BS EN 14491:2012

BSI Standards Publication

Dust explosion venting protective systems

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National foreword

This British Standard is the UK implementation of EN 14491:2012. It supersedes BS EN 14491:2006 which is withdrawn.

BSI, as a member of CEN, is obliged to publish EN 14491:2012 as a British Standard. However, attention is drawn to the fact that during the development of this European Standard, the UK committee voted against its approval as a European Standard.

The standard indicates that the calculation in equation 17, is considered valid for containers up to 10,000 m^3. In the opinion of the committee, extrapolation of data to this extent introduces large uncertainties and may not be safe; use of this equation for vessels up to $100m^3$ would be considered reasonable. In any case, there is rarely a need to fit vent ducts to large vessels. Long standing advice from HSE recommends[1] that silos and similar large vessels should be installed outside any building.

Annex D (informative) considers the use of explosion venting to protect buildings housing dust handling plants. Large areas of explosion relief are often needed in such cases. The standard states that a lightweight roof may be considered sacrificial if its movement can be tolerated. It also implies that wall panels may form elements of explosion venting.

Where elements of a building such as vent panels are placed on the market with the intention that they will be used to provide explosion protection, the ATEX directive requires that they arethird party certified, and the relevant harmonized standard sets close limits on the opening pressure and other parameters. Lightweight building cladding or roofing panels may be placed on the market with no claimed intention that they will provide explosion protection. In some circumstances they may achieve the objective of an explosion vent, but users should be aware that national authorities might not accept the use of uncertified panels in this way.

[1] Refer to the HSE publication, *Safe handling of combustible dusts: Precautions against explosions (2003)*, for advice on installing silos and similar large vessels.

The UK participation in its preparation was entrusted to Technical Committee EXL/23, Explosion and fire precautions in industrial and chemical plant.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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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.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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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·m·s^{-1} whereas the unit of the $(dp/dt)_{max}$ is bar·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 $\leq p_{red,max} <$ 1,5 bar overpressure

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

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 $\leq p_{red,max} \leq$ 2,0 bar overpressure

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

The formulae 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	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}
K_{St} and 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};

	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

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

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

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:

$$D_Z = \sqrt[3]{\frac{4\ V}{\pi}} \tag{10}$$

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

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.

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

with

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

$$Y = 0{,}166 \times e^{\frac{K_{St}}{129}} \times p_{red,\,max}^{\frac{-1{,}27}{k}} \tag{13}$$

with

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

k = 2 for 1 bar $< p_{red,max} \le$ 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 m$^3 \leq V \leq$ 120 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 m^3/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 bar·m·s$^{-1} \leq K_{St} \leq$ 220 bar·m·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 kg·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.

In the following sub-clauses, two alternative methods are presented for specific situations without explosion isolation.

5.4.2 Explosion venting may be used without explosion isolation for vessels interconnected with pipes having a nominal diameter up to 300 mm and a connecting length up to 6 m and for dusts with K_{St} values not exceeding 200 bar·m·s^{-1}, in accordance with the following criteria:

a) Both vessels of the same size (size differences not greater than 10 %) are to be vented according to Formulae (1) to (5).

b) The vent areas of different sized vessels shall be calculated using a maximum reduced explosion overpressure $p_{red,max} \leq 1{,}0$ bar. The design overpressure of each vessel shall be at least 2 bar. If it is not possible to vent the smaller vessel, then this vessel shall be designed for the maximum explosion overpressure and the vent area of the larger vessel shall be doubled. The use of explosion pressure venting is impossible if the larger vessel cannot be vented this way.

The static activation overpressure of the venting device, p_{stat}, shall be lower than 0,2 bar.

5.4.3 Explosion venting may be used without explosion isolation for vessels ≤ 20 m^3 interconnected with pipes with a nominal diameter up to 500 mm and a connecting length up to 15 m, in accordance with the following criteria:

a) For K_{St} values of 150 bar·m·s^{-1} or less, dimensionless vent areas of greater than 0,25 will limit the maximum reduced explosion overpressure to 0,5 bar.

b) For K_{St} values between 150 bar·m·s^{-1} and 250 bar·m·s^{-1}, dimensionless vent areas of greater than 0,4 will limit the maximum reduced explosion overpressure to 0,5 bar.

The venting devices shall be designed for a low static activation overpressure, $p_{stat} \leq 0{,}1$ bar.

