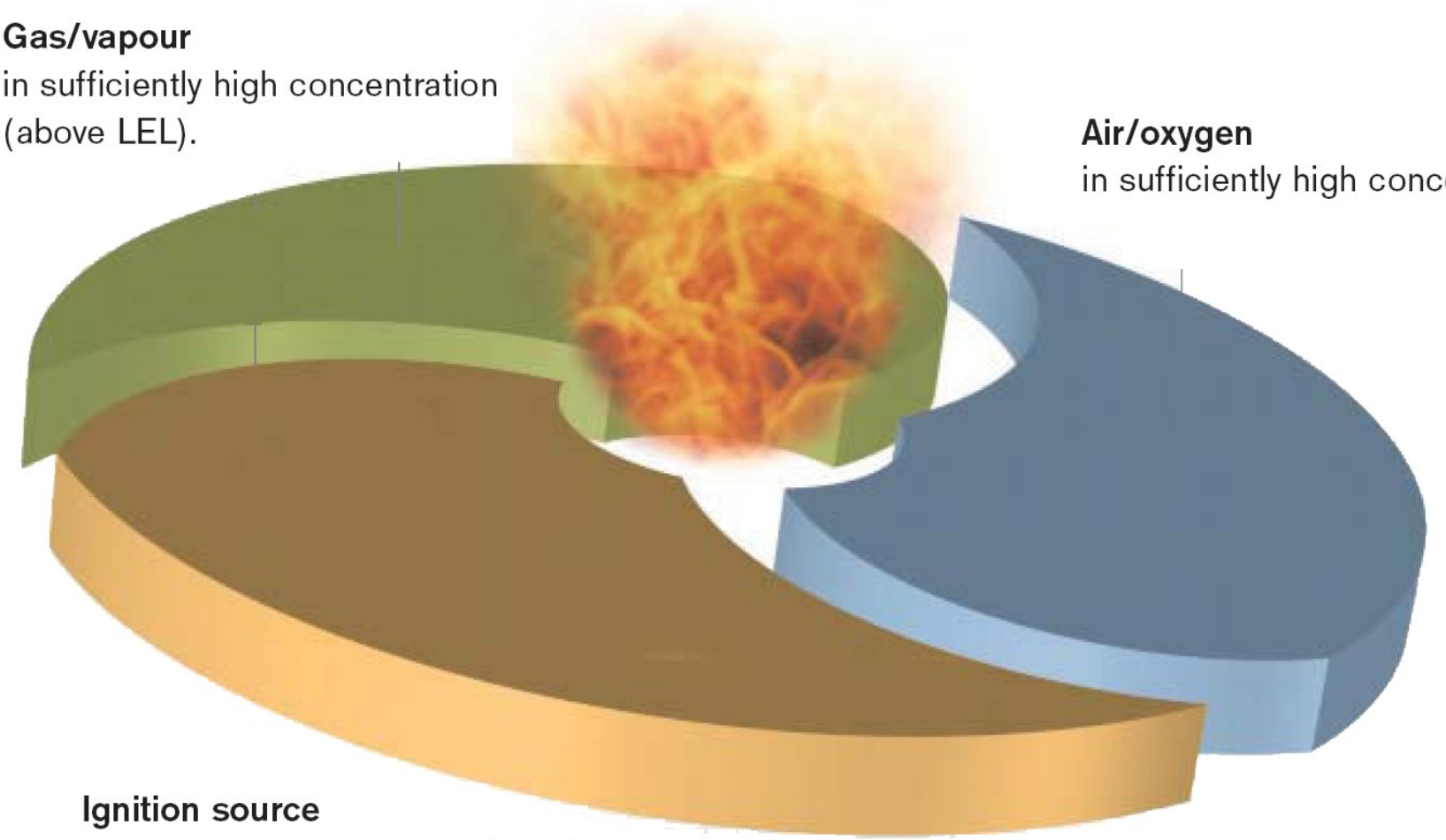
Explosion Protection

A short review of protection methods

Explosion triangle

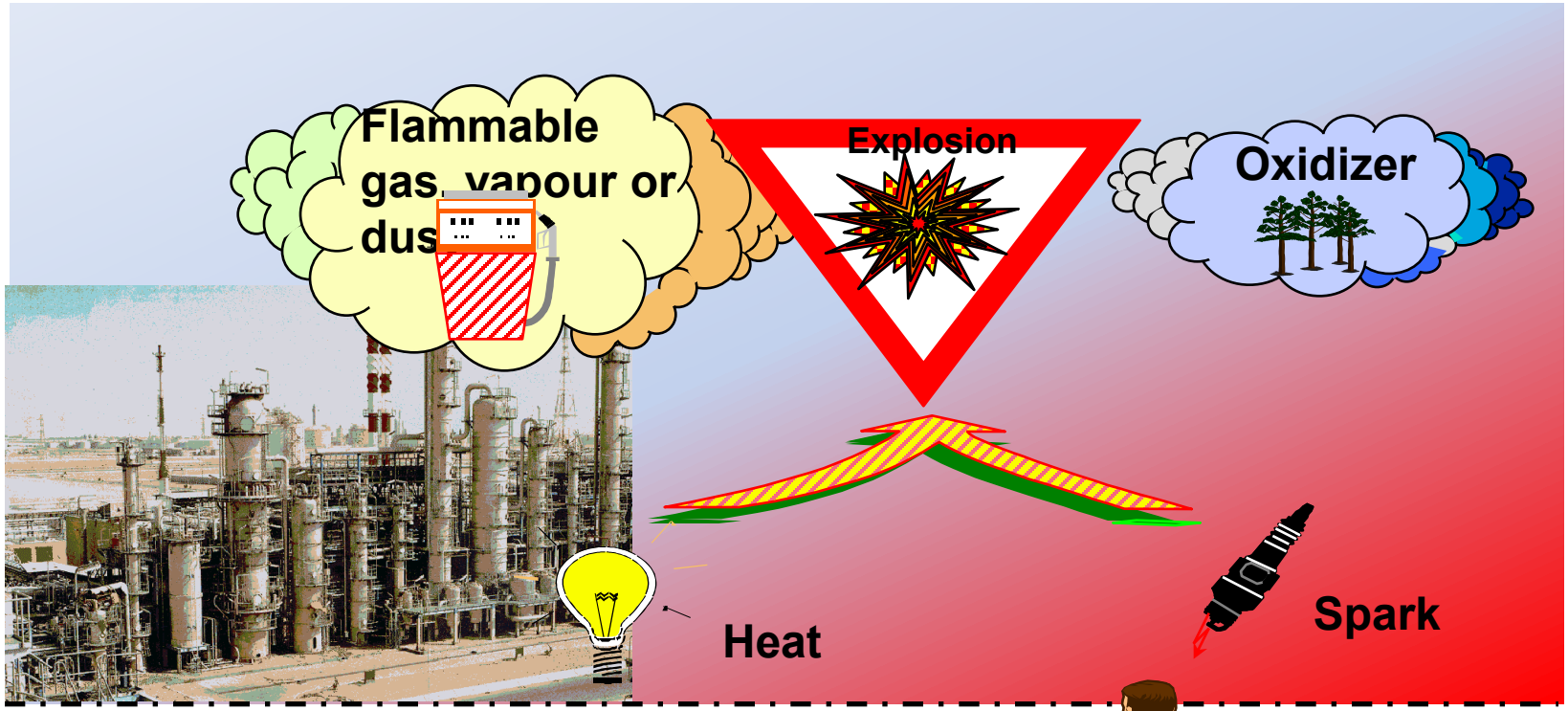
Gas/vapour
in sufficiently high concentration
(above LEL).

Air/oxygen
in sufficiently high concentration.

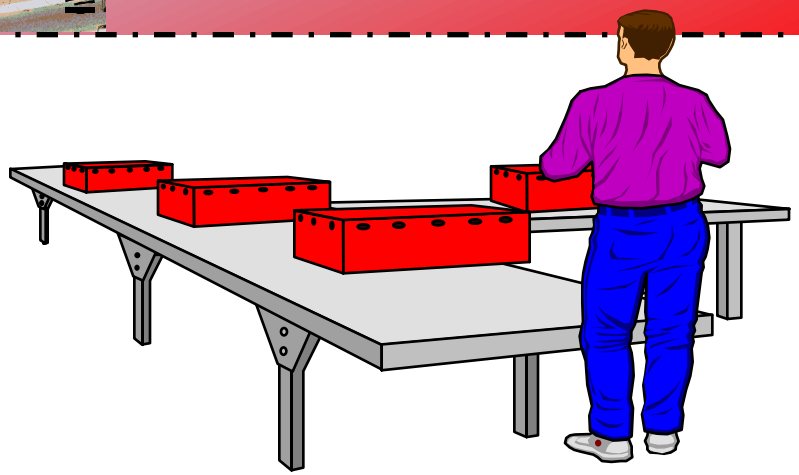


Ignition source
e.g. ignition spark with sufficient energy
or sufficiently high temperatures.

