60079-0:2009 (IEC 60079-0:2007 Edition 5)	Harmonisation expired April 2015	No	Possible
	IEC 60079-0:2011 Edition 6 EN 60079-0:2012 (Minor corrigendum issued June 13)	The EN version omits the clauses on fans (where thereis a separate harmonised standard EN 14986:2007) Harmonisation has been delayed because of issues on the status (Normative or Informative) for some of the text in Annex ZY and information in Annex ZZ. For most purposes, it can be used as if it is harmonised	No	Yes
	EN 60079-0:2012/ A11:2013	Harmonised version of IEC 60079-0:2011 Edition 6 with all the ATEX aspects now agreed. Note that the OJ lists the 2012 edition and the 2013 amendment separately but the intention is that only the version incorporatin	Yes	Yes (except in relation to fans)

Harmonization of ATEX & IECEx update (as of April 2015)

Protection Concept	Standard	Harmonization Status	Use for ATEX	Use for IECEx
Ex d	EN 50018:2000 (inc. amendment 1)	Harmonisation expired March 2007	No	No
	EN 60079-1:2004 (IEC 60079-1:2003 Edition 5)	Harmonisation expired July 2010	No	No
	EN 60079-1:2007 (IEC 60079-1:2007 Edition 6)	Harmonised	Yes	Possible
	EN 60079-1:2014 (IEC 60079-1:2014 Edition 7)	Not yet harmonised – Delay due to concerns re cemented joints	Possible	Yes
Ex p	EN 50016:2002	Never harmonised	No	NO
	EN 60079-2:2004 (IEC 60079-2:2001 Edition 4)	Harmonisation expired November 2010	No	Possible
	EN 60079-2:2007 (IEC 60079-2:2007 Edition 5)	Harmonised	Yes	Yes
Ex q	EN 50017:1998	Harmonisation expired November 2010	No	No
	IEC 60079-5:1997 +Amd 1 (Ed 2.1)		No	No
	EN 60079-5:2007 (IEC 60079-5:2007 Edition 3)	Harmonised	Yes	Possible
	IEC 60079-5:2015 Edition 4	EN standard awaited	Possible	Yes

Harmonization of ATEX & IECEx update (as of April 2015)

Protection Concept	Standard	Harmonization Status	Use for ATEX	Use for IECEx
Ex o	EN 50015:1998	Harmonisation expired November 2010	No	No
	IEC 60079-6:1999 (Ed 2)		No	No
	EN 60079-6:2007 (IEC 60079-6:2006 Edition 3)	Harmonised	Yes	Possible
	IEC 60079-6:2015 Edition 4	EN standard awaited	Possible	Yes
Ex e	EN 50019:2000	Harmonisation expired October 2009	No	No
	EN 60079-7:2003 (IEC 60079-7:2001 Edition 3)	Harmonisation expired October 2009	No	Possible
	EN 60079-7:2007 (IEC 60079-7:2006 Edition 4)	Harmonised – Next edition due July/August 2015	Yes	Yes
Ex i	EN 50020:2002	Harmonisation expired October 2009	No	No
	IEC 60079-11:1999 Edition 4		No	No
	EN 60079-11:2007 (IEC 60079-11:2006 Edition 5)	Harmonisation expired August 2014	No	Possible
	EN 60079-11:2012 (IEC 60079-11:2011 Edition 6)	Harmonized	Yes	Yes
Ex n	EN 50021:1999	Harmonisation expired June 2006	No	No
	EN 60079-15:2003 (IEC 60079-15:2001 Edition 2)	Harmonisation expired June 2008	No	No
	EN 60079-15:2005 (IEC 60079-15:2005 Edition 3)	Harmonisation expired May 2013	No	Possible
	EN 60079-15:2010 (IEC 60079-15:2010 Edition 4)	Harmonized	Yes	Yes

Harmonization of ATEX & IECEx update (as of April 2015)

Protection Concept	Standard	Harmonization Status	Use for ATEX	Use for IECEx
Ex m	EN 50028:1987	Harmonised, but parts of the standard are now moved to 60079-1, 60079-11 and 60079-18. Much of the remainder will appear in 60079-7 due to be published July/August	No	No
	EN 60079-18:2004 (IEC 60079-18:2004 Edition 2)	(inc. Corrigendum 2006) – Harmonisation expired October 2012	No	No
	EN 60079-18:2009 (IEC 60079-18:2009 Edition 3)	Harmonised	Yes	Possible
	IEC 60079-18:2014 Edition 4	EN standard awaited Possible Yes	Possible	Yes
Ex i Systems	EN 50039:1980	Never harmonised	No	No
	EN 60079-25:2004 (IEC 60079-25:2003 Edition 1)	Harmonisation expired October 2013	No	Possible
	EN 60079-25:2010 (IEC 60079-25:2010 Edition 2)	Harmonised	Yes	Yes
Category 1G / Zone 0 Equipment / EPL Ga	EN 50284:1999	Harmonisation expired October 2009	No	No
	IEC 60079-26:2004 Edition 1		No	No
	EN 60079-26:2007 (IEC 60079-26:2006 Ed 2 modified)	Harmonisation expected to expire December 2017	Yes	Possible

Harmonization of ATEX & IECEx update (as of April 2015)

Protection Concept	Standard	Harmonization Status	Use for ATEX	Use for IECEx
Dust Protection by enclosure	EN 60079-31:2009 (IEC 60079-31:2008 Edition 1)	Harmonised With 60079-0 replaces 61241-1 and 61241-0 Harmonisation expected to expire January 2017	Possible	Possible
	IEC 60079-31:2013 EN 60079-31:2014	Harmonized	Yes	Yes
	EN 50281-1-1:1998	Harmonisation expired October 2008. Superseded by EN 61241-0 plus EN 61241-1	No	No
	IEC 61421-1-1:1999 Edition 1	Superseded by IEC 61241-0 plus IEC 61241-1 Never published as an EN	No	No
Dust General Requirements	EN 61241-0:2006 (IEC 61241-0:2004 Ed 1 modified)	EN version has both technical and non-technical amendment to the IEC text. Harmonisation expired June 2012 except when supporting EN 61241-4 Superseded by latest edition of 60079-0 which combines gas and dust requirements	Possible	Possible
Ex tD	EN 61241-1:2004 (IEC 61241-1:2004 Edition 1)	Harmonisation expired October 2012 Superseded by 60079-31	No	No
Ex pd	EN 61241-4:2006 (IEC 61241-4:2001 Edition 1)	Harmonised	Yes	Yes

Properties of Hazardous Flammable Materials

- All Electrical sparks are capable of igniting a gas/air mixture — False
- The glass surface of a light bulb will prevent ignition of gas/air mixture — False
- Any concentration of flammable gas in air maybe ignited — False
- Acetylene has the widest flammable limit range — True
- Apparatus marked Gas Group II can be used in Gas Group IIA, IIB and IIC areas — True

Properties of Hazardous Flammable Materials

- All flammable vapors will rise in the atmosphere — False
- Apparatus marked IIA can be used in a IIC hazardous area — False
- A Zone 2 area indicates that a flammable atmosphere can occur during normal operating conditions — False
- The probability and duration of a gas leak in a hazardous area is indicated by the Zone — True
- Generally, apparatus with a T3 temperature rating can be used in place of apparatus rated T4 — False