The dimensionless vent area is defined as $A / V^{2/3}$ where A is the required vent area and V is the enclosure volume. The total vent area shall be divided between the enclosures so that the dimensionless vent area has the same value in each enclosure.

5.5 Protection of pipes

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 pipe, 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 are described in e.g. EN 15089, EN 16020 and the upcoming European standard for explosion isolation flap valves.

The basis of safety for pipes and interconnected enclosures rests on a combination of the strength of the pipe, 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 L along a straight pipe without obstructions at which a specified overpressure p_L will occur can be estimated from the formulae:

for $K_{St} \leq 100$ bar·m·s^{-1}

$$L = D \times \left[324{,}8 \times \left(1 - e^{-0{,}1072 \times p_L} \right) \right]$$, applicable to (L/D) ratios no greater than 100; (14)

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

$$L = D \times \left(83{,}57 - 81{,}99 \times e^{-0{,}1640 \times p_L}\right)$$, applicable to (L/D) ratios no greater than 50; (15)

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

$$L = D \times \left(63{,}76 - 62{,}42 \times e^{-0{,}1484 \times p_L}\right)$$, applicable to (L/D) ratios no greater than 50; (16)

where

L is the distance along a straight pipe without obstructions at which an overpressure p_L will occur, in metres (m);

D is the pipe diameter, in metres (m) with 0,2 m ≤ D ≤ 0,6 m;

p_L is the local overpressure at the distance L, in bar.

No guidance is available for other pipe diameters.

5.6 Influences of vent ducts

If the pressure venting device is activated and there is a vent duct downstream the system, such duct can be filled with an explosive mixture before the flames exit the protected vessel. This will result in a secondary explosion in the vent duct, which in turn, hinders the venting process. Therefore, the maximum reduced explosion overpressure inside the vessel will increase with the increasing length of the vent duct.

The presence of the vent duct has no effect on the $p_{red,max}$, if the l/d 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.

The maximum reduced explosion overpressure with vent duct $p'_{red,max}$ caused by the downstream vent duct can be calculated with the following formula:

$$p'_{red,max} = p_{red,max} \times (1 + 17{,}3 \times (A \times V^{-0{,}753})^{1{,}6} \times l) \quad (17)$$

where

$p'_{red,max}$ is the maximum reduced explosion overpressure in the protected vessel with vent duct, in bar;

$p_{red,max}$ is the maximum reduced explosion overpressure without vent duct, in bar;

A is the required vent area without vent duct, in square-metres (m^2);

V is the vessel volume of protected vessel, in cubic-metres (m^3);

l is the length of vent duct, in metres (m).

NOTE 1 For rectangular cross-sections use the hydraulic diameter.

The Formula (17) is valid for

vessel volumes	0,1 m^3 < V < 10 000 m^3;
l/d ratio of vent duct	0,5 < l/d ≤ 20;
l of vent duct	l ≤ 10 m;
static activation overpressure of pressure venting device	0,1 bar ≤ p_{stat} ≤ 0,2 bar;

maximum reduced explosion overpressure in the protected vessel with vent duct	$p'_{\text{red, max}}$ ≤ 2 bar;
maximum reduced explosion overpressure	0,1 bar < $p_{\text{red,max}}$ ≤ 2 bar; and $p_{\text{red,max}}$ shall be at least p_{stat} + 2 times the tolerance range of p_{stat}
maximum explosion overpressure	5 bar < $p_{\max}$ < 12 bar and a dust specific characteristic 10 bar·m·s^{-1} < K_{St} < 400 bar·m·s^{-1}, for metal dust K_{St} < 200 bar·m·s^{-1}.

If one of the following parameters: the maximum explosion overpressure, the dust specific characteristic, the static activation overpressure, is smaller than the one stated in the respective ranges of validity of the Formula (17), the formula shall be applied using the minimum values of that particular parameter given above.

The influence of the vent duct upon the pressure increase is most pronounced when the flame propagation from the secondary explosion in the vent duct reaches the velocity of sound. This is valid for vent ducts with a length of

$$l = l_{\text{s}} = 4{,}564 \ p_{\text{red, max}}^{-0{,}37} \tag{18}$$

Vent ducts with a length of l = l_{s} have no additional effect upon the pressure increase. For vent ducts longer than l_{s}, l_{s} may be used in Formula (17) for calculating $p'_{\text{red, max}}$.

