

Yale

ATEX 



Why explosion protection?

Explosion protection for electrical and mechanical machinery is an important precautionary measure to ensure the safety of persons and all kinds of production, storage and distribution systems, when explosive mixtures of combustible gases, dusts and air may occur.

What does explosion protection achieve?

Explosion protection can mean to generally prevent the occurrence of an explosive mixture. Explosion protection can also be achieved by eliminating potential ignition sources in advance, e.g. high temperatures and sparking by designing components accordingly and by permanent monitoring of operation, or by using a flame-proof enclosure for the source of ignition to protect the surrounding area against possible effects of an internal explosion.

Examples of explosion hazards in various industries:

Chemical industry

In the chemical industry, combustible gases, liquids and solids are converted and processed in various procedures. Explosive mixtures may be created during these processes.

Waste disposal sites

At waste disposal sites, combustible gases may form. Comprehensive technical measures are required to prevent their uncontrolled escaping and possible ignition.

Energy production companies

Coal dust, which may form explosive dust/air mixtures, may occur during production, breaking and drying from coal lumps which themselves are not explosive with air.

Waste management companies

The fermentation gases released during treatment of waste water in waste water treatment plants may form explosive gas/air mixtures.

Gas suppliers

If natural gas escapes through leakages or similar, explosive gas/air mixtures may be created.

Metal processing companies

During the production of formed metal parts, explosive metal dusts may occur during surface treatment (grinding). This applies in particular to light metals. These metal dusts may cause an explosion risk in separators.

Wood-processing companies

When processing wood workpieces, wood dust occurs, which may form explosive dust/air mixtures in filters or silos for example.

Paint shops

Overspray, which may occur during painting of surfaces using spray guns as well as any released solvent vapours, may form an explosive atmosphere with air.

Agriculture

Some agricultural facilities operate systems for the production of biogas. If biogas escapes as a consequence of leakages, for example, explosive biogas/air mixtures may form.

Food and feeding-stuffs industry

During the transportation and storage of grain, sugar, etc. explosive dusts may occur. When these are evacuated and separated using filters, an explosive atmosphere may occur in the filter.

Pharmaceutical industry

In pharmaceutical production, alcohols are frequently used as solvents. Furthermore, active and auxiliary substances with a dust explosion hazard may also be used.

Refineries

The hydrocarbons processed in refineries are all combustible and, depending on their flash point, are capable of causing an explosive atmosphere even at ambient temperatures.

Recycling companies

When processing recycling waste, explosion hazards may be caused by cans which are not completely empty or other containers with combustible gases and/or liquids; explosion hazards may also be caused by paper or plastic dust.

Cooperation of parties involved

Obligations of user, installer and manufacturer

Close cooperation of all parties involved is essential for the safety in potentially explosive areas.

The user is responsible for the safety of the installation. He has to assess possible explosion hazards and assign zones accordingly.

In addition, he is also responsible for ensuring that the equipment is installed in accordance with regulations and is tested before it is put into service for the first time. The equipment must be kept in appropriate condition by regular inspections and maintenance.

The installer must observe the relevant installation requirements and select and install the equipment correctly for its intended use.

Manufacturers of explosion-proof equipment must ensure that each device manufactured complies with the type-tested design.

Legal basis

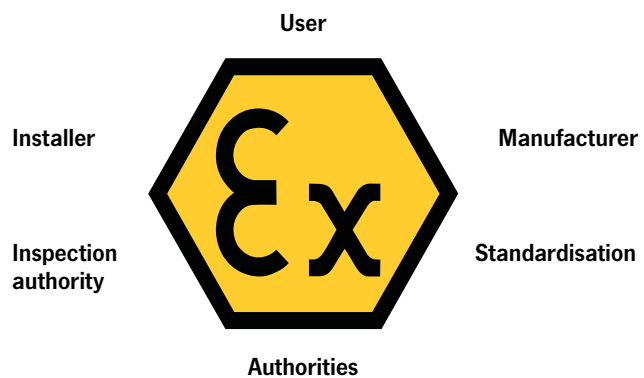
The acronym ATEX is the abbreviation of the French term "Atmosphères explosibles", which means explosive atmospheres. This designation is currently still used as a synonym for these two directives of the European Union: 2014/34/EU and 99/92/EC.

