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Zaščitni sistemi za razbremenitev tlaka eksplozije prahu

Dust explosion venting protective systems

Schutzsysteme zur Druckentlastung von Staubexplosionen

Systemes de protection par évent contre les explosions de poussieres

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Dust explosion venting protective systems

Systèmes de protection par évent contre les explosions de poussières

Schutzsysteme zur Druckentlastung von Staubexplosionen

This European Standard was approved by CEN on 13 February 2006.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This European Standard (EN 14491:2006) has been prepared by Technical Committee CEN/TC 305 "Potentially explosive atmospheres – Explosion prevention and protection", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2006, and conflicting national standards shall be withdrawn at the latest by September 2006.

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s) 94/9/EC.

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this European Standard.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard specifies the basic requirements of design for the selection of a dust explosion venting protective system. The standard is one of a series including prEN 14797 *Explosion venting devices* and prEN 14460 *Explosion resistant equipment*. The three standards together represent the concept of dust explosion venting. To avoid transfer of explosions to other communicating equipment one should also consider applying prEN 15089 *Explosion Isolation Systems*.

This European Standard covers:

— vent sizing to protect an enclosure against the internal pressure effects of a dust explosion;

— flame and pressure effects outside the enclosure;

— recoil forces;

— influence of vent ducts.

This European Standard is not intended to provide design and application rules against effects generated by detonation reactions or runaway exothermic reactions. This European Standard does not cover fire risks arising from either materials processed, used or released by the equipment or materials that make up equipment and buildings. This European Standard does not cover the design, construction, testing and certification of explosion venting devices that are used to achieve explosion venting[1)].

2 Normative references

These following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references the latest edition of the referenced document (including any amendments) applies.

EN 1127-1:1997, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*

EN 13237:2003, *Potentially explosive atmospheres — Terms and definitions for equipment and protective systems intended for use in potentially explosive atmospheres*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 1127-1:1997 and EN 13237:2003 and the following apply.

3.1
building
enclosed, roofed space that contains a working environment that may include process plant, offices and personnel, either separately or together, but is not, in itself, an item of process plant

3.2
enclosure
vessel that forms a distinct and identifiable part of a process plant and to which explosion protection by explosion venting can be applied as described in this European Standard

1) This is covered in the European Standard prEN 14797.

3.3
design pressure
p
design strength of the vessel/enclosure (explosion resistance)

3.4
hybrid mixture
mixture of flammable (combustible) substances with air in different physical states

NOTE An example for hybrid mixtures is a mixture of methane, coal dust and air.

[EN 1127-1:1997; 3.20]

3.5
K_{st} value
parameter, specific to the dust, that characterises the explosibility of a dust and which is calculated according to the cubic law

NOTE The K_{St} value is numerically equal to the value for the maximum rate of explosion pressure rise, $(dp/dt)_{max}$, measured in the 1 m^3 vessel under specified test conditions.

3.6
vent area
A
geometric vent area of vent

NOTE It is the minimum cross-sectional flow area of the vent opening taking into consideration the possible reduction of the cross section, e.g. by back pressure supports, retaining devices and parts of the explosion venting device which remain after bursting or venting.

3.7
cross sectional area
A_c
area of cross section of rectangular enclosure normal to longest dimension of this enclosure

3.8
required vent area
A_v
quotient of the geometric vent area *A* and the venting efficiency E_f for the venting device

NOTE The required vent area is used in making up the vent area for explosion venting.

3.9
effective enclosure area
A_{eff}
ratio of the total free volume of an enclosure and its height

3.10
maximum explosure overpressure
p_{max}
maximum overpressure occurring in a closed vessel during the explosion of an explosive atmosphere and determined under specified test conditions

[EN 1127-1:1997; 3.27]

3.11
pipeline
connection, which is at least 20 times longer than the diameter, carrying process material between two or more enclosures in a process plant and which cannot be explosion protected by the explosion venting methods for enclosures described in this European Standard

3.12
explosive atmosphere
mixture with air, under atmospheric conditions, of flammable (combustible) substances in the form of gases, vapours, mists or dusts, in which, after ignition has occurred, combustion spreads to the entire unburned mixture

3.13
maximum reduced explosion overpressure
$p_{\mathrm{red,\,max}}$
maximum overpressure generated by an explosion of an explosive atmosphere in a vessel, protected by either explosion relief (venting) or explosion suppression

3.14
maximum rate of explosion pressure rise
$(\mathrm{d}p/\mathrm{d}t)_{\mathrm{max}}$
maximum value of the pressure rise per unit time during explosions of all explosive atmospheres in the explosion range of a combustible substance in a closed vessel determined under specified test conditions

NOTE This parameter measured in a 1 m^3 vessel is numerically identical with the parameter K_{St}, if the test vessel is 1 m^3 in volume, but the unit of the latter is bar m s^{-1} whereas the unit of the $(\mathrm{d}p/\mathrm{d}t)_{\mathrm{max}}$ is bar s^{-1}.