Formula (18) is not valid for metal dusts.

The other applications limits for Formula (17) also apply for Formula (18).

NOTE 2 Experimental studies indicate that formulae (17) and (18) overestimate the influence of vent ducts for elongated vessels with the vent located as shown in Figure C.1. Reductions in the reduced explosion pressure are allowed as long as these are based on either published or experimental data that has been obtained from representative explosion venting trials.

5.7 Design of vent ducts

Vent ducts require at least the same design strength as the protected vessel. The explosion resistance of the duct shall be proven according to EN 14460.

If an inspection door is provided near the venting device for maintenance, then the cover and closure shall have at least the same strength as the vent duct.

A vent duct, between the protected vessel and the venting device is not covered by 5.6 and needs specific consideration. The venting device shall be placed directly on the protected vessel and not on the end of the vent duct.

In principle, vent ducts downstream of pressure venting devices shall not be closed. However, light covers (weight < 0,5 kg/m^2) are permissible, e.g., plastic sheets or panels in rubber mouldings, in order to prevent rain or snow from entering. The covers shall be thrown off at very low overpressure (less than 50 % of p_{stat}, to be proven by tests). The vent cover shall not become a dangerous projectile.

Vent duct configurations to which Formulae (17) and (18) can be applied are shown in Figure 1.

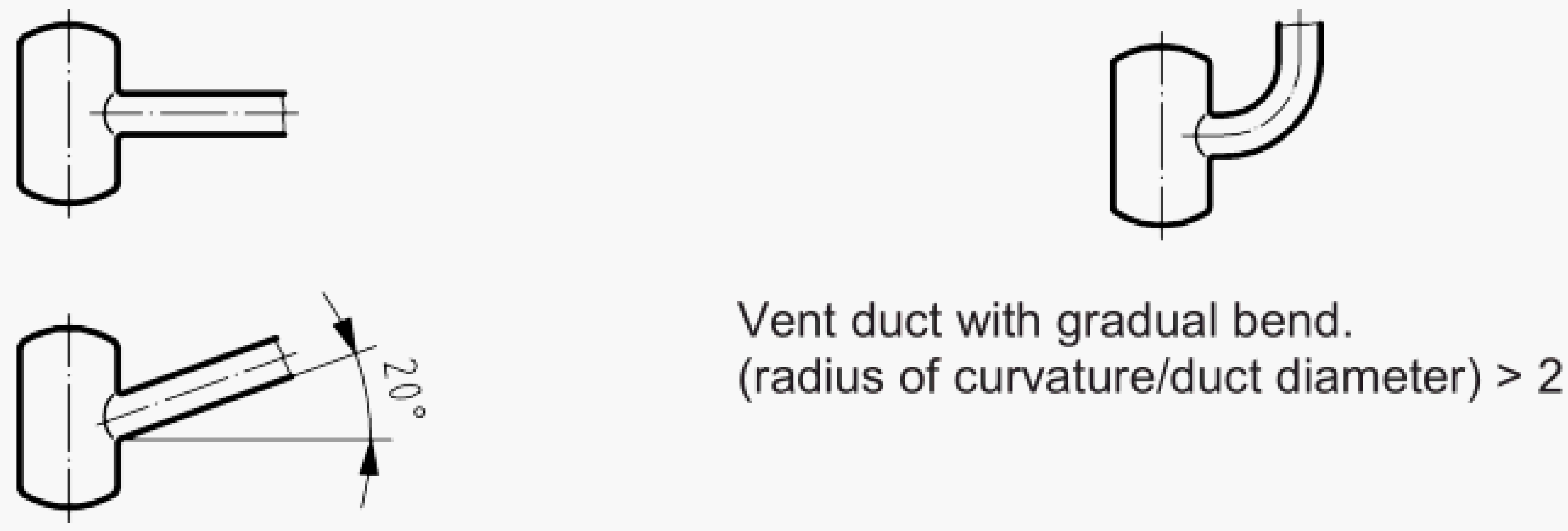


Figure 1 — Vent duct design to which Formulae (17) and (18) apply

Vent ducts which are characterised by a change of direction can be exposed to increased dynamic forces. This shall be reflected in their design.

Vent duct configurations to which Formulae (17) and (18) cannot be applied are shown in Figure 2.