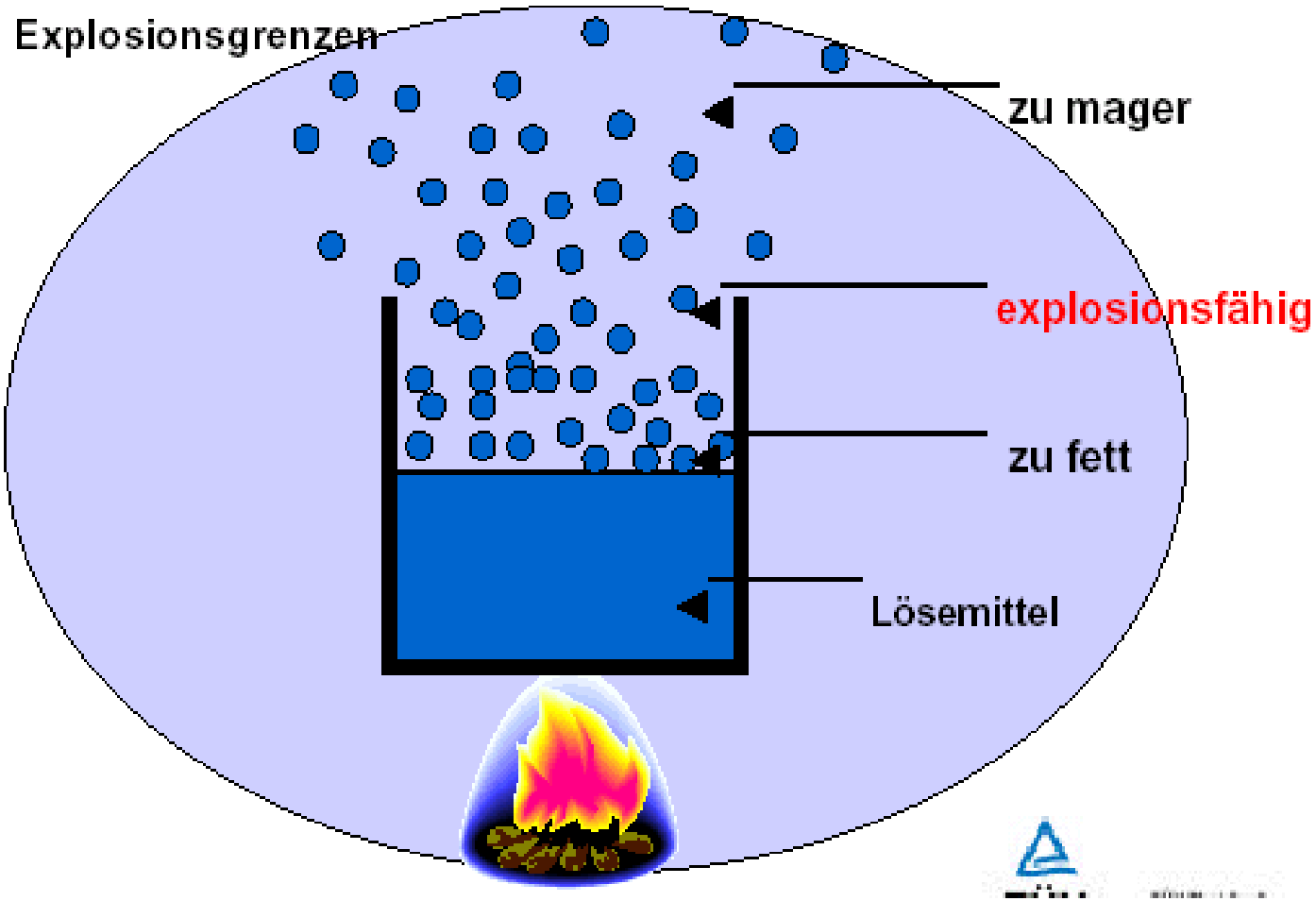
Hazardous Area



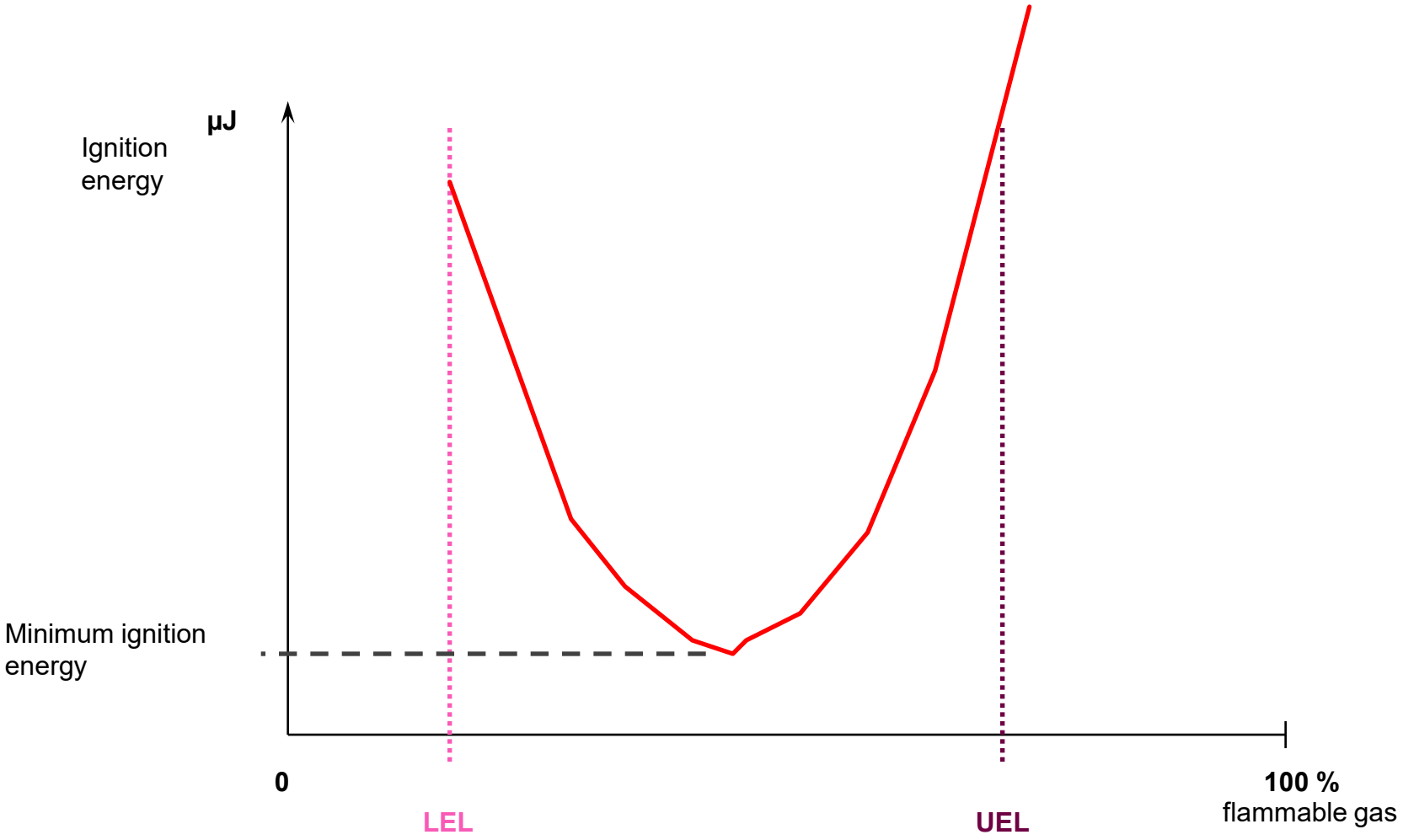
Non Hazardous Area



Explosion limits



Ignition characteristic (concentration)



Static electricity (human body)

Limit of the human sensitivity for static electricity:

$$\approx 2 \text{ kV}$$

Capacity of the human body to earth:

$$\approx 200 \text{ pF}$$

Stored energy:

$$W = \tfrac{1}{2} CV^2 \; ; \; W = 0.5 \times 200 \times 10^{-12} \times 4 \times 10^{6} \text{ J}$$

$$W_{\text{human body}} = 400 \text{ J} = 0.4 \text{ mJ}$$

Ignition energy (examples)

Substance (mixture with air)	Minimum ignition energy [mj]	Best ignition %
Acetylene	0,019	7,7
Ammonia	680,00	
Benzene	0,20	4,7
Diethyl ether	0,19	5,1
Ethane	0,25	6,5
Ethylene	0,07	
Methanol	0,14	14,7
Methyl acetate	0,11	6,5
Propane	0,25	5,2
Carbon bisulphide	0,009	7,8
Hydrogen	0,019	28

Substance (mixture with oxygen)	Minimum ignition energy [mj]
Acetylene	0,0002
Diethy lether with 86% vol	0,0012
Ethane	0,0019
Ethylene	0,0009
Propane	0,0021
Hydrogen	0,0012

Ignition energy



Ignition temperature

- The lowest temperature of a heated surface at which, under specified conditions, the ignition of a flammable substance in the form of a gas vapour mixture with air will occur.
- The flammable gases are classified in temperature classes according to their ignition temperature.
- The electrical apparatus are classified in the same temperature classes according to their surface temperature.

Dust

Generic name for dispersed firm material

- Dust consists in a huge quantity of small particles

- Particle size lower than ca. 400 µm (0,4 mm) are considered as explosible

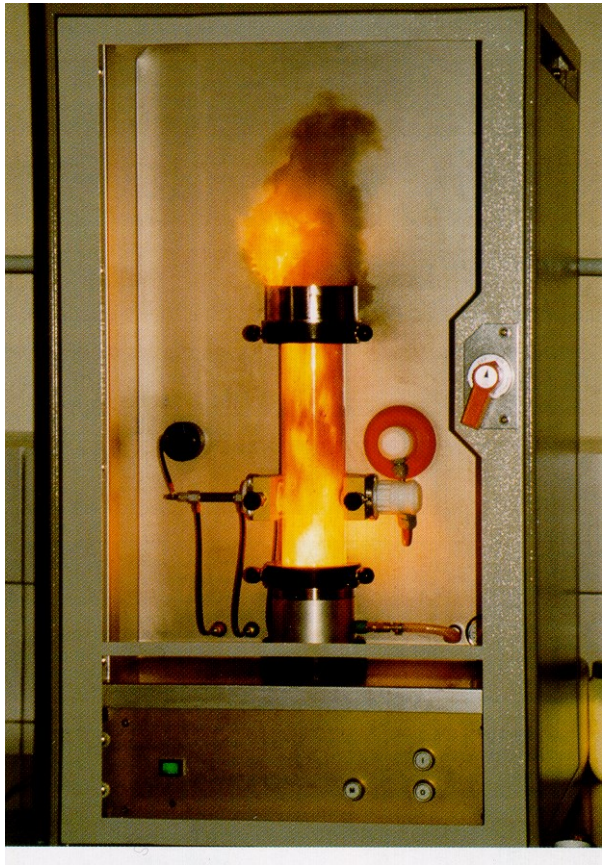


Ignition temperature

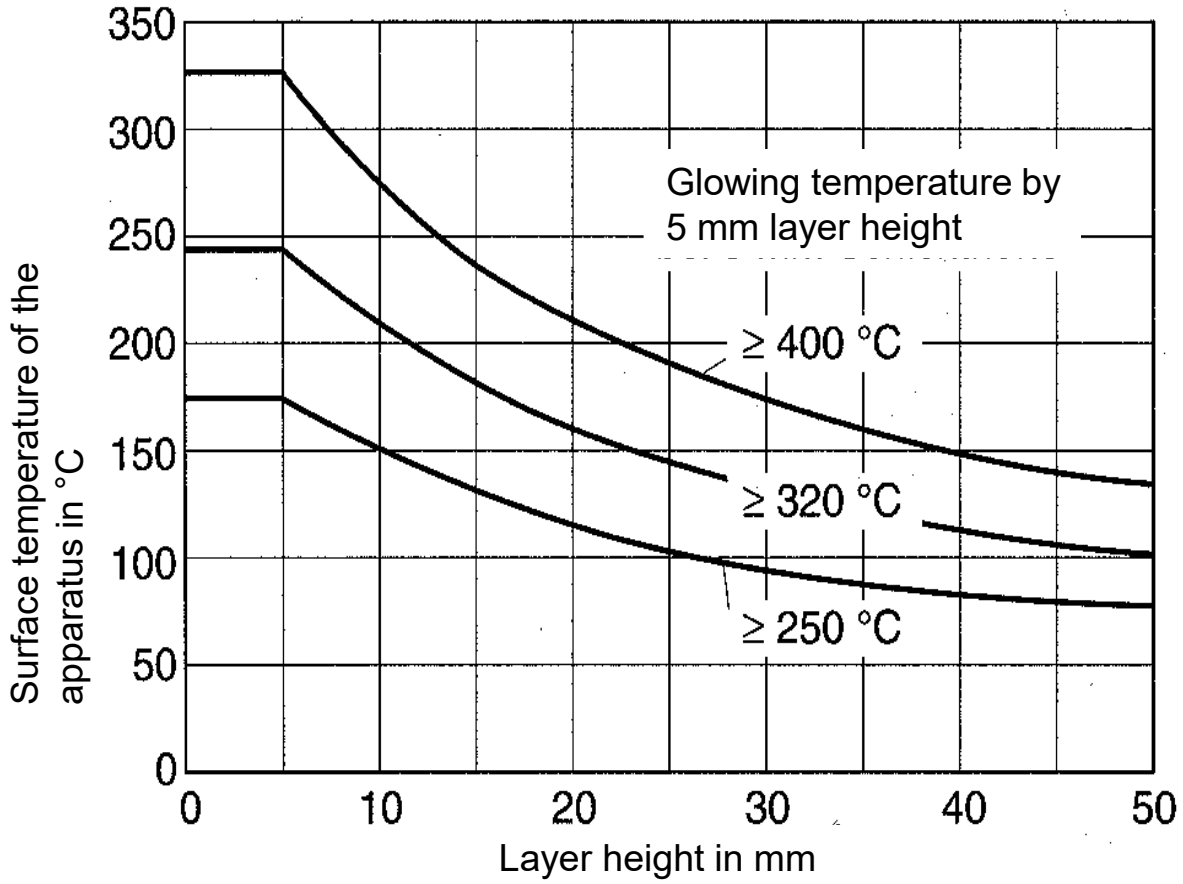
The ignition temperature of a dust cloud is the lowest temperature of a surface which will ignite the dust air mixture.

