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New Revised European Norm on Dust Explosion Venting Protection Systems EN 14491

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In 2006 the EN 14491 was published (EN 14491, 2006). This European Standard specifies the basic requirements of design for the selection of a dust explosion venting protective system. Thepresent paper will explain the significant changes between the new revised European Standard and the previous one (EN 14491,2006) which are as follows:(1) Additional Information and requirements for pneumatic conveying of the product with axial or tangential release into vessels and silos.(2) Additional Information and requirements on free fall filling of product from e.g., rotary air locks or screw feeder into vessels and silos.(3) Additional Information and requirement on the effect of vent ducts upon the reduced explosion overpressure.(4) - Additional information of flame and pressure effects outside enclosures.(5) - Information on the influence of the filter elements on the explosion venting has been added.(6) - Information on the design of explosion venting of cyclones has been added.

The changes in this standard refers to changes regarding the previous standard, which add new or modify existing technical requirements, in a way that new options are given, but without increasing requirements for equipment that was fully compliant with the previous standard. Therefore these changes will not have to be considered for products in conformity with the preceding edition.

1. Introduction

The national committees members of section II of the “Fédération Européenne de la Manutention” (FEM) have decided at their Plenary meeting in Malmö (June 1892) to adopt the VDI Guideline “Pressure release of duet explosions”(VDI3673, 1979) and to recommend to its members and their clients the utilisation of this document with practical indications, which have proven themselves, for the selection and the calculation of the release devices.Through extensive experiments, conducted between 1989 and 2002, new findings were made which made necessary revisions of VDI3673 in 1995 and 2002. When (EN 14491,2006)was released not all information from (VDI 3673,2002) were implemented because findings from other European countries were implemented instead. Since the publication of (EN 14491,2006) untilnow a wide experience of the applications of (EN 14491,2006) or (VDI3673,2002) respectively could be gained. Because the EN Norms must be checked every 5 years, it was exactly the right time to implement the experience gained into the new revised EN 14491.

2. Significant Changes

2.1 Special dust cloud conditions

Three sizing cases of pressure venting devices for special conveying condition are introduced in Table 1. The information as well as the equations where used from the Guideline (VDI 3673,2002).

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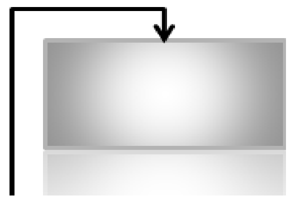
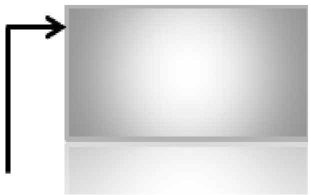
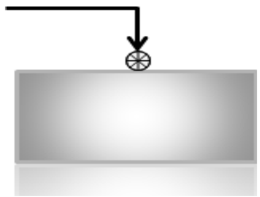
Table 1.Sizing cases of pressure venting devices

Pneumatic conveying of product with axial introduction into vessels and silos. The equations are valid for inter alia: Enclosure volumes :$10m^3 \leq V \leq 250m^3$ Maximum volume flow rate : 2'500 m^3/h Maximum explosion overpressure: $P_{max} \leq 9$ bar Dust specific characteristic : $50 m \cdot bar \cdot s^{-1} \leq K_{St} \leq 300 m \cdot bar \cdot s^{-1}$	
Pneumatic conveying of product with tangential introduction into vessels and silos. The equations are valid for inter alia: Enclosure volumes : $10\ m^3 \leq V \leq 120\ m^3$ Maximum volume flow rate : 2'500 $m^3 \cdot h^{-1}$ Maximum explosion overpressure: $P_{max} \leq 9$ bar Dust specific characteristic : $100 m \cdot bar \cdot s^{-1} \leq K_{St} \leq 220 m \cdot bar \cdot s^{-1}$	
Free fall filling The equations are valid for inter alia: Enclosure volumes : $10\ m^3 \leq V \leq 250\ m^3$ Maximum volume flow rate : 2'500 m^3/h Maximum explosion overpressure: $P_{max} \leq 9$ bar Dust specific characteristic : $50 m \cdot bar \cdot s^{-1} \leq K_{St} \leq 300 m \cdot bar \cdot s^{-1}$ Feed rate : 8000 $kg \cdot h^{-1}$	

2.2 Vent duct

The presence of the vent duct has no effect on the $P_{red,max}$ if the length to diameter ratio of a single vent duct is ≤ 0.5 provided that the volume of the vent duct is less than the volume of the protected vessel.Independent of the location of the vent duct, the maximum reduced explosion overpressure $P'_{red,max}$caused by the downstream duct can be calculated for vessels with the following equation:

$$P'_{red,max} = P_{red,max} \cdot (1 + 17.3 \text{ x } (A \text{x } V^{0.753})^{1.6} \text{ x } \ell, \text{in bar} \qquad (1)$$

where

$P_{red,max}$ is the maximum reduced explosion overpressure without vent duct, in bar;
A is the required vent area without vent duct, in m^2;
V is the vessel volume of protected vessel, in m^3;
ℓ is the length of vent duct, in m.

