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Zaščitni sistemi za razbremenitev tlaka eksplozije prahu

Dust explosion venting protective systems

Schutzsysteme zur Druckentlastung von Staubexplosionen

Systèmes de protection par évent contre les explosions de poussières

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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 30 June 2012.

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Contents

Page

Foreword

This document (EN 14491:2012) 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of an identical text or by endorsement, at the latest by February 2013, and conflicting national standards shall be withdrawn at the latest by February 2013.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 14491:2006.

Annex F provides details of significant technical changes between this European Standard and the previous edition.

This document 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 94/9/EC.

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

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

1 Scope

This European Standard specifies the basic requirements of design for the selection of a dust explosion venting protective system. This European Standard is one of a series including EN 14797, *Explosion venting devices* and EN 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 EN 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;

— hybrid mixtures.

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 materials either processed, used or released by the equipment or from 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

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

EN 14460:2006, *Explosion resistant equipment*

EN 14797:2006, *Explosion venting devices*

EN 15089, *Explosion isolation systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13237:2003, EN 14460:2006 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

1) This is covered in EN 14797.

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

3.3
hybrid mixture
mixture of flammable substances with air in different physical states

[SOURCE: EN 13237:2003]

3.4
dust explosion constant
K_{St}
maximum value of the pressure rise per unit time $(dp/dt)_{max}$ during the explosion of a specific explosive atmosphere involving dust in a closed vessel under specified test conditions normalised to a vessel volume of 1 m^3 multiplied by $V^{1/3}$

Note 1 to entry: See EN 14034-2.

3.5
gas explosion constant
K_G
maximum value of the pressure rise per unit time $(dp/dt)_{max}$ during the explosion of a specific explosive atmosphere involving gas or vapour in a closed vessel under specified test conditions normalised to a vessel volume of 1 m^3 multiplied by $V^{1/3}$

[SOURCE: EN 14994:2007, 3.8, modified]

3.6
geometric vent area
A_v

ratio of required vent area A and venting efficiency E_f for the venting device

Note 1 to entry: The geometric vent area 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
required vent area
A
vent area required for the explosion venting assuming optimum venting efficiency

3.8
overpressure
required vent area pressure above ambient pressure

3.9
maximum explosion overpressure
p_{max}
maximum overpressure occurring in a closed vessel during the explosion of an explosive atmosphere and determined under specified test conditions

Note 1 to entry: See EN 14034-1.

3.10
pipe
connection between two or more enclosures

Note 1 to entry: A pipe cannot be explosion protected by the explosion venting methods for enclosures described in this European Standard.

3.11
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

3.12
maximum reduced explosion overpressure
$p_{red,max}$
resulting maximum overpressure generated by an explosion of an explosive atmosphere in a vessel at optimum fuel concentration, after effective explosion venting or explosion suppression

3.13
maximum rate of explosion pressure rise
$(dp/dt)_{max}$
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 1 to entry: This parameter 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 $bar \cdot m \cdot s^{-1}$ whereas the unit of the $(dp/dt)_{max}$ is $bar \cdot s^{-1}$.

Note 2 to entry: See EN 14034-2.

3.14
maximum external overpressure
$p_{ext,max}$
external maximum value of the overpressure generated by vented dust explosion

3.15
static activation overpressure
p_{stat}
differential pressure at which the retaining element activates such that the venting element is able to open

[SOURCE: EN 14797:2006, 3.11]

3.16
vacuum breaker
device which prevents damage to a vessel when the internal pressure falls below atmospheric pressure

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. Information required for calculation of the vent area includes the explosion resistance 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 1 There is no direct guidance for estimating an endangered area for toxic or other harmful emissions, but the safe discharge area for external flames calculated according to the formulae in 6.2 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 can be required.

This European Standard shall be used together with EN 14797 and EN 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.

NOTE 2 If burning continues inside the vented vessel after the explosion, it can cause damage to the vessel, even though it has been protected from damage caused by overpressure.

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 formula 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 act as a large ignition source in a connected enclosure. This combination of effects can enhance the violence of the secondary explosion. 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 explosion venting can be applied to protect the integrity of the building. A separate method for calculating the venting requirements for buildings is given in Annex D.

The effects of internal or external obstructions on venting effectiveness shall be taken into account. Recoil forces shall be taken into account when considering the location and distribution of the vent area. Explosion venting devices shall be positioned so that the effectiveness of the venting process is not impeded. Positioning shall be such that personnel and the nearby plant will not be at risk from the venting action. If the enclosure is small and relatively symmetrical, one large vent can be as effective as several small vents of equal combined area. For large enclosures, the location of multiple vents to achieve uniform coverage of the enclosure surface to the greatest extent practicable is recommended.

NOTE 3 In the formulae presented in this standard, it is important to use the correct units, which are not always SI-units. The units are indicated for every parameter used in the limits of application. Where log is used in the formulae, $\log_{10}$ is meant.