$T_{max} = 2/3\ T_{cl}$

T_{cl} : Ignition temperature of the dust cloud



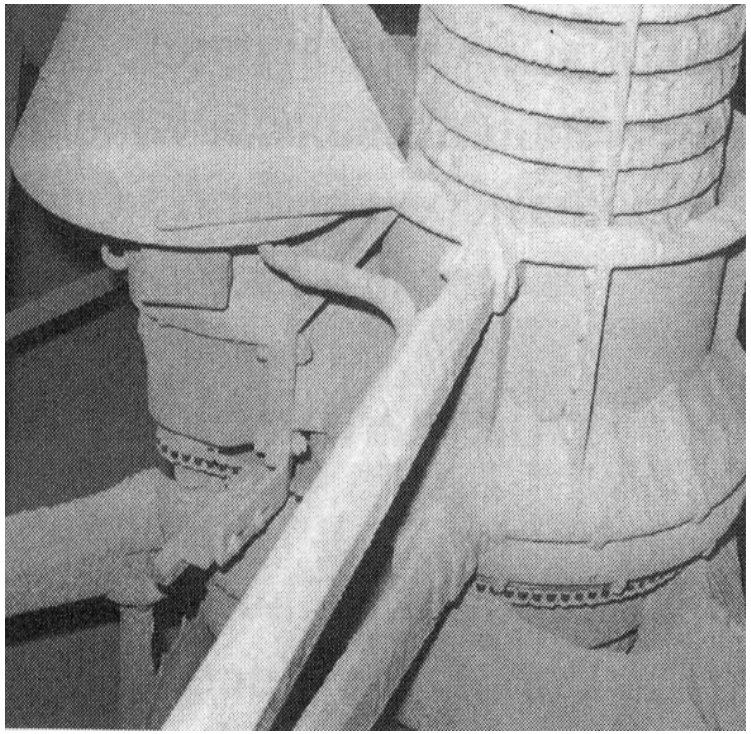
Glowing combustion



Dust layer



Dust layer too high



Protective cover

Dust

Glowing/ignition temperature of dust

Relations

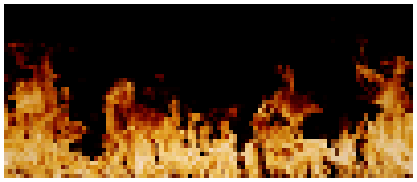
Dust state	Formula	Wheat flour	Paper	Polyvinyl acetate
Layer	$T_{zulS} = T_{minS} - 75K$	450°C – 75K = 375°C	300°C – 75K = 225°C	340°C – 75K = 265°C
Cloud	$T_{zulW} = 2/3\ T_{minW}$	2/3 x 480°C = 320°C	2/3 x 540°C = 360°C	2/3 x 500°C = 333°C
PE	$T_{zulS} \geq T_{zul} \leq T_{zulW}$	320°C	225°C	265°C

Ignition sources

- Hot surfaces



- Flames, hot gases

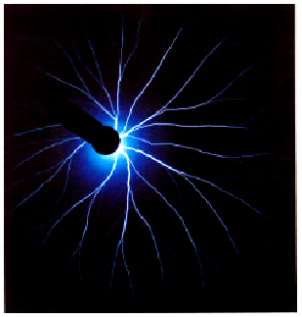


Kraeft

- Mechanically produced sparks



- Electrically generated sparks as opening or closing electrical circuits, electrostatic discharges or lightning strikes



- Electromagnetic waves



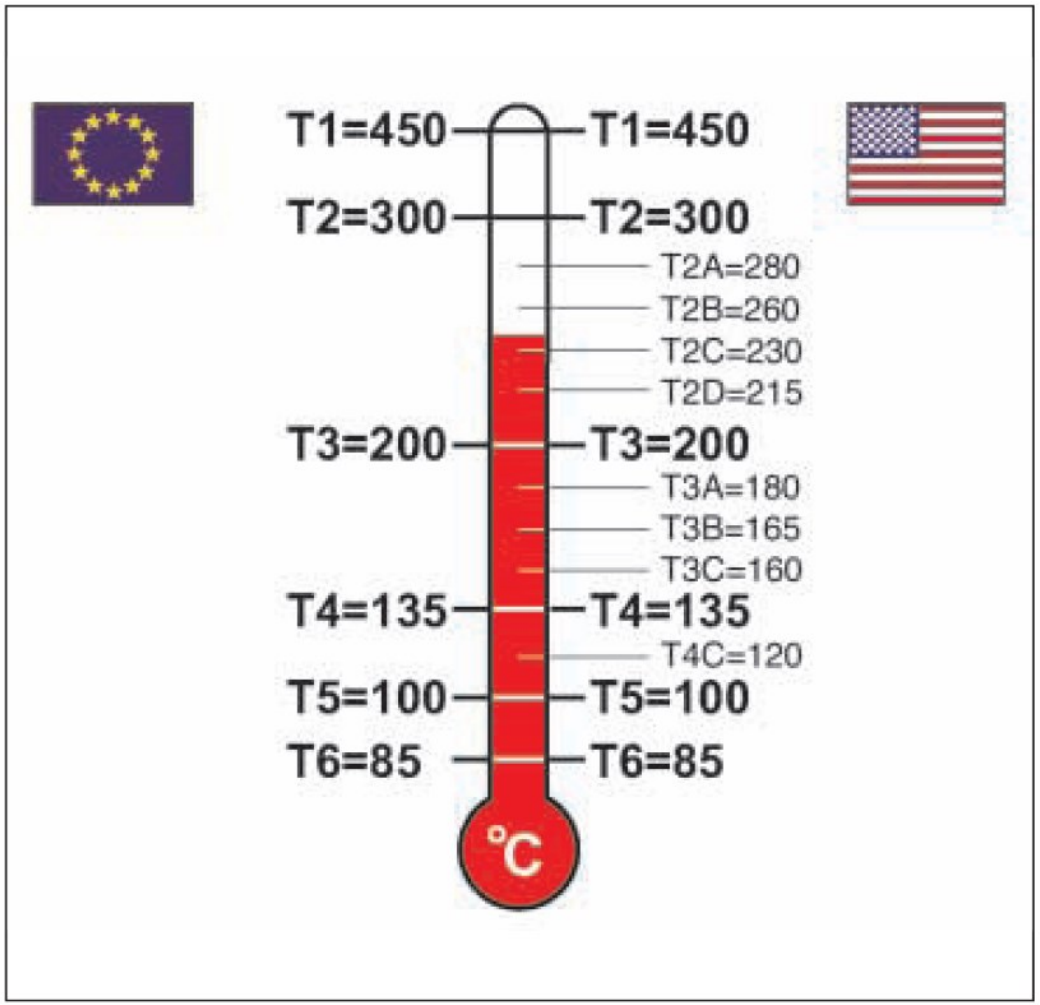
Material Classification

CLASS I (gases and vapors)	Group A (acetylene)
	Group B (hydrogen)
	Group C (ethylene)
	Group D (propane)
CLASS II (dusts)	Group E (metal dust)
	Group F (coal dust)
	Group G (grain dust)
CLASS III (fibers)	No subgroups

Temperature classes and explosion groups

Ex. group	Min. ignition energy	Temperature classes (surface) T1 (<450°C)	T2 (<300°C)	T3 (<200°C)	T4 (<135°C)	T5 (<100°C)	T6 (<85°C)
I	(<260 μJ)	methane	-	-	-	-	-
IIA	(<160 μJ)	acetone acetate ethylacetate ethylchloride ammonia benzene acetic acid methanol naphtaline phenol propan toluol	ethanol i-amyl acetat n-butane n-butyl alcool cyclo hexanon 1,2-dichloro-ethan acetic acid anhydride	gasoline diesel kerosine fuel oil n-hexane	ethanal		
IIB	(<80 μJ)	town gas	ethylene ethyl oxide	hydrogen sulphide	ethyl ether		
IIC	(<20 μJ)	hydrogene	acetylene	-	-		carbon bisulphide

Permissible surface temperatures [°C] for group II:



Comparison between the ignition energies

Lowest ignition energy of gases
(0,02 - 0,7) mJ

Lowest ignition energy of dusts
(10,5 - 700) mJ

Explosion !



Duties of employer

- Prevention of explosions and protection from explosions
- Assessment of explosion risks
- Duty of coordination
- Classification of places where explosive atmospheres may occur
- Explosion protection document
- Special requirements for work equipment and workplaces

Zones and Divisions

Zones	Type of danger
Zone 0	continuous, long periods, frequent
Zone 1	occasional
Zone 2	normally not, only for a short period

Zone 0 / Zone 20

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances

Zone 0: in the form of gas, vapour or mist

Zone 20: in the form of a cloud of combustibles dust in air

is present continuously or for long periods or frequently.

Zone 1 / Zone 21

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances

Zone 1: in the form of gas, vapour or mist

Zone 21: in the form of a cloud of combustable dust in air

is likely to occur in normal operation occasionally.

Zone 2 / Zone 22

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances

Zone 2: in the form of gas, vapour or mist

Zone 22: in the form of a cloud of combustable dust in air

is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Zones

Zones

=

Probability of the presence of an explosible atmosphere

Area classification

Taking into account relevant parameters, the following are typical values which will be obtained for this example:

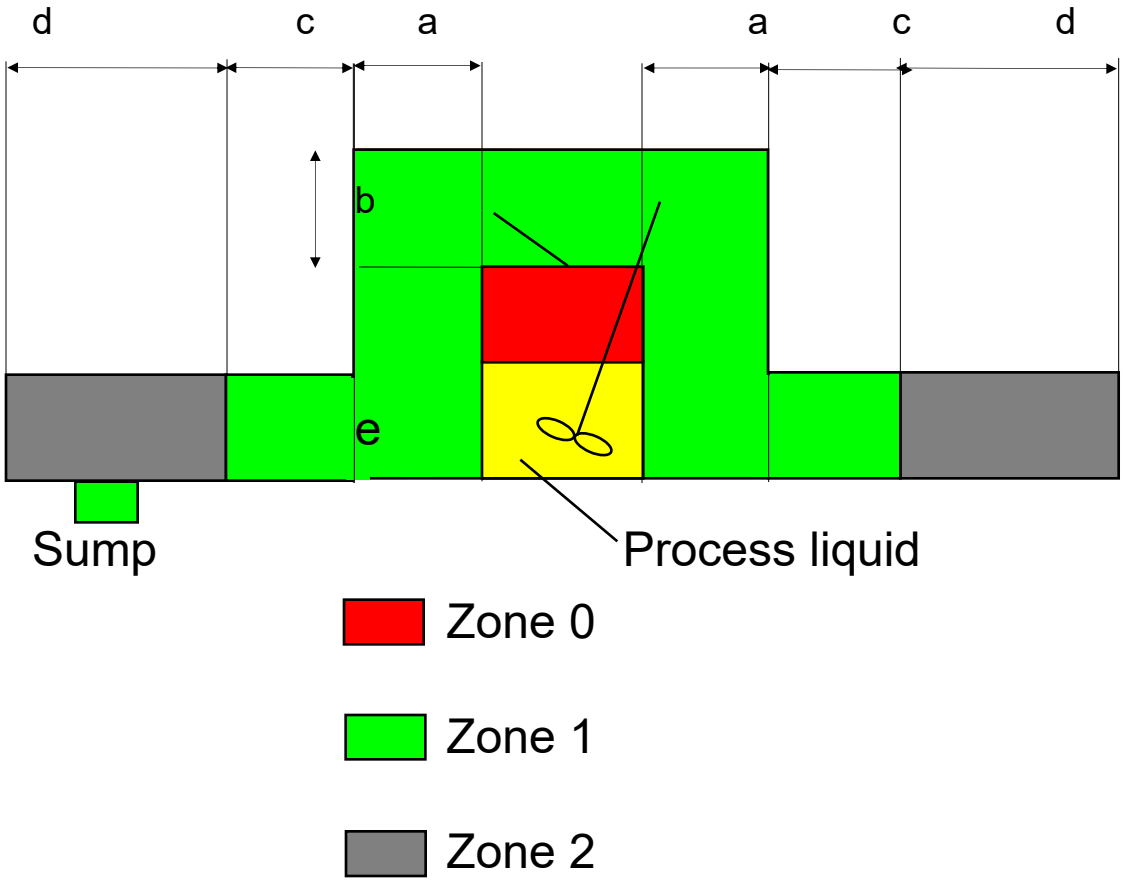
a = 1 m horizontally from source of release