3.15
maximum value of the peak overpressure
p_{ext}
external maximum value of the peak overpressure generated by vented dust explosion

NOTE This maximum occurs at a distance R_S from the vent opening.

3.16
static activation overpressure
p_{stat}
overpressure that activates a rupture disk or an explosion door when a slow rate of pressure rise ($\leq$ 0,1 bar min^{-1}) is applied

4 Venting of enclosures

Explosion venting is a protective measure for enclosures by which unacceptably high internal explosion overpressures are prevented. Weak areas in the walls of the enclosure open at an early stage of the explosion, burning and/or un-burnt material and combustion products are released and the overpressure inside the enclosure is reduced. The vent area is the most important factor in determining the value of $p_{\mathrm{red,\,max}}$, the maximum reduced explosion overpressure generated inside the enclosure by the vented explosion. Information required for calculation of the vent area includes the design pressure of the enclosure, the explosion characteristics of the dust, the shape and size of the enclosure, the static activation overpressure and other characteristics of the vent closure, and the condition of the dust cloud inside the enclosure.

Explosion venting shall not be performed if unacceptable amounts of materials that are classified as poisonous, corrosive, irritant, carcinogenic, teratogenic or mutagenic can be released. Either the dust or the combustion products can present a hazard to the immediate environment. If there is no alternative to explosion venting an endangered area shall be specified.

NOTE There is no direct guidance for estimating an endangered area for toxic or other harmful emissions, but the safe discharge area for flame calculated in 7.2 gives some indication of the area required in direct line from the vent.

Harmful emissions will be dispersed by air movements, however, and an extensive area in lateral directions may be required.

This European Standard shall be used together with prEN 14797 and prEN 14460.

Venting neither prevents or extinguishes an explosion; it only limits the explosion overpressure. Flame and pressure effects outside the enclosure and flying debris are to be expected and suitable precautions shall be taken. Fires inside the enclosure can also occur.

The increase of the length-to-diameter ratio of an enclosure results in an increase of the rate of flame propagation. This is taken into account in the equation for vent sizing (see Clause 5). Enclosures in this European Standard are limited to $L/D \leq 20$.

In a system consisting of connected enclosures, a dust explosion ignited in one enclosure can propagate through the connection, generating increased turbulence, perhaps causing some pre-compression and then acting as a large ignition source in a connected enclosure. This combination of effects can enhance the violence of the secondary explosion and the venting requirements of the system thus need to be increased, or the enclosures isolated (see 5.4).

Internal dust explosions can endanger buildings or parts of buildings and venting may be applied to protect the integrity of the building. A separate method for calculating the venting requirements is given in 5.5.

5 Sizing of vent areas

5.1 General

Accurate sizing of vents is the most important aspect of vent design. The size of the vent depends on the explosion characteristics of the dust, the state of the dust cloud (concentration, turbulence and distribution), the geometry of the enclosure and the design of the venting device.

The two principal explosion characteristics of the dust are the maximum overpressure p_{max} and the dust explosion constant K_{St}. These are measured by standard test procedures that establish representative conditions of fuel concentration and dust cloud homogeneity and turbulence considered to encompass those in the majority of practical applications. For cubical enclosures, p_{max} and K_{St} are essentially independent of enclosure volume.

The volume of the enclosure and the length-to-diameter ratio L/D relevant to the shape of the enclosure and the position of the explosion vent are required for sizing vents. The design pressure of the enclosure $p_{red,\,max}$ is also required for vent sizing. All parts of the enclosure, e.g. valves, sight-glasses, man-holes and ducts, that are exposed to the explosion pressure shall be taken into account and the design pressure of the weakest part shall be taken as the design pressure for the enclosure.

The two principal vent device parameters are the static activation overpressure p_{stat} and the weight per unit area of the venting element. The maximum value of the tolerance range of the static activation overpressure shall be used when sizing vents. The weight per unit area of the venting element determines its venting effectiveness factor.

5.2 Venting of isolated enclosures

The following equation shall apply to single enclosures where appropriate measures (explosion isolation) have been taken to prevent flame propagation between enclosures.

For enclosures the following equations allow the calculation of the required vent area A_v. The required vent area can, in practical applications, be divided into several smaller areas as long as the total area equals the required vent area:

a) 0,1 bar overpressure $\leq p_{red,\,max} <$ 1,5 bar overpressure

$$A = B\left(1 + C \times log\ L/D\right) \text{ in m}^2 \qquad (1)$$

with

$$B = \left[3{,}264 \times 10^{-5} \times p_{max} \times K_{St} \times p_{red,\,max}{}^{-0{,}569} + 0{,}27 \times (p_{stat} - 0{,}1) \times p_{red,\,max}{}^{-0{,}5}\right] \times V^{0{,}753} \qquad (2)$$