Directive 2014/34/EU is primarily intended for manufacturers of explosion-proof equipment.

Directive 99/92/EC is primarily intended for users of installations with a potentially explosive atmosphere.

Risk assessment

For taking efficient measures in areas with an explosion hazard, a risk assessment – in accordance with national health and safety regulations taking into account national industrial safety acts as well as hazardous substances ordinances must be carried out first. If this risk assessment shows that the formation of explosive atmospheres is not safely prevented, the likelihood that explosive atmospheres will occur based on their frequency and persistence, the likelihood that ignition sources will be present and become active and effective and the scale of the anticipated effects of explosions must be determined. The results of the risk assessment must be recorded in the form of an **explosion protection document**.



Technical basis

In Directive 2014/34/EU, equipment for areas with an explosion hazard is assigned to groups, categories and temperature classes. This is necessary as the requirements for equipment need not be the same for every application and for every hazard classification.

Equipment group I (mines, firedamp and combustible dusts)

Category M1	Category M2
Very high level of protection: Equipment must feature integrated explosion protection measures	High level of protection: Protection measures must ensure the required level of safety during normal operation also under arduous conditions and in particular heavy handling and under changing ambient conditions
The equipment must continue to operate in an explosive atmosphere even in the event of rare faults	It must be possible to switch off the equipment if an explosive atmosphere occurs

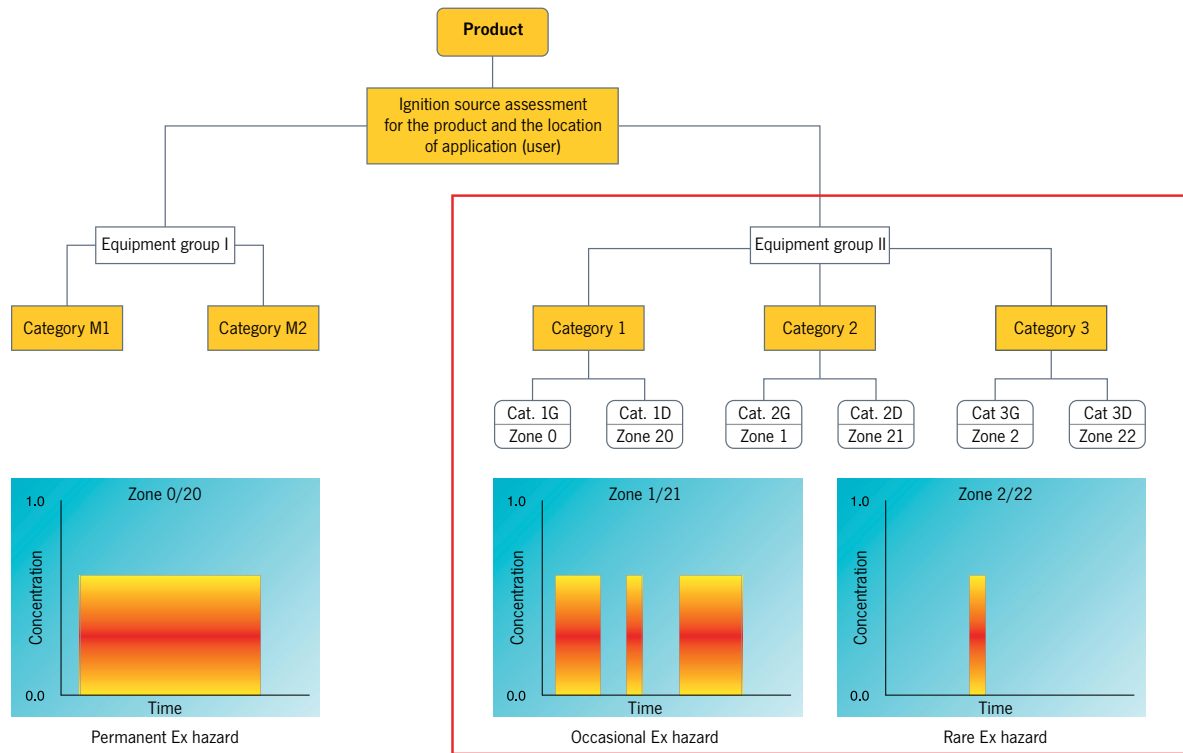
Equipment group II (explosive atmospheres caused by mixtures of gas/air or dust/air, vapours or mists)