b = 1 m above source of release

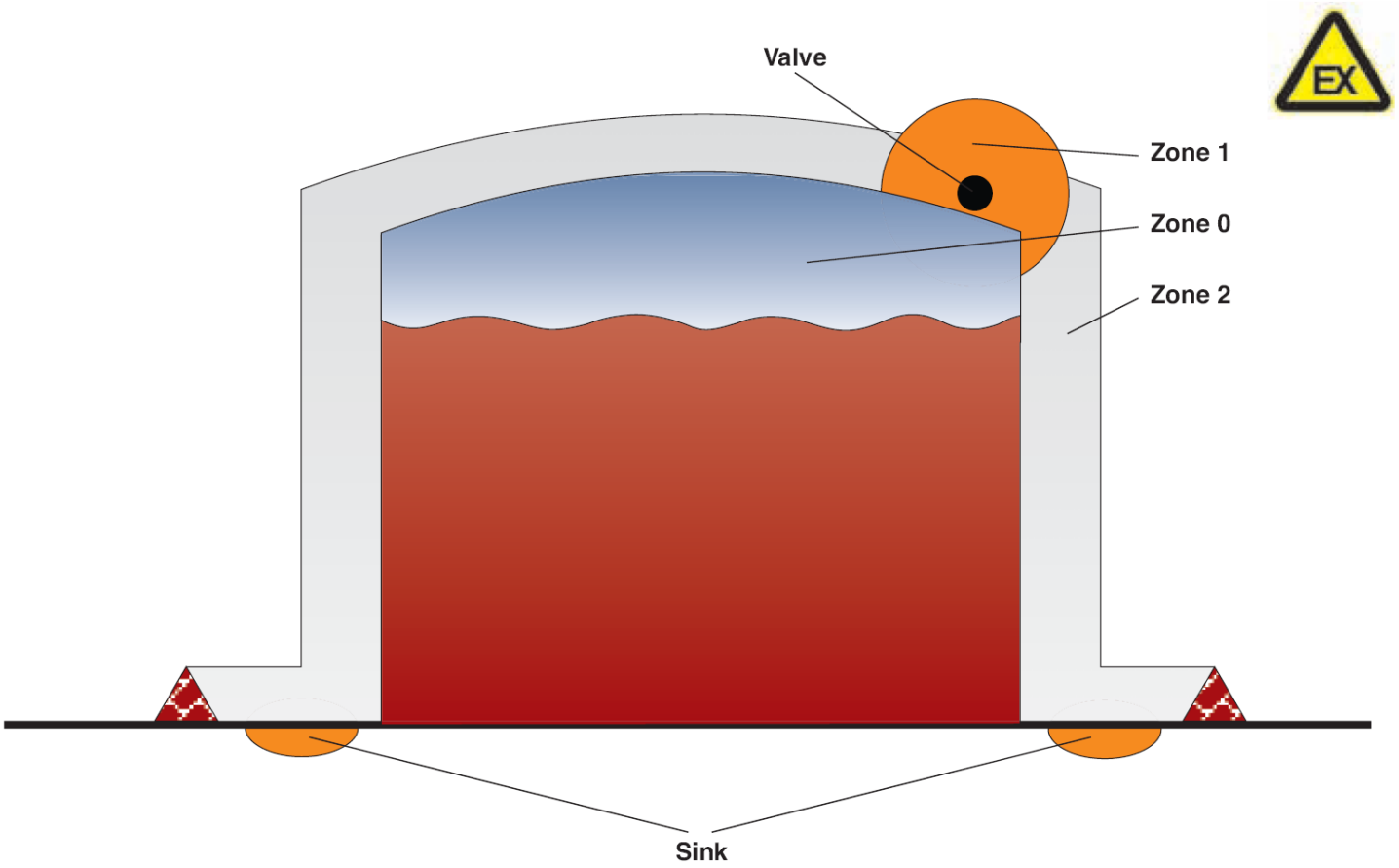
c = 1 m horizontally

d = 2 m horizontally

e = 1 m above ground



Tank for Flammable Liquids



Methods of Protection

Explosion containment:

The only method that allows the explosion to occur but confines it to a well-defined area, thus avoiding the propagation to the surrounding atmosphere. Explosion-proof enclosures are based on this method.

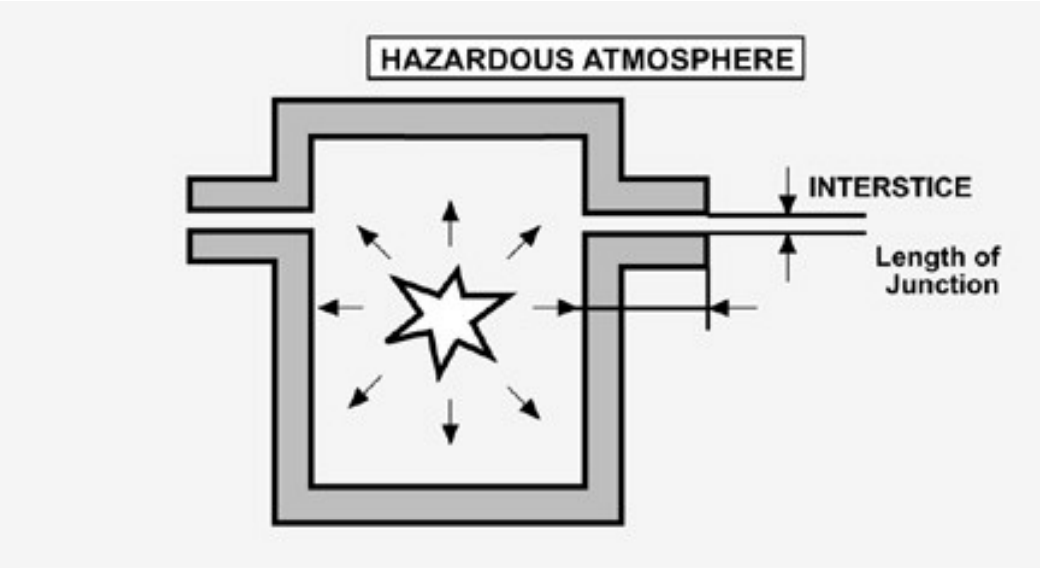
Segregation:

A method that attempts to physically separate or isolate the electrical parts or hot surfaces from the explosive mixture. This method includes various techniques, such as pressurization, encapsulation, etc.

Prevention:

A method that limits the energy, both electrical and thermal, to safe levels under both normal operation and fault conditions. *Intrinsic safety* is the most representative technique of this method.

Flameproof enclosure "d"

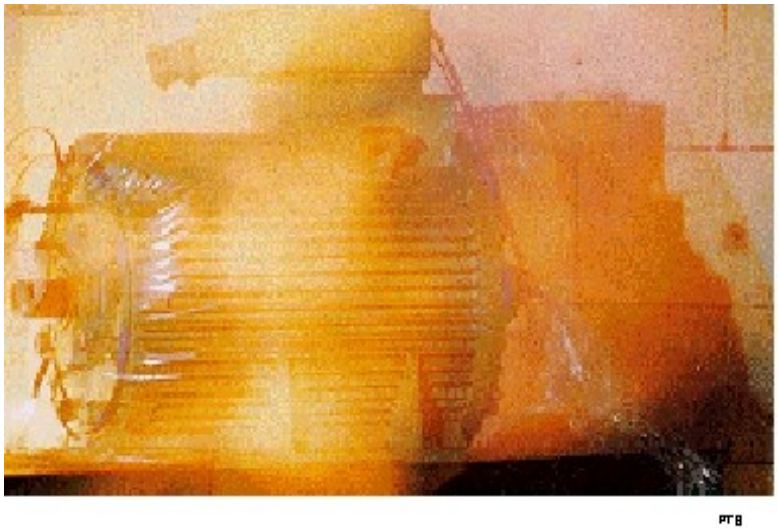


If an ignition occurs inside the enclosure, the enclosure must be able to withstand the pressure and contain the internal explosion (s-gap width).

Used in high powered applications, switches and components that arc.

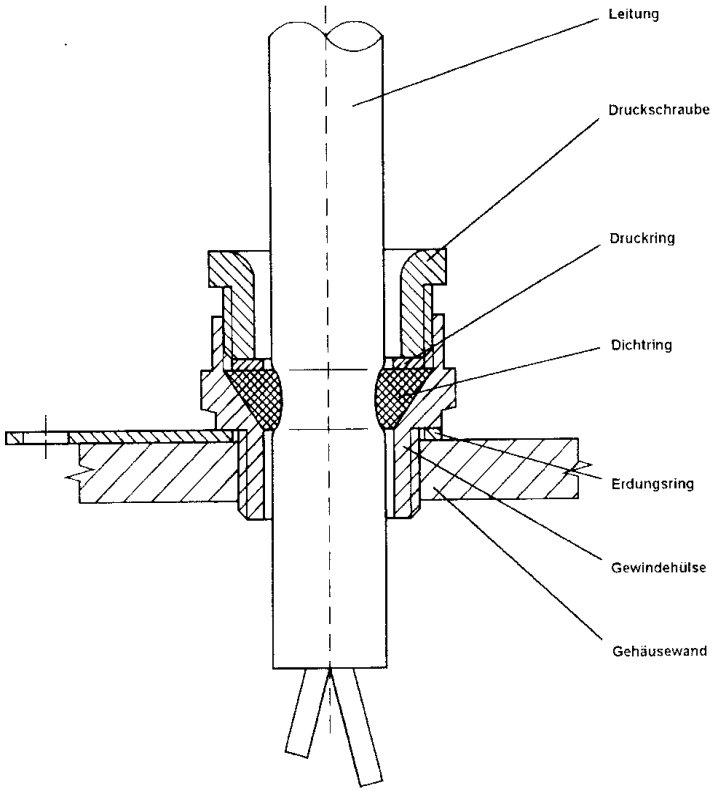
Flameproof enclosure "d"