$$C = \left(-4{,}305 \times \log p_{red,\,max} + 0{,}758\right)$$

$$A_v = A/E_f \qquad (E_f\text{: venting efficiency}) \qquad (3)$$

b) 1,5 bar overpressure $\leq p_{red,\,max} \leq$ 2,0 bar overpressure

$$A = B$$

$$A_v = A/E_f \qquad (E_f\text{: venting efficiency}) \qquad (4)$$

The equations are valid for:

enclosures volume	0,1 m$^3 \leq V \leq$ 10 000 m^3;
static activation overpressure of the venting device	0,1 bar $\leq p_{stat} \leq$ 1 bar; for $p_{stat} <$ 0,1 bar, use p_{stat} = 0,1 bar;
maximum reduced explosion overpressure	$p_{stat} \leq p_{red,\,max} \leq$ 2 bar. It is recommended that $p_{red,\,max}$ shall at least be 0,12 bar;
maximum explosion overpressure	5 bar $\leq p_{max} \leq$ 10 bar for a dust specific parameter of 10 bar m s$^{-1} \leq K_{St} \leq$ 300 bar m s^{-1};
maximum explosion overpressure	5 bar $\leq p_{max} \leq$ 12 bar for a dust specific parameter of 300 bar m s$^{-1} < K_{St} \leq$ 800 bar m s^{-1};
atmospheric conditions	conditions of the surrounding medium where the atmospheric pressure can vary between 80 kPa and 110 kPa, the temperature between – 20 °C and 60 °C (the variation of temperature being less then 0,5 °C/min), the relative humidity between 5 % volume fraction and 85 % volume fraction and oxygen content (20,9 ± 0,2) % volume fraction;
length-to-diameter ratio	1 $\leq L/D \leq$ 20 (Examples for calculating *L/D* are given in Annex A).

If one or more of the above conditions are not fulfilled the applicability of the above equation shall be proven.

A is the venting area that shall be fitted to the enclosure assuming the venting efficiency factor of the venting device is 1 and thus the effective venting area is equal to the physical venting area. Some venting devices have a venting efficiency factor less than 1, and the effective venting area is thus less than the geometric venting area. To compensate for the lower efficiency of the venting device the required venting area A_v shall be larger than the geometric vent area A.

5.3 Special dust cloud conditions

The equations in 5.2 are designed to calculate vent areas for most practical applications – an enclosure completely full of a turbulent dust cloud of optimum dust concentration.

In some practical applications, however, the test procedures specified in accepted European Standards may overstate or understate the explosion intensity compared to the actual processing environment.

In conditions of moderate and low turbulence, and in conditions where a non-homogeneous fuel-air mixture or low dust concentration is the norm, the procedure specified in accepted European Standards is likely to overstate the explosion hazard. In such circumstances a reduced vent area can be used but shall be based on either published or experimental data that has been obtained from representative explosion venting trials.

In conditions of particularly severe turbulence (e.g. in enclosures with turbulence inducing obstructions) there is a possibility that the explosion intensity is understated. In some plants there can be conditions that may generate severe turbulence, and in these cases the equations in 5.2 can underestimate the necessary vent area. In such specific circumstances an increased vent area shall be based on either published or experimental data that has been obtained from representative explosion venting trials.

5.4 Protection of pipelines and interconnected enclosures

The vent sizing methods in 5.2 are suitable for enclosures that are isolated and can be treated as single units. If an explosion can propagate from one enclosure to another through a connecting pipeline, increased turbulence, a relatively large flame jet and pressure piling effects may combine to give an explosion of increased violence.

Interconnected enclosure systems shall normally be protected by isolating each separate enclosure so that an explosion in one protected enclosure is stopped from propagating into a second one. Isolation methods have been discussed in prEN 15089.

The basis of safety for pipelines and interconnected enclosures rests on a combination of the strength of the pipeline, isolation of the explosion effect and explosion protection of the enclosures.

If the explosion begins following an ignition in a protected enclosure and the maximum reduced explosion overpressure $p_{red,\,max}$ does not exceed 0,5 bar the distance along a straight pipeline, L, at which a specified overpressure p_L will occur can be estimated from the equations:

for $K_{St} \leq 100$ bar m s^{-1}

$$L = D \times \left[324{,}8 \times \left(1 - e^{-0{,}1072 \times p_L} \right) \right], \text{ applicable to } (L/D) \text{ ratios no greater than 100;} \quad (5)$$

for $100 < K_{St} \leq 200$ bar m s^{-1}

$$L = D \times \left(88{,}57 - 81{,}99 \times e^{-1{,}640 \times p_L} \right), \text{ applicable to } (L/D) \text{ ratios no greater than 50;} \quad (6)$$

for $200 < K_{St} \leq 300$ bar m s^{-1}

$$L = D \times \left(63{,}76 - 62{,}42 \times e^{-0{,}1484 \times p_L} \right), \text{ applicable to (L/D) ratios no greater than 50.} \quad (7)$$

where D is the pipeline diameter between 0,2 m to 0,6 m. No guidance is available for other pipeline diameters.