Category	Zone		Equipment safety	Explosive atmosphere
	G [Gas]	D [Dust]		
1	0	20	Equipment which ensures a very high level of safety. In the event of rare equipment faults.	Intended for use in areas in which explosive atmospheres caused by mixtures of air and gases, vapours or mists or by air/dust mixtures are present continuously, for long periods or frequently.
2	1	21	Equipment which ensures a high level of safety. If equipment faults are to be expected.	Intended for use in areas in which explosive atmospheres caused by mixtures of air and gases, vapours or mists or by air/dust mixtures are likely to occur occasionally.
3	2	22	Equipment which ensures a normal level of safety. For normal operation.	Intended for use in areas in which explosive atmospheres caused by gases, vapours or mists or whirled up dust are unlikely to occur or, if they do occur, are likely to do so only infrequently and for a short period.

Categories and zones

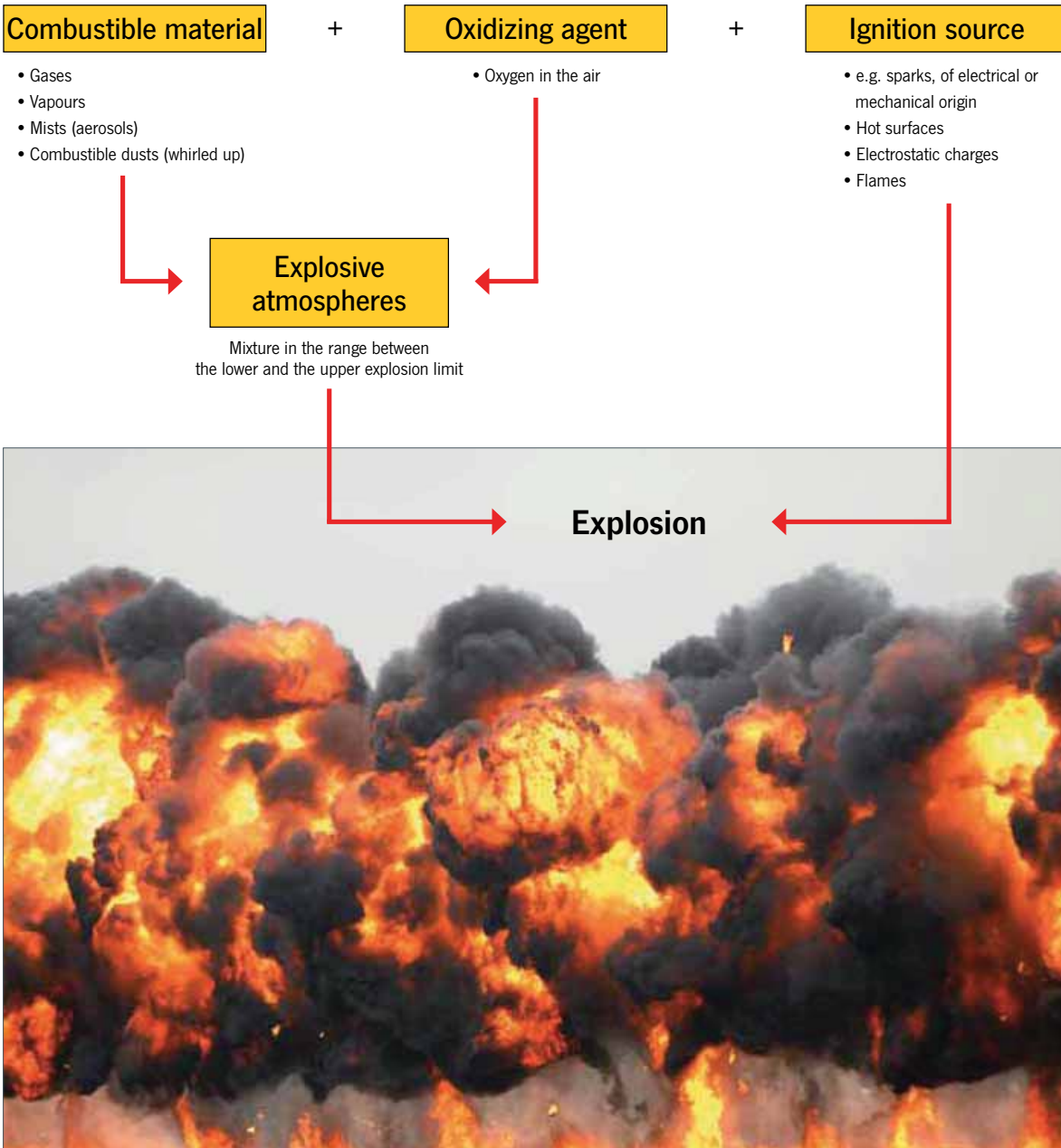
Requirements from the ATEX directives to be fulfilled by manufacturer and user