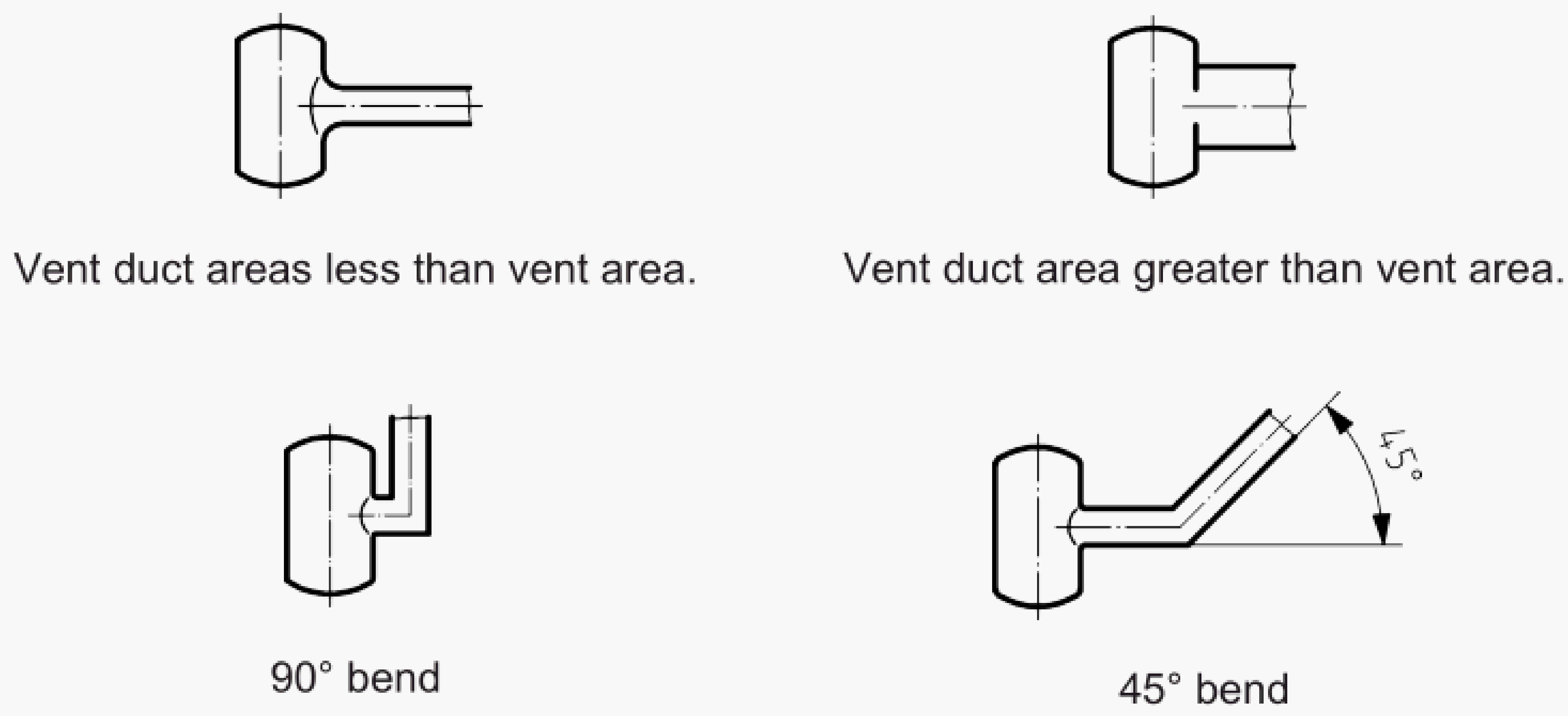


Figure 2 — Vent duct designs to which Formulae (17) and (18) do not apply

NOTE The vent duct designs in Figure 2 are not forbidden; rather Formulae (17) and (18) do not apply to them. These and other designs can be used as long as the predictions of the effects of the vent duct on the maximum reduced explosion overpressure are based on either published or experimental data that has been obtained from representative explosion venting trials.

5.8 Hybrid mixtures

A hybrid mixture can be ignitable if the concentration of one of the fuel components, or even if all concentrations of each individual fuel component, are below their respective lower explosion limits. If the gas and solvent vapour concentration everywhere in the vessel is below 20 % of the lower explosion limit ($LEL_{gas,vapour}$), the hybrid mixture shall be assessed using the explosion indices of the dust present in the mixture. If products containing more than 0,5 % w/w flammable solvents are handled, the possibility of a hybrid mixture shall always be considered.