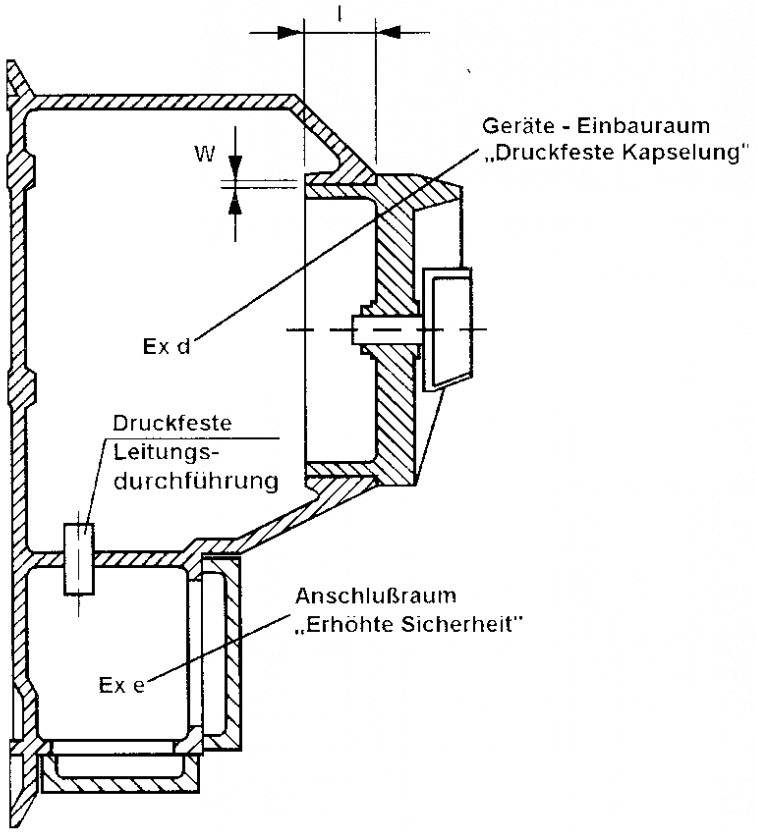
Test

Flameproof enclosure



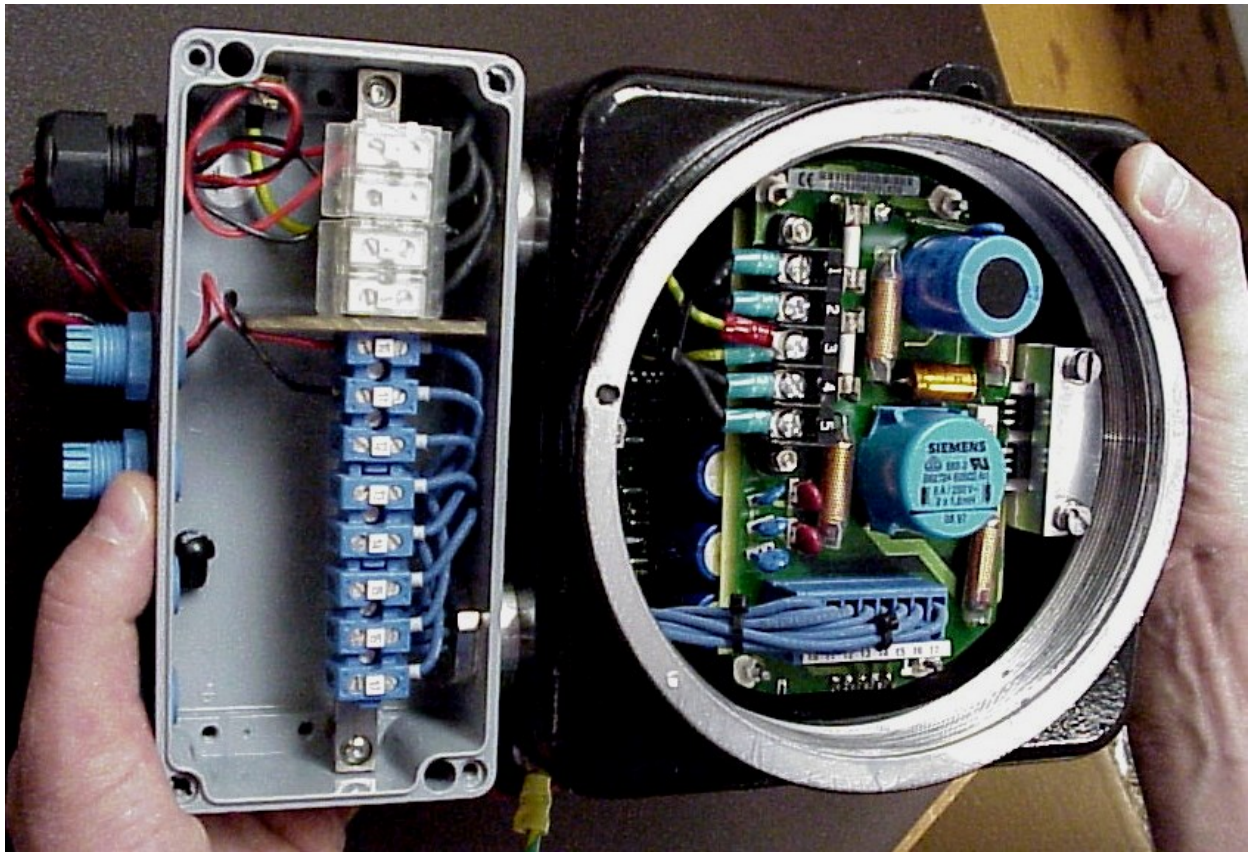
Direct cable entry

Flameproof enclosure



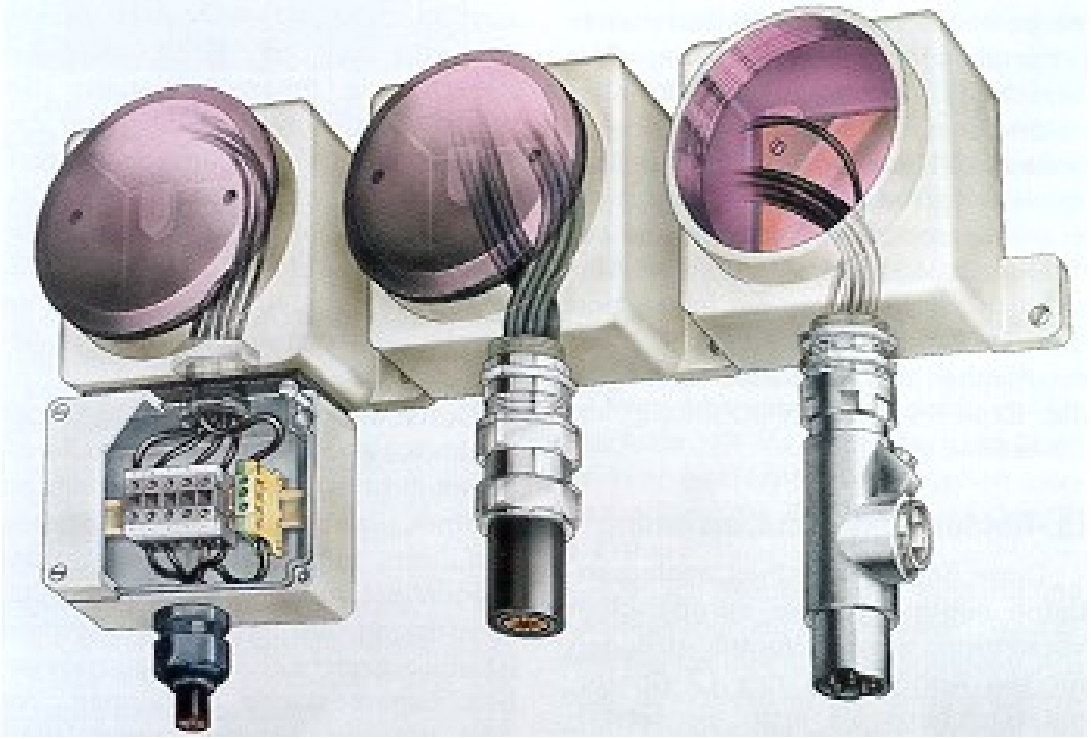
Indirect cable entry

Flameproof enclosure



Power supply in protection "d" and "e"

Cable enty systems for Ex d devices



indirect entry with Ex-e-components

direct Ex-d-entry

Conduit entry

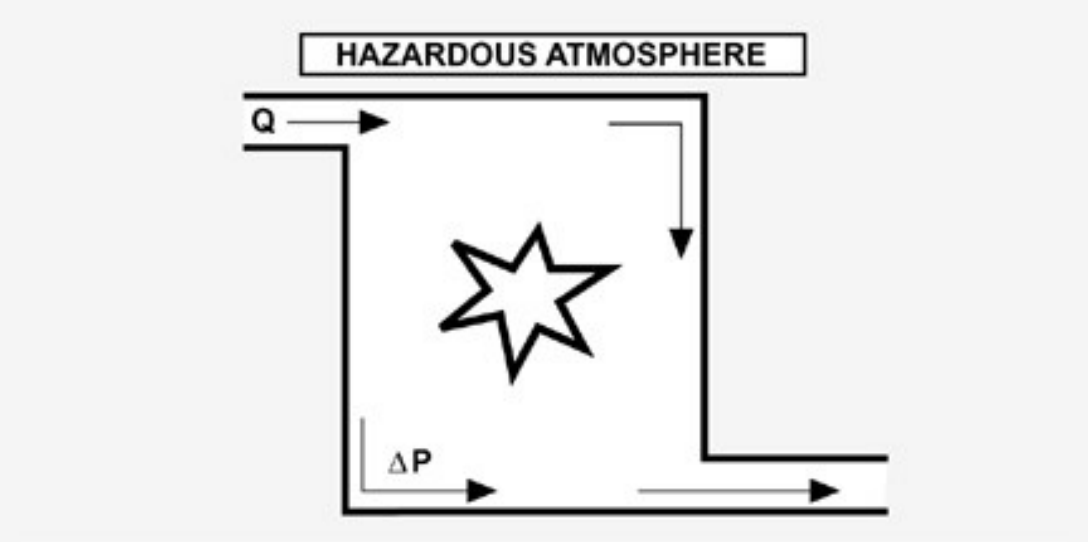
The american way



Ex d motor (US standards)



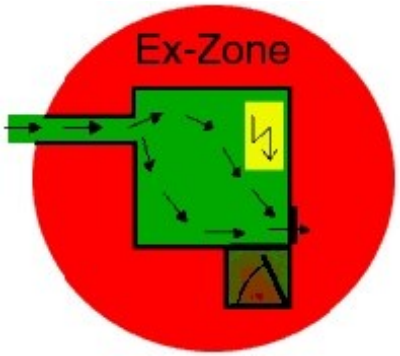
Pressurized enclosure "p"

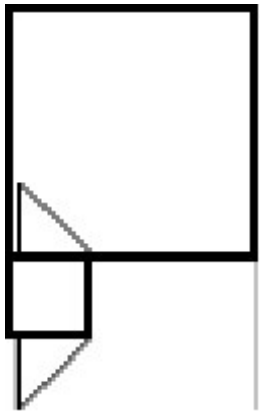


- An inert gas, under an over pressure of (p0 < p1), neutralizes or contains the ignition source.

- Used in machines, collector motors, switch cabinets, control rooms, monitors, keyboards and pads, and analyzers.

Pressurized enclosure “p"







Ex p room with integrated lock

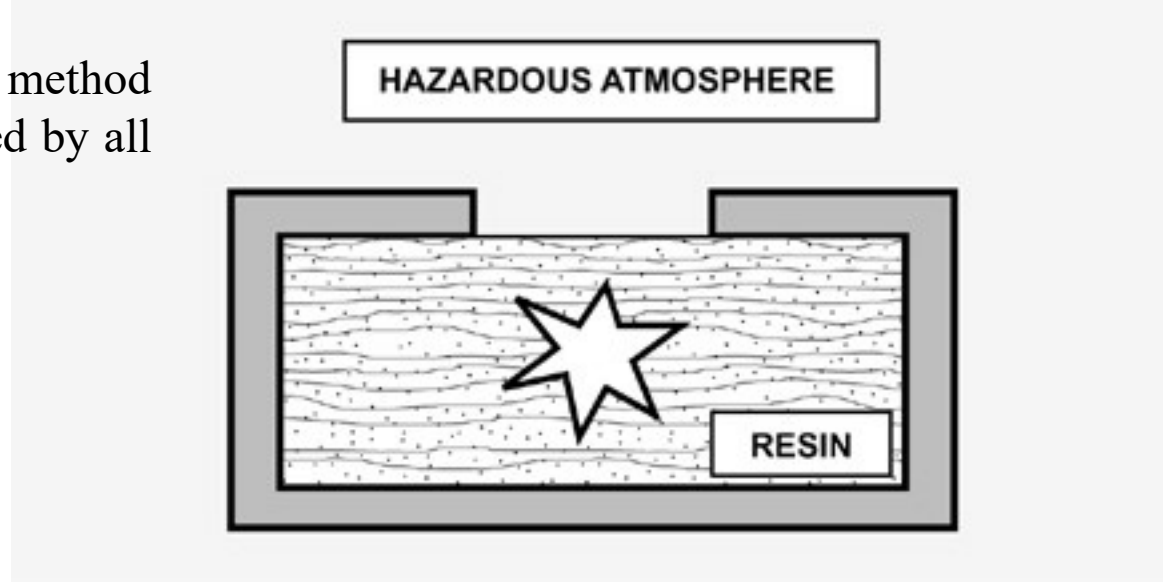
Pressurized enclosure “p"



Gas turbine in “p”

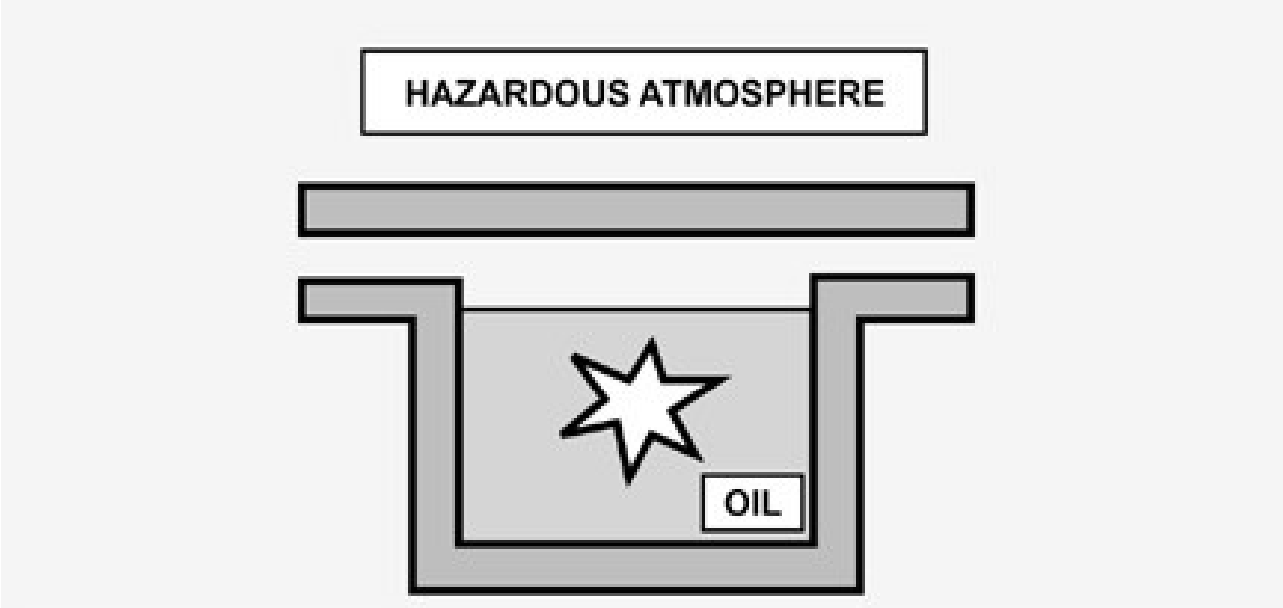
Encapsulation

This protection method is not recognized by all the standards.



- Encapsulation ensures a good mechanical protection and is very effective in preventing contact with an explosive mixture
- it is used to protect electrical circuits that do not contain moving parts, unless these parts, (e.g. reed relays)

Oil immersion "o"



- The ignition source is constantly immersed in oil.
- Application in switches and transformers.