Essential requirements to be fulfilled by the manufacturer according to 2014/34/EU	Essential requirements to be fulfilled by the user according to 99/92/EG
Definition of the area for the use of equipment, specifications of equipment group II/category	Definition of zones in an installation; selection of the appropriate equipment
The equipment must comply with the essential safety and health requirements or the relevant standards	Compliance with the relevant requirements for installation, putting into service and maintenance
Category 1 Category 2 Category 3	Zone 0/20 Zone 1/21 Zone 2/22
Performance of a risk/ignition source assessment for the relevant equipment	Performance of a hazard analysis for the operating area; need for coordination
Compilation of a declaration of conformity	Compilation of an explosion protection document
Appropriate quality assurance	Regular updating



Preconditions for an explosion

Explosive atmospheres may occur wherever combustible gases, vapours, mists or dusts can form. These are mixtures which produce a chemical reaction when they meet the oxygen in the air; this reaction may trigger an explosion, even if only an extremely small spark occurs.



Explosion limits

In order to prevent an explosion, the relevant key data of combustible substances must be observed.

Mixtures can only cause an explosive ignition within a specific range. This is defined by the lower and the upper explosion limit.

Explosion limits of selected gases and vapours

Substance designation	Explosion limits in air	
	lower volumes %	upper volumes %
Acetone	2.5	13.0
Benzol	1.2	8.0
Methane	5.0	15.0
City gas	4.0	30.0
Hydrogen	4.0	75.6

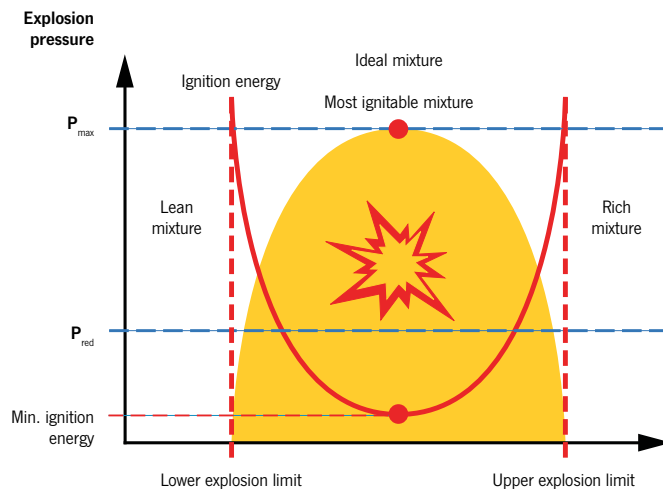
Minimum ignition energy

The minimum ignition energy is an explosion related parameter.

It describes the ignition sensitivity compared to the discharge of static electricity.