<u>New validities of the Equation (1) are</u>

length to diameter ratio of a vent duct	$0.5 < \ell/d \leq 20$
length of the vent duct	$\ell \leq 10$ m
maximum reduced explosion overpressure in the protected vessel with vent duct	$P'_{red,max} \leq 2$ bar
dust specific characteristic	$10 m \cdot bar \cdot s^{-1} \leq K_{St} \leq 400 m \cdot bar \cdot s^{-1}$
dust specific characteristic for metal dust	$K_{St} \leq 200 m \cdot bar \cdot s^{-1}$

Experimental studies have proven that the influence of vent duct,when located on the roof (longitudinal arrangement), decreases markedly with increased length diameter ratio of the vessel to be protected. The increase of the maximum explosion overpressure is at its maximum if length diameter ratio of the vessel is $L/D_E = 1$.

For a <u>length to diameter ratio of vessels of L/D_E = 6</u> the elevated "maximum reduced explosion overpressure" $P'_{red,max}$ caused by the downstream vent duct can be calculated from the simple equation:

$$P'_{red,max} = (0.0586 \times \ell + 1.023) \times P_{red,max}^{(0.981 - 0.01907 \times \ell)}, \text{in bar} \quad (2)$$

With a given
maximum explosion overpressure with vent pipe of 0.1bar<$P'_{red,max}$≤ 2bar,
length diameter ratio of vessel between 1<L/D_E< 6,
length of vent pipe ≤10 m.

The reduced maximum explosion overpressure between L/D_E 1 and 6 with vent duct becomes for:

$$P'_{red,max} = 0.2\ (C_1 - C_2)\ (1 - L/D_E) + C_1, \text{in bar} \quad (3)$$

Where $C_1 = P'_{red,max}$ from the equation (1) and $C_2 = P'_{red,max}$ from the equation (2).

2.3 Overpressure due to explosion of the dust cloud in the area outside the vent

Pressure and blast effects external to a vent arise from pressures generated by the vented explosion inside the vented enclosure and the explosion of the dust cloud in the area outside the vent. The overpressure due to the vented explosion has a strong directional effect. The overpressure due to the explosion of the dust cloud in the area outside the vent has no directional effect.
The maximum external overpressure arising at any location outside the vented enclosure can either be due to one of these two effects. Therefore both shall be calculated and the worst (highest) value shall be used.

2.3.1 Overpressure due to the explosion of the dust cloud in the area outside the vent

The maximum external overpressures $P_{ext,max}$can be estimated using the following equations:

$$P_{ext,max} = 0.2 \times P_{red,max} \times A_v^{0.1} \times V^{0.18}, \text{in bar} \quad (4)$$

where
$P_{red,max}$ is the maximum reduced explosion overpressure, in bar;
A_v is the geometric vent area, in m^2;
V is the vessel volume, in m^3.

The maximum external overpressure, $P_{ext,max}$ can be expected at a distance

$$R_S = 0.25 \times L_F, \text{in m} \quad (5)$$

where
$L_F$is the flame length, in m.

At larger distances, $r (r > R_s)$, from the vent, the external overpressure $P_{ext,r}$ decreases according to:

$$P_{ext,r} = P_{ext,max} \times (R_s/r)^{1.5}, \text{in bar} \quad (6)$$

2.3.2 Overpressure due to vented explosion

The maximum external overpressure $P_{ext,r}$ at a certain location can be estimated using the following equation:

$$P_{ext,r} = 1.24 \times P_{red,max} \times (D/r)^{1.35} / [1+(\alpha/56)^2] \quad , \text{in bar} \quad (7)$$

where

r is the distance from the vent area, in m with $r>R_s$;

D is the hydraulic diameter of the vent, in m;

α defines the direction towards the vent; α=0° means in front of the vent area;
α=90° means sideways from the vent area.

2.4 Annex A: Explosion venting of dust filters

Dust filters are the most common type of dust/air separation equipment. Dust filters will typically have a dirty air volume and a clean air volume. The clean air volume includes the inner volume of filter bags, cartridges and envelopes if the dust is separated from the air at the outer surface of the filter.

If the distance a between the circular filter elements is ≤ the radius of the filter elements, then the entire enveloping volume of the filter elements can be subtracted from the dirty air volume. The same is valid if $a \leq b$ with b being the width of enveloped or pocket filters (see Figure 1).

The instructions in this annex do not apply to reverse type filters where the dust is separated on the inside of the filter elements.