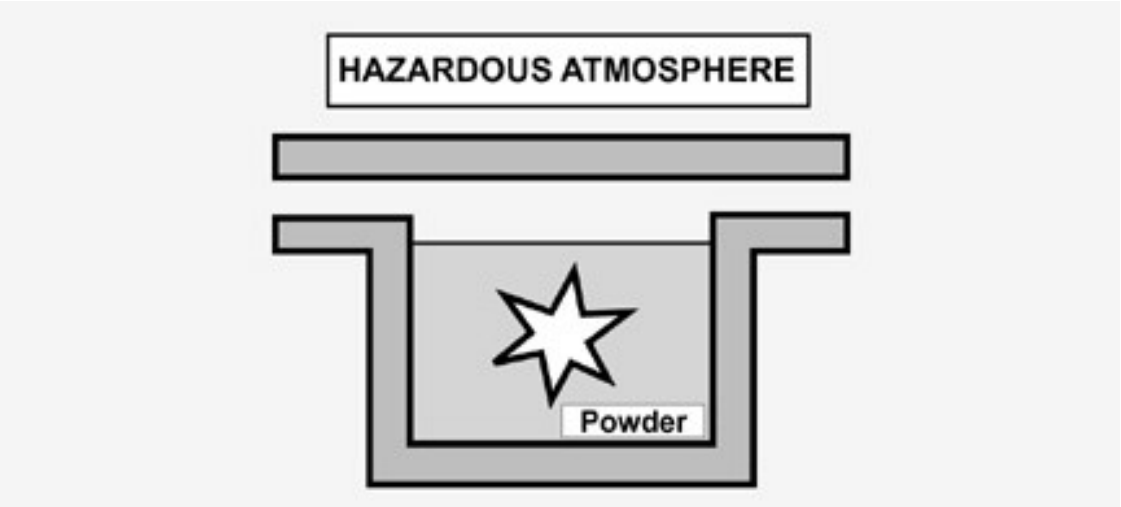
Oil immersion



Oil filled Capacitor



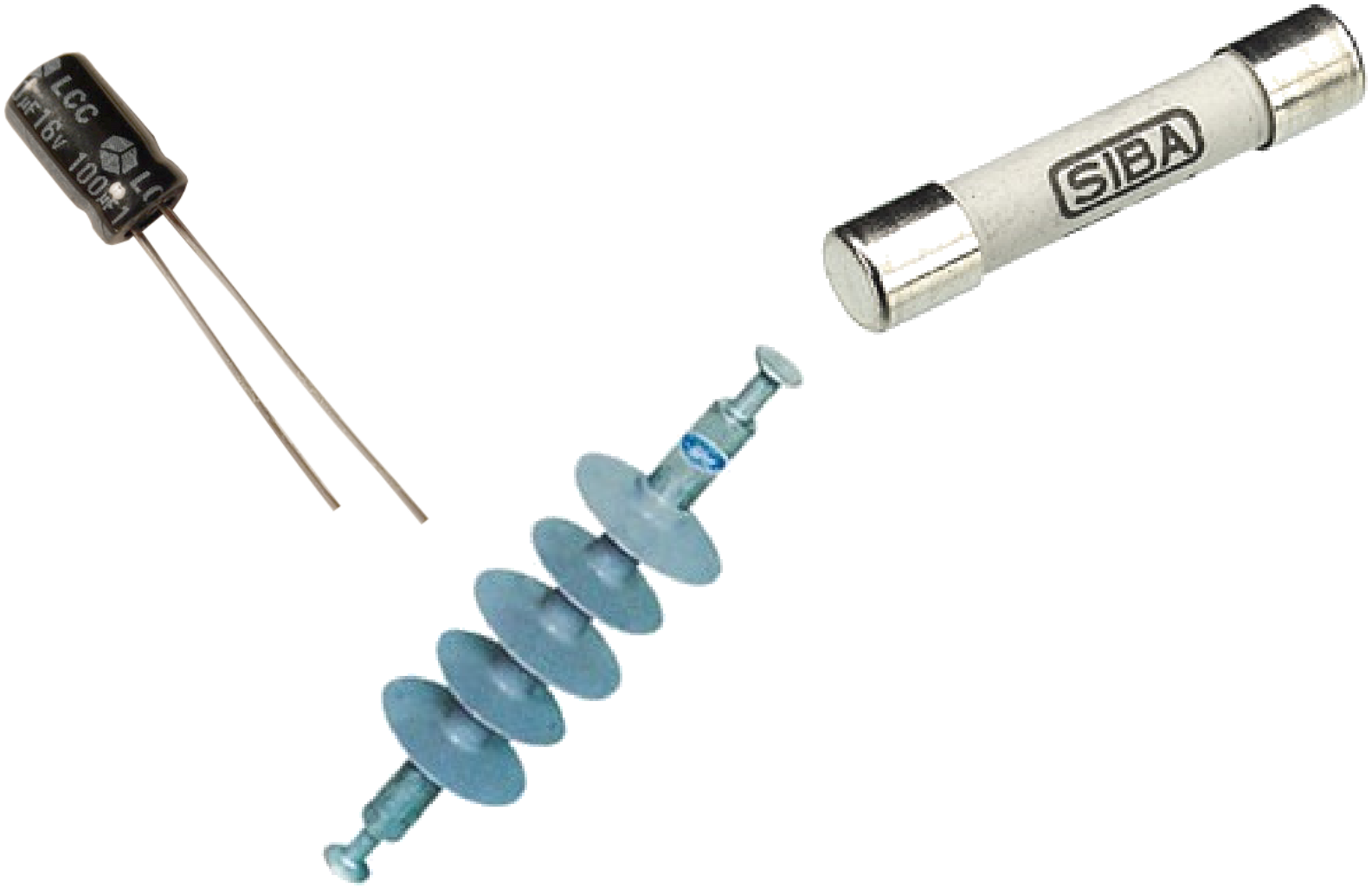
Sand/ Quartz filled "q"



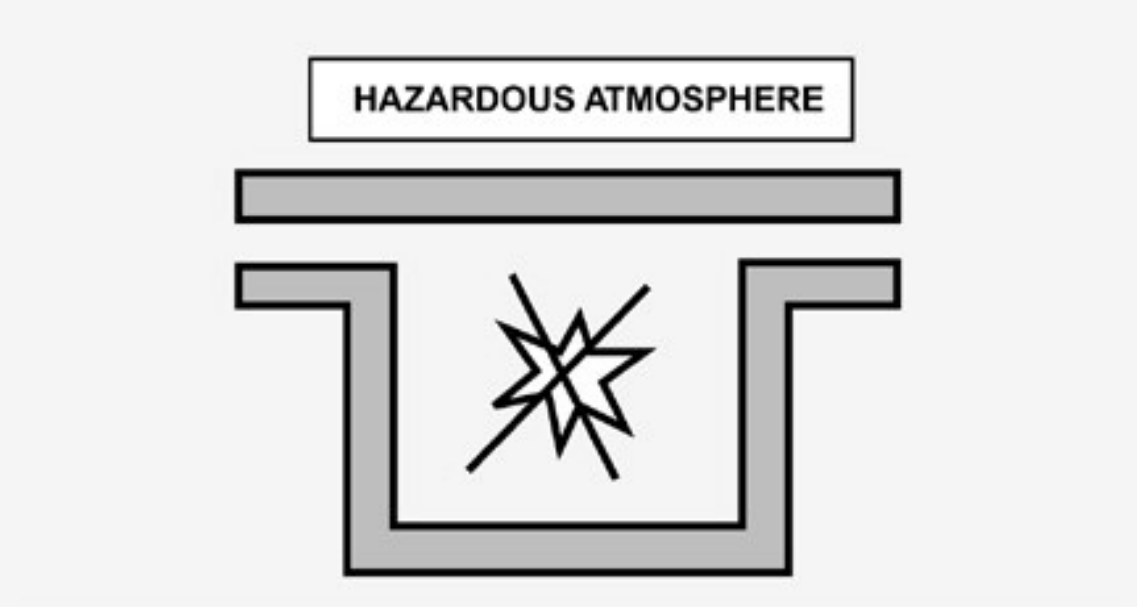
The fine grained filling surrounds the ignition source, an arc from the inside of the housing may not ignite the surrounding combustible atmosphere.

Used in capacitors, ballasts for lamps, and measurement apparatus.

Power filled Capacitor



Increased safety "e"

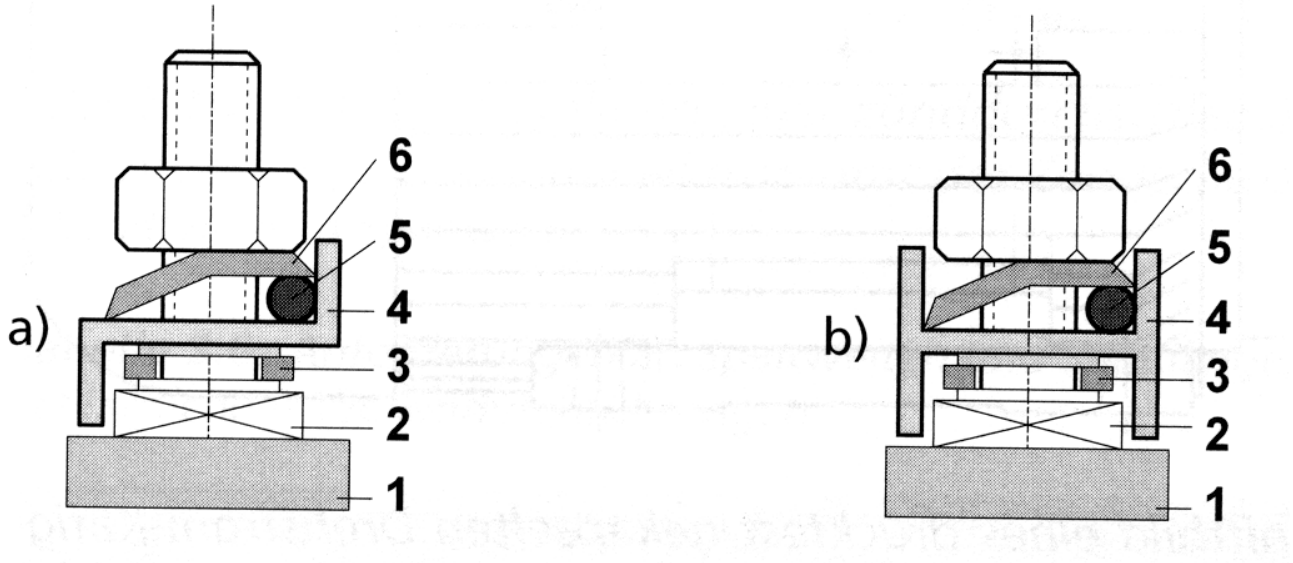


Measures that reduce the change of arcing and increased temperatures. No ignition source can be present during normal operation.

Ex e motor

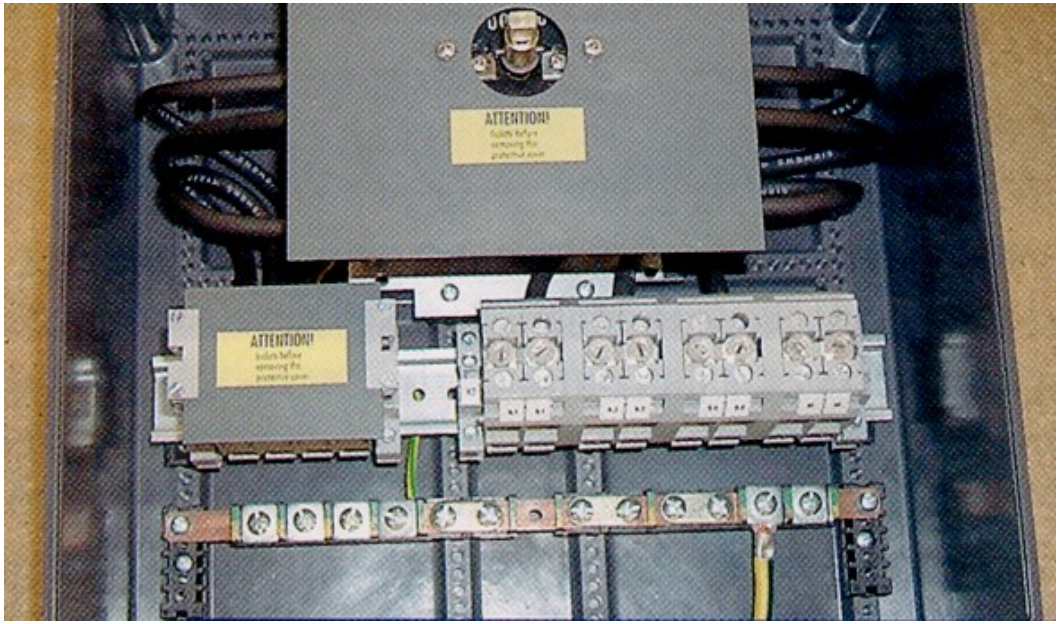


Increased safety



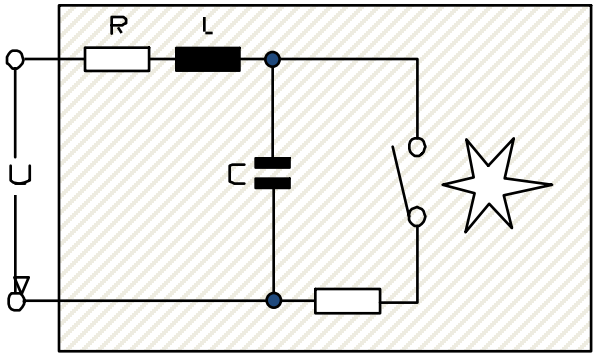
Connection technology

Increased safety



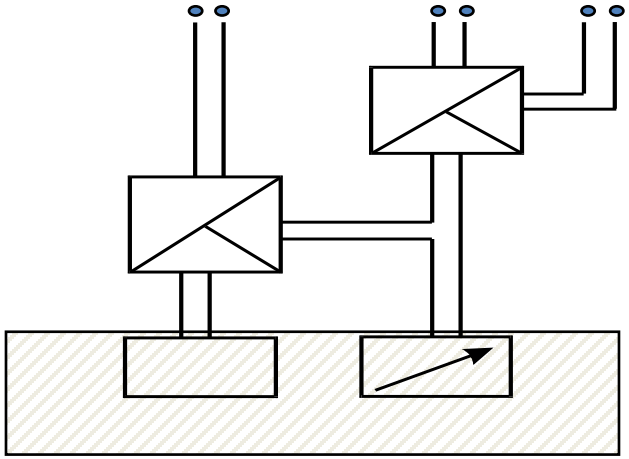
Live parts partially protected against accidental contact