Examples for minimum ignition energy

Substance designation	Min. ignition energy
Mustard seed oil	3.8 mJ
Methane	0.29 mJ
Ethylene	0.082 mJ
Hydrogen	0.017 mJ



Primary explosion protection	Secondary explosion protection	Tertiary explosion protection
Prevent the formation of potentially explosive atmospheres	Prevent the ignition of potentially explosive atmospheres	Restrict the effects of an explosion
Inerting ¹	Open flames	Explosion-pressure resistant design
Limit concentration under the lower explosion limit	Hot gases	Pressure compensation surfaces for buildings
	Hot surfaces	Explosion suppression
	Electrical sparks	
	Atmospheric discharge	

¹ Inerting substances

Inerting substances means their transformation or processing into slow-reacting (inert) substances. Inert substances are, for example, inert gases, glass and porcelain. In refuse dump systems, inerting is used, for example, to render hazardous waste substances harmless. Substances containing heavy metal, which are radioactive or otherwise detrimental, are, for example, often glazed in order to make it possible to finally dispose of them.

Inerting rooms

Inerting rooms means to displace the oxygen contents in the air or potentially reactive or explosive gases or gas mixtures in rooms by adding inert gases or vapours. When inerting as a protection against fire and explosion (industry example: chemicals storage or production facilities), the oxygen contents in the air are displaced by adding inert gas (e.g. argon, nitrogen, carbon dioxide) in order to prevent an explosive atmosphere. In fire protection, this is also called "active fire prevention by permanent inerting".

Temperature classes

The ignition temperature is the lowest temperature of a heated surface at which the gas/air or vapour/air mixture ignites. In other words, it represents the lowest temperature value at which a hot surface is capable of igniting the corresponding explosive atmosphere.

Thus the highest surface temperature of any equipment must always be less than the ignition temperature of the gas/air or vapour/air mixture.

Temperature classes

Temperature classes	Permissible max. surface temperature of the equipment	Ignition temperature range of the mixtures
T1	450 °C	> 450 °C
T2	300 °C	> 300... ≤ 450 °C
T3	200 °C	> 200... ≤ 300 °C
T4	135 °C	> 135... ≤ 200 °C
T5	100 °C	> 100... ≤ 135 °C
T6	85 °C	> 85... ≤ 100 °C

Explosion groups

Equipment of group II, for appropriate use in explosive gas atmospheres may also be classified by the type of explosive area.

Explosion groups

Explosion group of the explosive atmosphere	Equipment with marking of the explosion group which may be used in these atmospheres
IIA	IIA, IIB, IIC
IIB	IIB, IIC
IIC	IIC

Explosion groups and maximum experimental safe gap

Explosion group	Maximum experimental safe gap
IIA	> 0.9 mm
IIB	≤ 0.9 - ≥ 0.5 mm
IIC	< 0.5 mm

This classification is based on the Maximum Experimental Safe Gap (MESG) and the Minimum Ignition Current (MIC) of the gas mixture (see IEC 60079-12) or the explosion groups can also be used for classification of the equipment based on their inflammability.



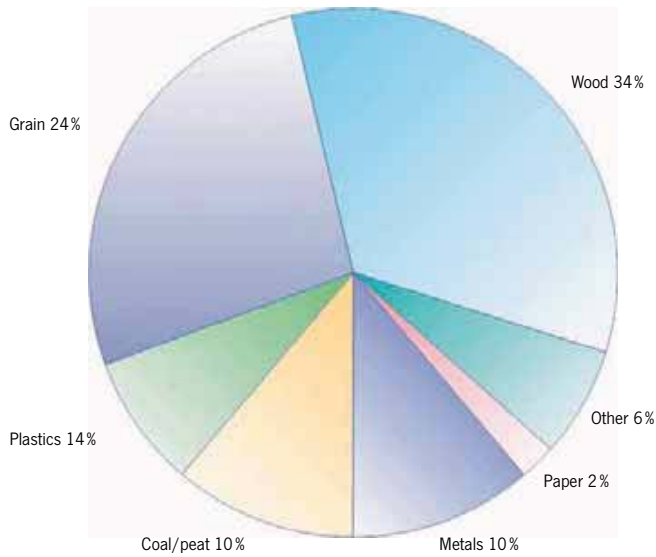
Classification of combustible gases, vapours and mists