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.

Two explosion characteristics of the dust are the maximum overpressure p_{max} and the dust explosion constant K_{St}. 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 explosion resistance 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 explosion resistance of the weakest part shall be taken as the explosion resistance for the enclosure.

The two principal vent device parameters are the static activation overpressure p_{stat} and the venting efficiency of the venting device. When sizing vents, the nominal value of the static activation pressure p_{stat} can be used when the tolerance range of the static activation overpressure does not exceed ± 25 %. Otherwise, the maximum value of the tolerance range of the static activation overpressure shall be used.

A is the required venting area that shall be fitted to the enclosure assuming the venting efficiency factor of the venting device is 1 and that therefore the effective venting area is equal to the geometric 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 geometric venting area A_v shall be larger than the required vent area A.

$$A_v = A/E_f \qquad (E_f\text{: venting efficiency}) \tag{1}$$

NOTE See EN 14797 for details.

5.2 Venting of isolated enclosures

The following formulae are designed to calculate vent areas for most practical applications: an enclosure completely full of a turbulent dust cloud of optimum dust concentration.

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

For enclosures, the following formulae allow the calculation of the required vent area A. 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 ≤ $p_{red,max}$ < 1,5 bar overpressure

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

with

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

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

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

$$A = B \tag{5}$$

The formulae are valid for:

enclosures volume	0,1 m^3 ≤ V ≤ 10 000 m^3;
static activation overpressure of the venting device	0,1 bar ≤ p_{stat} ≤ 1 bar; for p_{stat} < 0,1 bar, use p_{stat} = 0,1 bar;
maximum reduced explosion overpressure	0,1 bar < $p_{red,max}$ ≤ 2 bar; and $p_{red,max}$ shall be at least p_{stat} + 2 times the tolerance range of p_{stat}
K_{St} and maximum explosion overpressure	5 bar ≤ p_{max} ≤ 10 bar for a dust specific parameter of 10 bar·m·s^{-1} ≤ K_{St} ≤ 300 bar·m·s^{-1};

	5 bar ≤ p_{max} ≤ 12 bar for a dust specific parameter of 300 bar·m·s^{-1} < K_{St} ≤ 800 bar·m·s^{-1};
initial process conditions	conditions prevailing inside the protected enclosure at the moment of ignition: — absolute pressure ≤ 110 kPa; — oxygen concentration ≤ 21 %; — temperature between -20 °C and +60 °C; NOTE 1 The formulae can be applied outside this temperature range if the explosion characteristics are corrected to the actual process conditions.
length-to-diameter ratio of the vessel	1 ≤ L/D ≤ 20 NOTE 2 Examples for calculating L/D are given in Annex C.

If one or more of the above conditions are not fulfilled the applicability of the above formula shall be verified.

5.3 Special dust cloud conditions

5.3.1 General

Subclause 5.3 outlines vent area calculations for specific situations verified by testing. Vent areas, which have been sized in accordance with 5.3, can be used for these specific situations provided the parameters stay within the range of validity given for the formulae.

5.3.2 Pneumatic conveying of product with axial introduction into vessels and silos

The following empirical formulae may be used to calculate the required vent area A for pneumatic filling of vessels where the filling line is axial near the centre of the roof.

NOTE 1 A typical example is a silo filled from a pipe in the centre of the roof.

For vessels with a height L ≤ 10 m:

$$A = X(1 + Y \times \log(L/D)) \quad \text{in m}^2 \tag{6}$$

For vessels with a height L > 10 m:

$$A = 0{,}1 \times L \times X(1 + Y \times \log(L/D)) \text{ in m}^2 \tag{7}$$

with

$$X = (1/D_Z \times (8{,}6 \times \log p_{\text{red, max}} - 6) - 5{,}5 \times \log p_{\text{red, max}} + 3{,}7) \times 0{,}011 \times K_{\text{St}} \times D_{\text{F}} \tag{8}$$

$$Y = 1{,}0715 \times p_{\text{red, max}}^{-1{,}27} \tag{9}$$

where

L/D is the length-to-diameter ratio of the vessel;

NOTE 2 Examples for calculating L/D are given in Annex C.

D_F is the diameter of conveying pipe;

D_Z is the effective diameter of the vessel and is calculated as follows:

$$D_Z = \sqrt[3]{\frac{4\,V}{\pi}} \qquad (10)$$

The formulae are valid for:

axially filling near the centre **from above** through **one** pipe with a diameter D_F (in m) into a vessel/silo without obstructions (measurement devices are not taken into account);

vessel volumes	10 m^3 $\leq V \leq$ 250 m^3;
maximum volume flow rate	2 500 m^3/h;
air conveying velocities	$v_L \leq$ 30 m · s^{-1};
diameter of the pipe	$D_F \leq$ 0,3 m;
static activation overpressure of pressure venting device	$p_{stat} \leq$ 0,1 bar;
maximum reduced explosion overpressure	0,1 bar < $p_{red,max} \leq$ 2 bar; and $p_{red,max}$ shall be at least p_{stat} + 2 times the tolerance range of p_{stat};
maximum explosion overpressure	$p_{max} \leq$ 9 bar;
dust specific characteristic	50 bar·m·s^{-1} $\leq K_{St} \leq$ 300 bar·m·s^{-1}.