Intrinsic safety "i"



- The energy in the circuit is limited to values which do not result in unacceptably high temperatures and/or arcs of sufficient energy to cause an explosion.

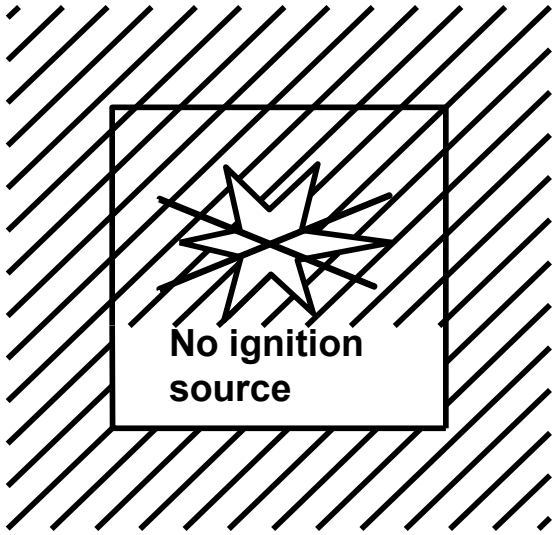
Intrinsic safety systems "i-SYST"



- The seamless interconnection of electronic equipment documented by a system description.

- Circuits that are used entirely or partially within a hazardous area, are intrinsically safe circuits.

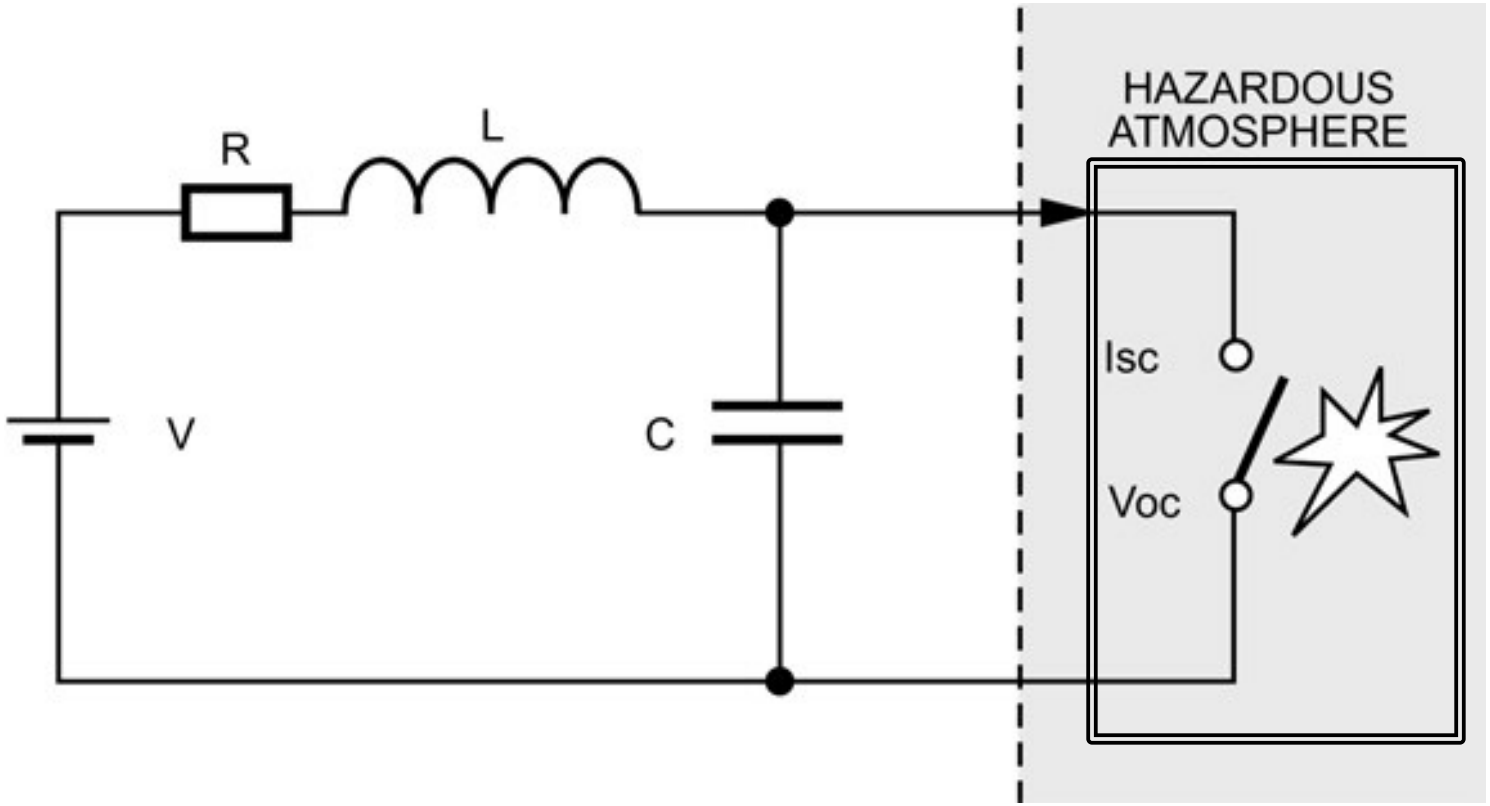
Non incentive "n"



- Measures which are limiting the probability of sparking and high surface temperatures. No ignition source shall be present during normal operation.

- Use only in zone 2.

Schematic of an intrinsically safe circuit



Protection method "n":

Abbreviation	Meaning	Comparable to	Method	Divisions of group II
A	Non-sparking	EEx e	Occurrence of arcs, sparks or hot surfaces is minimized	None
C	Sparking equipment	partly EEx d, EEX m	Enclosed break device Non-incendive components Hermetically sealed, sealed or encapsulated installations	IIA, IIB, IIC
R	Restricted breathing housing	---	Intrusion of explosive gases is limited	None
L	Power-limited	EEX i	Power limitation so that neither sparks nor thermal effects cause an ignition	IIA, IIB, IIC
P	Simplified pressurized encapsulation	EEx p	Intrusion of explosive gases is prevented by overpressure, monitoring without disconnection	None

* different in North America and Europe

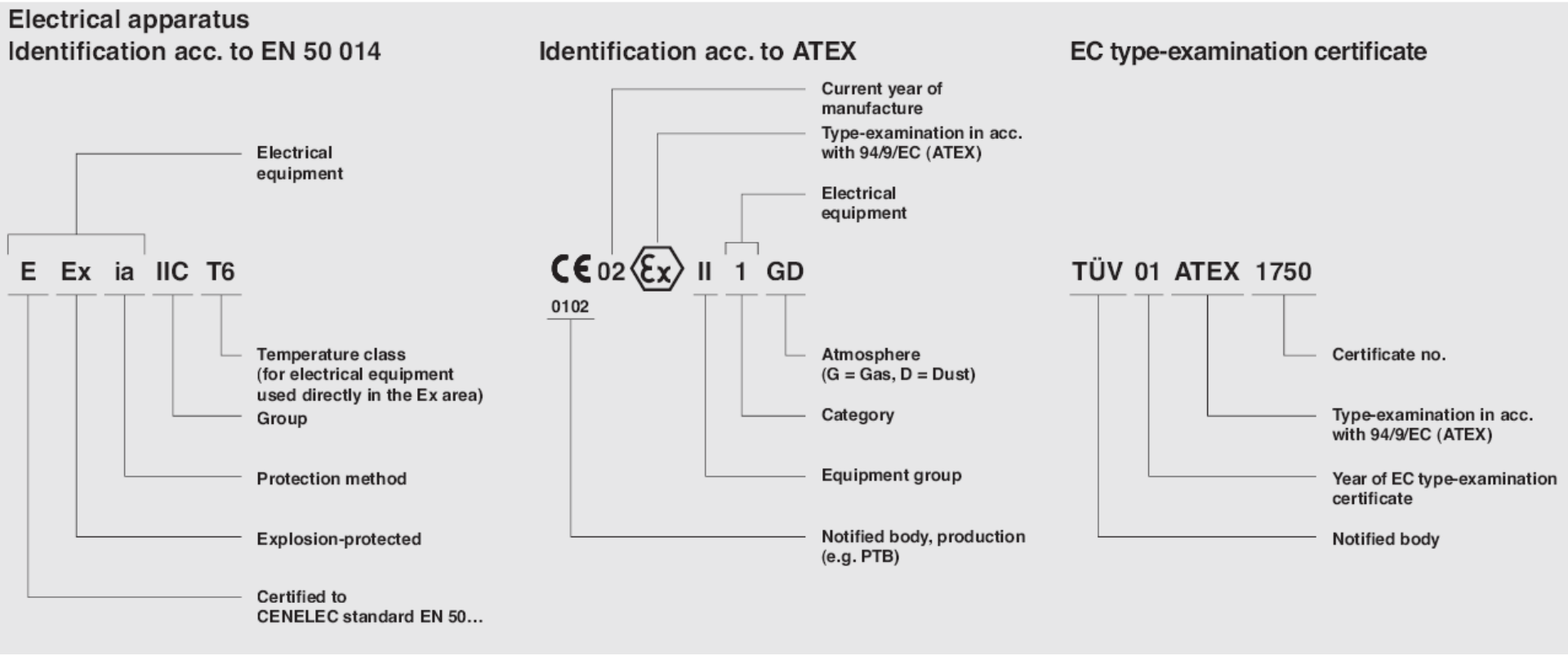
Comparison of the most widely used protection methods

	Safety	Flexibility	Cost of Installa-tion	Cost of Mainte-nance
Intrinsic Safety	+	+	-	-
Explosion-proof	=	=	=	=
Purging, or Pressurization	+	+	+	=