Explosion groups and temperature classes of some gases and vapours (selection)

Classification of combustible gases, vapours, mists

Ex group	Temperature classes					
	T1	T2	T3	T4	T5	T6
	Ignition temperature range of the mixtures					
	> 450 °C	> 300 ≤ 450 °C	> 200 ≤ 300 °C	>135 ≤ 200 °C	>100 ≤ 135 °C	>85 ≤ 100 °C
	Permissible max. surface temperature of the equipment					
	450 °C	300 °C	200 °C	135 °C	100 °C	85 °C
IIA	Acetone	Ethanol	Petrol (general)	Acetaldehyde		
	Ammonium	i-Amyl acetate	Diesel fuels			
	Benzene (pure)	n-Butane	Aircraft fuels			
	Acetic acid	n-Butanol	Fuel oil DIN 51603			
	Ethane	Cyclohexan	n-Hexane			
	Ethyl acetate	Acetic anhydride				
	Ethyl chloride					
	Carbon monoxide					
	Methane					
	Methanol					
	Methyl chloride					
	Naphthalene					
	Phenol					
	Propane					
Toluene						
IIB	City gas	Ethylene	Ethylene glycol	Ethyl ether		
		Ethylene oxide	Hydrogen sulfide			
IIC	Hydrogen	Acetylene				Carbon disulphide





Dust-explosion protection

Today, in many industries, powder or dust-like products are processed or are by-products of the production process.

The vast majority of all dust-like substances pose a danger of fire or – under certain conditions – even explosion. A dust layer of only 1 mm in a closed room is already sufficient to trigger an explosion when the dust is whirled up and ignited.

The graphic shows that many different industries are affected by the hazard of dust, ranging from the food-stuffs and wood-processing industries, paper and plastic material production to the pharmaceutical industry.

Compared with gas explosions, dust explosions have a different process of propagation which may in some cases be much more devastating. If a gas/air mixture is ignited, the pressure of the resulting explosion causes the gas cloud to dissipate rapidly and thus finally dilutes the gas/air mixture to a concentration lower than that necessary for further combustion. If no further gas is added, the explosion is over after several milliseconds.

With combustible dusts it is different: If, for example, a draft of air whirled up a layer of dust, the dust, together with oxygen, forms a combustible dust/air mixture. If this mixture is ignited by an ignition source, an explosion is triggered.

The resulting blast wave whirled up further dust layers, which are in turn also ignited. This process continues, and, under adverse conditions, “chain reactions” such as these sweep through entire buildings or facilities and destroy them.

As is the case with gases, there are various ignition sources for dusts, such as sparks generated by electrical or mechanical processes, electric arcs, open flames, electrostatic discharges, electromagnetic waves and others.

Permissible equipment IP code¹ by zones and type of dust

Zone 20	Zone 21 Zone 22 electrically conductive dust	Zone 22
IP 6X	IP 6X	IP 5X
Marking II 1 D	Marking II 2 D	Marking II 3 D

¹ IP code = International protection code: EN 60529; VDE 0470-1 degrees of protection provided by enclosures (IP code)

Definitions in dust explosion protection

Term	Definition	Remarks
Explosive dust atmosphere	Mixture with air, under atmospheric conditions, of combustible substances in the form of dust or fibres in which, after ignition, combustion spreads throughout the entire unconsumed mixture. (EN 50281-1-1,3,4)	The condition is that the process ends only after one reactant has been entirely consumed.
Atmospheric condition	Range of pressure between 0.8 and 1.1 bar Temperature range between -20 °C and +60 °C	
Hazardous explosive atmospheres	Explosive atmosphere in hazardous amount. The presence of a hazardous explosive atmosphere must be assumed if ignition causes an exothermal reaction that endangers persons, domestic animals and property	A thickness of a dust layer of less than 1 mm on the floor of a normal room is sufficient to fill it with a hazardous explosive atmosphere.