If a hybrid mixture is present, Formulae (1) to (5) shall be used. The combustible dust shall have a K_{St} < 300 bar·m·s^{-1} and the combustible gas or solvent a K_G < 100 bar·m·s^{-1}. The following values shall be entered into Formulae (1) to (5):

— maximum explosion overpressure p_{max} = 10 bar;

— maximum dust explosion constant K_{St} = 500 bar·m·s^{-1}.

NOTE For hybrid mixtures made up with combustible dusts with K_{St} > 300 bar·m·s^{-1} or of flammable gases being more reactive than propane, it might be necessary to determine the explosion characteristics of specific hybrid mixtures before the venting requirements can be assessed.

This standard applies only to hybrid mixtures where the main component of the mixture is explosive dust.

6 Supplementary design considerations

6.1 General

Successful application of explosion venting is not only a matter of specifying a sufficient vent area, but also of dealing effectively with the hazards that arise from the venting process.

These hazards include:

— explosion effects external to the vent;

— deformation of the vented enclosure.

6.2 Explosion effects external to the vent

6.2.1 General

A vented explosion ejects burning, burnt and unburnt material into the area outside the vent. Measures shall therefore be taken to ensure that the nearby plant and personnel will not be at risk. The area into which the explosion is vented shall be sufficiently distant from other process equipment to prevent additional fire and explosions, and personnel shall not be allowed to enter this area when an explosion hazard is present.

NOTE Danger can extend for a longer period if dust conveying systems do not shut down but continue to deliver dust to the area where the explosion occurred.

6.2.2 Flame effects

The flame length external to a vent can be estimated using the following formula:

$$L_F = 10\,V^{1/3} \tag{19}$$

where

L_F is the flame length, in metres (m);

V is the enclosure volume, in cubic-metres (m^3).

Formula (19) applies to horizontally discharging explosion venting. For vertically discharging venting, the formula is:

$$L_F = 8\,V^{1/3} \tag{20}$$

The formulae are valid for:

volume	0,1 m^3 ≤ V ≤ 10 000 m^3;
static activation overpressure	0,1 bar ≤ p_{stat} ≤ 0,2 bar;
maximum reduced explosion overpressure	0,1 bar < $p_{red,max}$ ≤ 2 bar;

maximum explosion overpressure 5 bar ≤ p_{max} ≤ 10 bar;

K_{St} value 10 bar·m·s^{-1} ≤ K_{St} ≤ 300 bar·m·s^{-1};

the L/D ratio of the enclosure L/D < 2.

NOTE 1 In practice, the flame length is not expected to exceed 60 m, even for large volumes, and this figure can be taken as the upper limit for any estimation of L_F.

For dusts with K_{St} ≤ 200 bar·m·s^{-1}, an estimate of the flame width for both horizontally and vertically discharging venting is given by

$$W_F \approx 2{,}8\, V^{1/3} \tag{21}$$

where

W_F is the flame width, in metres (m);

V is the enclosure volume, in cubic-metres (m^3).

NOTE 2 To limit the external flame length deflectors can be used. For more information see Annex E.

6.2.3 Pressure effects

6.2.3.1 General

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.

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

The maximum external overpressures can be estimated using the following formula:

$$p_{ext,max} = 0{,}2 \times p_{red,max} \times A_v^{0,1} \times V^{0,18} \tag{22}$$

where

$p_{ext,max}$ is the maximum external overpressure, in bar;

$p_{red,max}$ is the maximum reduced explosion overpressure, in bar;

A_v is the geometric vent area, in square-metres (m^2);

V is the vessel volume, in cubic-metres (m^3).

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

$$R_S = 0{,}25 \times L_F \tag{23}$$

where

L_F is the flame length, in metres (m), calculated by Formulae (19) or (20) in 6.2.2.

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

$$p_{ext,r} = p_{ext,max} \times (R_S / r)^{1,5} \quad (24)$$

where

r is the distance from the vent area, in metres (m).