A key assumption is that the clean air volume is essentially free of fuel. With this statement being true, the vent panel will be calculated for the dirty air volume and be installed on the dirty air section. This requires that the structural integrity of the elements that separate the clean air volume from the dirty volume (tube sheet and filter elements) is maintained during the initial explosion event.

If the clean air contains fuel then an additional separate vent on the clean air side should be calculated based on the clean air side volume.

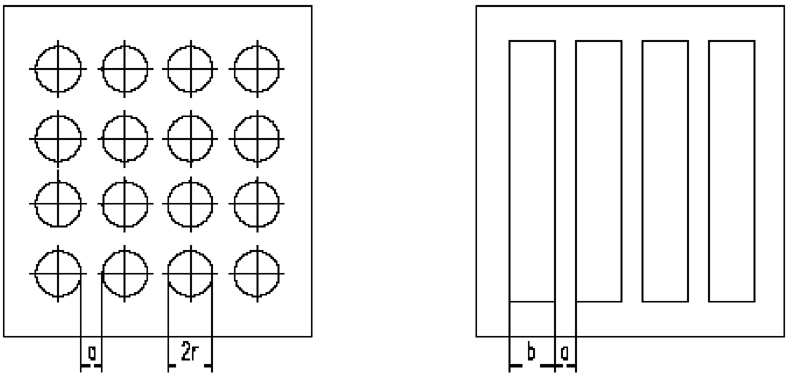


Figure 1:Various filter element arrangements (a ≤ r; a ≤ b) - Left-hand side: bag, candle or cartridge filter elements; right-hand side: pocket, flat bag, cassette filter elements or disk filters.

The preferred location of the vent is below the filter elements. When filter elements (partially) block the vents, either completely remove the filter elements in front of the vent or shorten them so that they do not extend below the top of the vent. In addition, bars should be installed to refrain the filter elements from obstructing the venting process.

The distance X between the first arrays of filter elements and the venting device (see Figure 2) should be such that the passage area directly in front of the venting device at least equals that of the venting device.

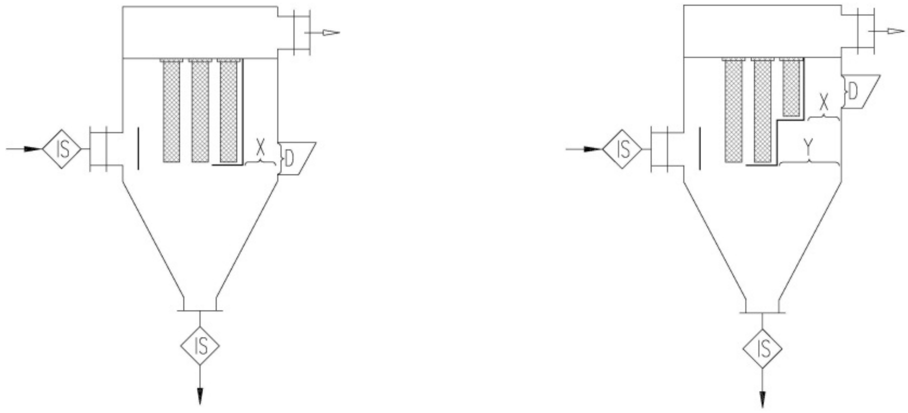


Figure 2:Filter elements in front of the venting device right: filter bags removed, left: filter bags shortened (X = distance between the first arrays of filter elements and the venting device, *D* = diameter of venting device, *IS = Isolation System)*

2.5 Annex A: Explosion venting of cyclones

For calculating the explosion venting device of a cyclone (see Figure 3), take into account the entire cylindrical volume, V_1 (without subtracting the air outlet pipe), the conical volume, V_2, as well as the volume of the settling chamber, V_3.

Typically the explosion vent is located on top of the air outlet pipe implying that the vent area equals the total cross-sectional area, *A*, of the air outlet pipe. For the venting design according to Clause 5 the air outlet pipe should be considered as a vent duct with length, L_A. Should the air outlet pipe be tapered inside, use the smaller cross-sectional area *X* for the calculation of P_{red}.

If additional vents are required, these will be preferably located on top of the cyclone (shoulders), around the air outlet pipe.

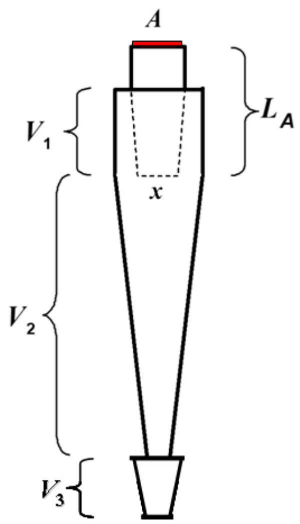


Figure 3:Cyclone with settling chamber

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