Safety characteristics of dusts

Characteristic	Definition/description	Remarks
Particle size	Dust with a particle size larger than 400 µm is not considered to be ignitable. Dust particles are ignitable when they measure less than 20 µm up to 400 µm.	Due to abrasion, the transportation and processing of coarse dust result in the formation of fine dust.
Explosion limits	For most dust/air mixtures of combustible substances the lower explosion limit is approx. 20... 60 g/m ³ air and the upper explosion limit approx. 2... 6 kg/m ³ air.	In this case allocation of particle size, density, humidity as well as the ignition point is decisive.
Maximum explosion pressure	In enclosed containers of simple design, combustible dust can reach explosion pressures of 8... 10 bar.	For light metal dusts the explosion pressure can exceed this value.
KSt value	This is a classification value which expresses the shattering effect of the combustion. Numerically, it is equal to the value of the maximum rate of explosion pressure rise during the explosion of a dust/air mixture in a 1 m ³ vessel.	This value is the basis for calculating explosion pressure relief surfaces.
Moisture	The moisture of a dust is a significant factor for its ignition and explosion behaviour. Currently it is only known that a higher moisture content requires a higher ignition energy and impedes the formation of dust swirls.	
Minimum ignition energy E_{min}	Lowest energy of an electrical spark which is sufficient to effect ignition of the critical (most easily ignitable explosive) dust/air mixture under defined framework conditions.	Not every spark is ignitable. The decisive factor is whether sufficient energy is introduced into the dust/air mixture to initiate a self-sustaining combustion of the entire mixture.
Ignition temperature $T_{zünd}$	The lowest temperature of a hot inner wall (e. g. furnace) on which the dust/air mixture is ignited after brief contact. The surface temperature must not exceed 2/3 of the ignition temperature in °C of the relevant dust/air mixture, e. g. starch/milk powder/gelatine: Ignition temperature 390 °C x 2/3 = 260 °C max. permissible surface temperature $T_{max} \leq \frac{2}{3} T_{zünd}$	
Smouldering temperature T_{glimm}	The lowest temperature of a hot surface on which ignition occurs in a dust layer with a thickness of 5 mm. On surfaces where a dangerous deposit of ignitable dust is not effectively prevented, the surface temperature must not exceed the ignition temperature reduced by 75 K of the respective dust. With layer thicknesses over 5 mm, a further reduction of the temperature of the surface is necessary: e. g. wood, grinding dust Ignition temperature 290 °C - 75 °C = 215 °C max. permissible surface temperature $T_{max} \leq T_{glimm} - 75 K$	The smoldering temperature is usually well below the calculated ignition temperature of a dust cloud. The smoldering temperature decreases almost linearly with an increase in the layer thickness. For the acceptable surface temperatures safety clearances have to be adhered to.