NOTE 3 The formulae can be used for vessels with integrated filters as long as the enveloping volume of the filter elements is less than 5 % of the overall vessel volume. The pressure resistance of these integrated filters needs to be at least equal to that of the vessel. Separate filters on top of the vessel with a chute into the vessel require explosion isolation and explosion venting of these filters.

5.3.3 Pneumatic conveying of the product with tangential introduction into vessels and silos

The following empirical formulae may be used to calculate the required vent area A for pneumatic filling of vessels where the filling line is mounted tangential at the perimeter near the top of the silo.

$$A = X(1 + Y \cdot \log(L/D)) \quad \text{in m}^2 \qquad (11)$$

with

$$X = ((1/D_Z)((8{,}6/k)\log p_{\text{red, max}} - (K_{St}/44) - 0{,}513) - (5{,}5/k)\log p_{\text{red, max}} + (K_{St}/69) + 0{,}191) \times 0{,}011 \times K_{St} \times D_F \qquad (12)$$

$$Y = 0{,}166 \times e^{\frac{K_{st}}{129}} \times p_{\text{red, max}}^{\frac{-1{,}27}{k}} \qquad (13)$$

with

k = 1 for 0,1 bar $\leq p_{red,max} \leq$ 1 bar;

k = 2 for 1 bar < $p_{red,max} \leq$ 1,7 bar.

The formulae are valid independent from the product load of the conveying stream in case of a tangential pneumatic filling for:

tangential product introduction through **one** pipe with a diameter of $D_F \leq 0{,}2$ m;

round vessels/silos without obstructions (measuring devices are not to be taken into account);

vessel volume	$10 \text{ m}^3 \leq V \leq 120 \text{ m}^3$;
length/diameter ratio	L/D with $1 \leq L/D \leq 5$;

NOTE 1 Examples for calculating L/D are given in Annex C.

maximum volume flow rate	$2\,500 \text{ m}^3/\text{h}$;
air conveying velocities of	$v_L \leq 30 \cdot \text{m} \cdot \text{s}^{-1}$;
static activation overpressure of pressure venting device:	$p_{stat} \leq 0{,}1$ bar;
maximum reduced explosion overpressure:	0,1 bar < $p_{red,max} \leq 1{,}7$ bar and $p_{red,max}$ shall be at least p_{stat} + 2 times the tolerance range of p_{stat};
maximum explosion overpressure:	$p_{max} \leq 9$ bar;
dust specific characteristic:	$100 \text{ bar} \cdot \text{m} \cdot \text{s}^{-1} \leq K_{St} \leq 220 \text{ bar} \cdot \text{m} \cdot \text{s}^{-1}$;

D_Z is calculated according to Formula (10).

Alternatively the calculation according to 5.3.2 may be used, taking into account the stated boundary conditions.

NOTE 2 The formulae can be used for vessels with integrated filters as long as the enveloping volume of the filter elements is less than 5 % of the overall vessel volume. The pressure resistance of these integrated filters needs to be at least equal to that of the vessel. Separate filters on top of the vessel with a chute into the vessel require explosion isolation and explosion venting of these filters.

5.3.4 Free fall filling

Formulae (6) to (10) may be used to calculate the required vent area in case a product enters the vessel by free fall (gravity) from, e.g. a rotary valve or screw feeder.

The feed rate shall be limited to smaller or equal $8\,000 \text{ kg} \cdot \text{h}^{-1}$ and the (equivalent) diameter of the feed opening has to be substituted for D_F in the formulae. Apart from these requirements, the conditions remain the same as for the numerical formulae given in 5.3.2.

NOTE The formulae can be used for vessels with integrated filters as long as the enveloping volume of the filter elements is less than 5 % of the overall vessel volume. The pressure resistance of these integrated filters needs to be at least equal to that of the vessel. Separate filters on top of the vessel with a chute into the vessel require explosion isolation and explosion venting of these filters.

5.4 Protection of interconnected enclosures

5.4.1 Vent areas determined by the Formulae (1) to (5) are too small if a dust explosion propagates from one vessel into another through a pipe. Increased turbulence, pressure piling and broad flame jet ignition may result in an increased explosion violence, especially with duct length > 6 m. This results in an elevated maximum reduced explosion overpressure. Measures for explosion isolation in the connecting pipe are therefore needed in most situations.