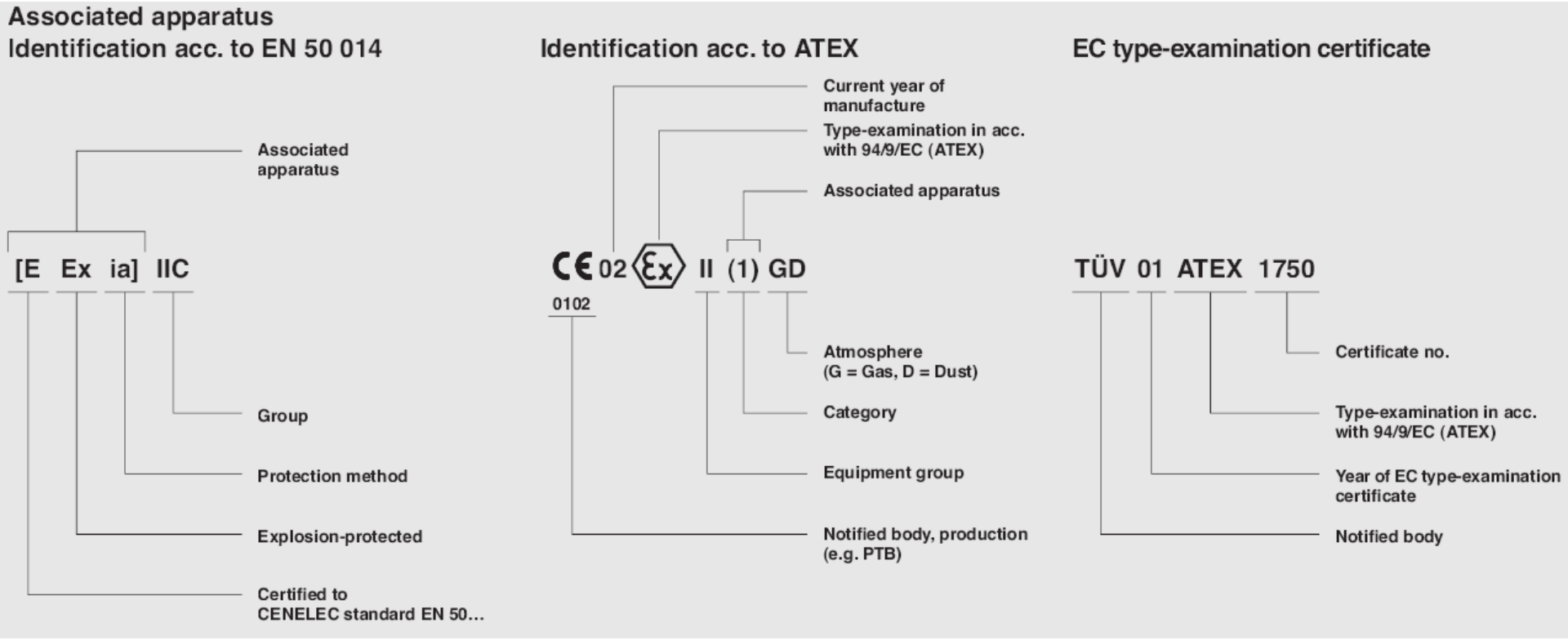
Identification and Marking



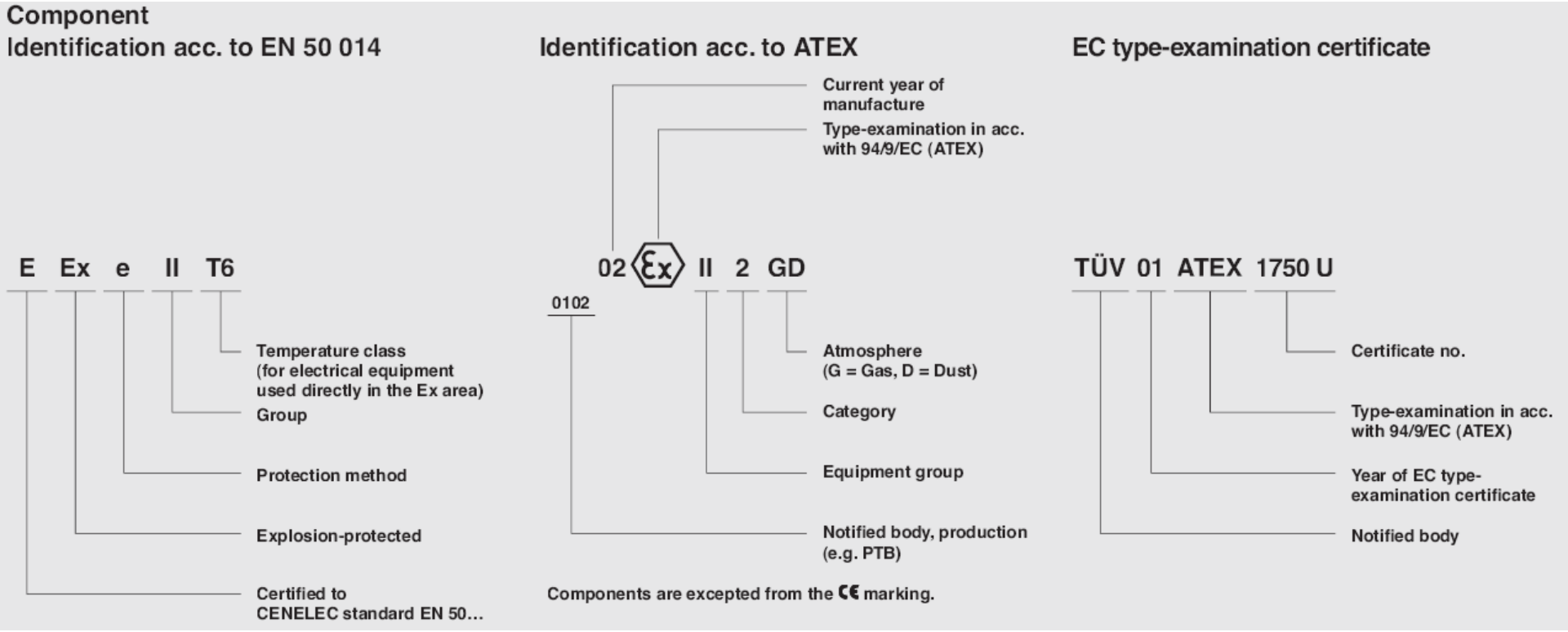
Identification and Marking



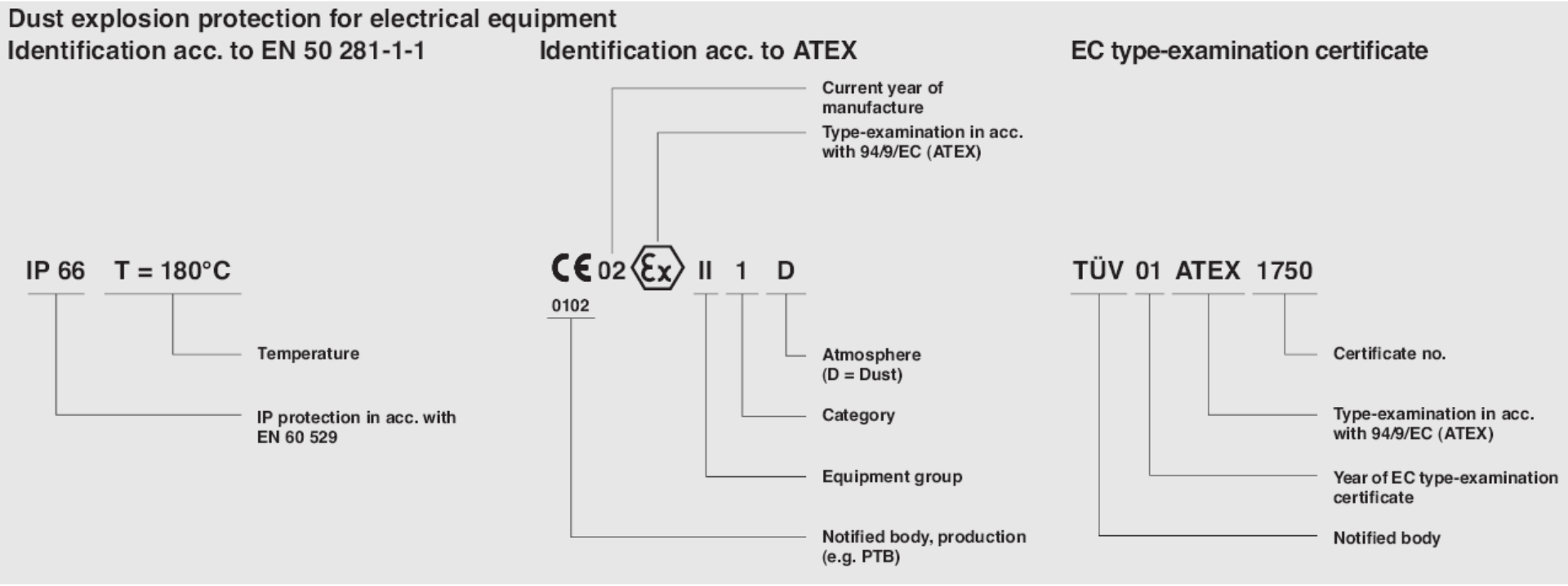
Identification and Marking

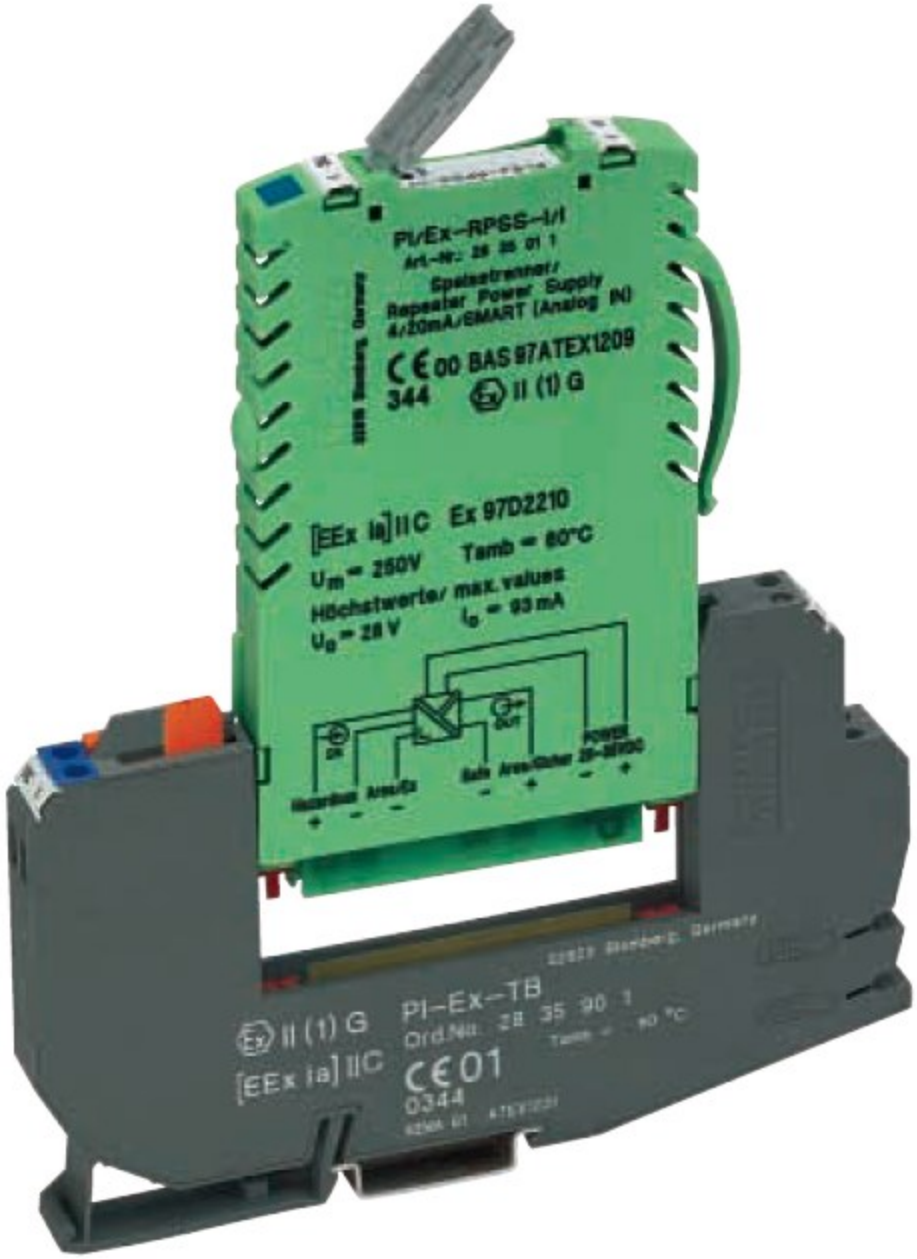


Identification and Marking



Identification and Marking




PI/Ex-RPSS-I/I
Art.-Nr.: 28 35 01 1
Speisetrenner/
Repeater Power Supply
4/20mA/SMART (Analog IN)
CE 00 BAS 97ATEX1209
344 II (1) G
[EEx ia] IIC Ex 97D2210
Um = 250V Tamb = 60°C
Höchstwerte/ max. values
Uo = 28 V Io = 93 mA
IN
OUT
POWER
PI-Ex-TB
Ord.Nr. 28 35 90 1
II (1) G
[EEx ia] IIC
CE 01
0344

Electrical equipment and associated apparatus