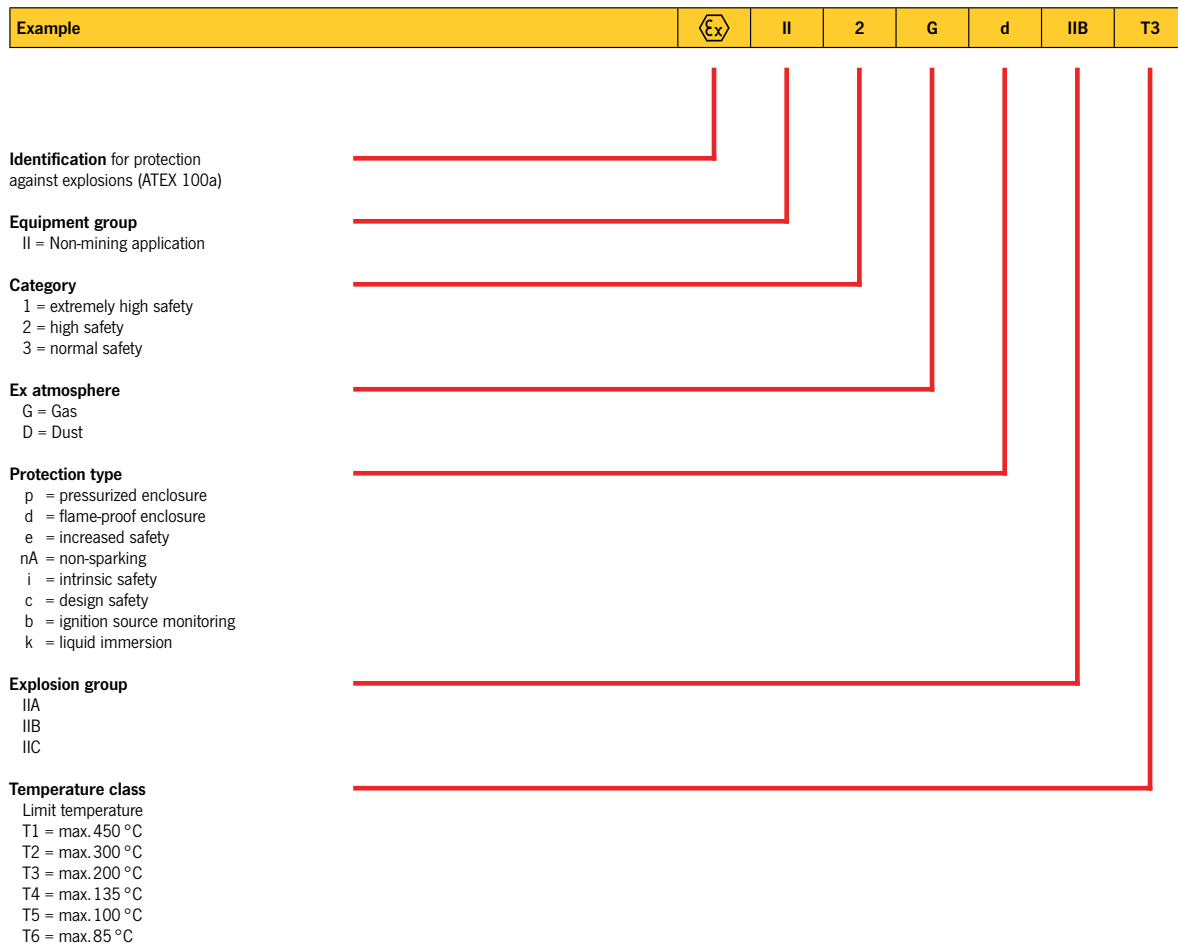
Explosion characteristics of dusts

Generally applicable values for dust-specific characteristics cannot be specified.
The table shows some limit values for selected products:

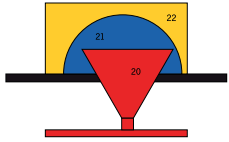
Examples of explosion characteristics of dusts

Substance	T _{zünd} [°C]	T _{glimm} [°C]	ØE _{min} [mJ]	min [mJ]
Wood	≥ 410	≥ 200	≥ 100	6
Lignite	≥ 380	≥ 225	–	5
Coal	≥ 500	≥ 240	≥ 1000	13
PVC	≥ 530	≥ 340	≥ 5	< 1
Aluminium	≥ 560	≥ 270	≥ 5	< 1
Sulphur	≥ 240	≥ 250	10	5
Lycopodium	≥ 410	–	–	–

Marking key



International comparison of zones in areas with an explosion hazard

Country	Standard	Zone/division		
AS	AS 2430.2:1986	Class II		
GB	BS6467.2:1988	Z	Y	
DE	VDE 0165:1991	10	11	
USA	NEC 500-6: 2002	Div. 1	Div.2	
EU	EN50281-3:2002	20	21	22
INT	IEC 61241-10:2004	20	21	22
EU	EN 61241-10:2005			
		Area 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.	Area in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur occasionally in normal operation.	Area in which during normal operation, it is not to be expected that an explosive atmosphere occurs in the form of a cloud of combustible dust in the air, if it does occur, however, only for a brief time.