The formulae are valid for:

vessel volume	0,1 $m^3 \leq V \leq 250$ m^3;
static activation overpressure of vent	$p_{stat} \leq 0{,}1$ bar;
maximum reduced explosion overpressure	0,1 bar < $p_{red,max} \leq 1{,}0$ bar;
distance from the vent area	$r > R_s$;
maximum explosion overpressure	$p_{max} \leq 9$ bar;
K_{St}-value	$K_{St} \leq 200$ bar·m·s^{-1};
length-to-diameter ratio	$L/D < 2$.

6.2.3.3 Overpressure due to the vented explosion

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

$$p_{ext,r} = 1{,}24 \times p_{red,max} \times (D / r)^{1,35} / \left[1 + (\alpha / 56)^2\right] \quad (25)$$

where

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

D is the hydraulic diameter of the vent, in metres (m);

α defines the direction towards the vent;

with

α = 0° means in front of the vent area;

α = 90° means sideways from the vent area.

The application limits are the same as defined in 6.2.3.2.

6.2.4 Effects of flameless explosion venting devices

See EN 16009.

6.2.5 Recoil forces

Recoil forces are generated during explosion venting by ejection of material from the vent opening. These forces can cause vented enclosures to deform or, in the worst case, to collapse.

The maximum recoil force can be calculated using the following formula:

$$F_{Rmax} = 119 \times A_v \times p_{red,\,max} \tag{26}$$

where

F_{Rmax} is the recoil force, in kN;

A_v is the geometric area of the vent, in square-metres (m^2);

$p_{red,max}$ is the maximum reduced explosion overpressure, in bar.

The total recoil force can be considered as a force applied at the geometric centre of the vent. Installation of vents of equal area on opposite sides of a vessel can in some instances compensate for recoil forces. Imbalances can occur due to non-simultaneous opening of the vents and these shall be considered when designing.

Knowing the duration of the recoil forces can aid in the design of certain support structures for vented vessels. The duration calculated by the following formula is a conservative estimate:

$$t_R = \left(K_{St} \times V \times 10^{-4}\right) / \left(A_v \times p_{red,\,max}\right) \tag{27}$$

where

t_R is the duration of the pulse, in seconds (s);

K_{St} is the dust explosion constant, in bar·m·s^{-1};

$p_{red,max}$ is the maximum reduced explosion overpressure, in bar;

A_v is the geometric area of the vent, in square-metres (m^2).

The impulse transmitted by the recoil force can be approximated by a rectangular impulse equal to the integrated force time curve.

The impulse transmitted by the recoil force is given, approximately, by:

$$I_R = 0{,}52\, F_{Rmax} \times t_R \tag{28}$$

where

I_R is the impulse, in kN·s.

6.2.6 Vacuum breakers

When explosion doors that close the vent area after the explosion are used, the cooling of the hot gases of combustion can create a vacuum in the vessel, resulting in its deformation. In order to prevent this from happening, vacuum breakers shall be provided.

An unacceptably high vacuum is prevented if the vacuum breaker is sized in accordance with Formula (29) which describes the correlation of the minimum required suction area with the size of the protected enclosure and its vacuum resistance.

$$A_{suc} = \left[-0{,}00219 \times \ln p_{vac} + 0{,}014\right] \times V^{\left(-0{,}0207 \times \ln p_{vac} + 0{,}8147\right)} \tag{29}$$

where

A_{suc} is the effective suction area, in square-metres (m^2);

p_{vac} is the vacuum resistance of vessel, in mbarg;

V is the vessel (silo) volume, in cubic-metres (m^3).

The formula is valid for:

vessel volume	$5\ m^3 \leq V \leq 5\ 000\ m^3$;
vacuum resistance	$25\ mbarg \leq p_{vac} \leq 500\ mbarg$.

7 Marking

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 EN 14797 *Explosion venting devices* and EN 14460 *Explosion resistant equipment*. The three standards together represent the concept of dust explosion venting. Marking is required for explosion resistant equipment and venting devices.

8 Information for use

All powder handling equipment that is explosion protected by means of explosion venting shall be accompanied by instructions that include:

a) all details of operational requirements;

b) method used to assess the vent area;

c) maximum reduced explosion overpressure $p_{red,max}$ (bar);

d) the value of the static activation overpressure p_{stat} (bar) defined for sizing of vent areas;

e) upper limit of the explosibility characteristics of the dust p_{max} (bar) and K_{St} (bar·m·s^{-1});

f) information on external effects (flame, pressure) and safety distances;

g) full description of procedures to be followed after an explosion.

In addition, the instructions for maintenance shall include:

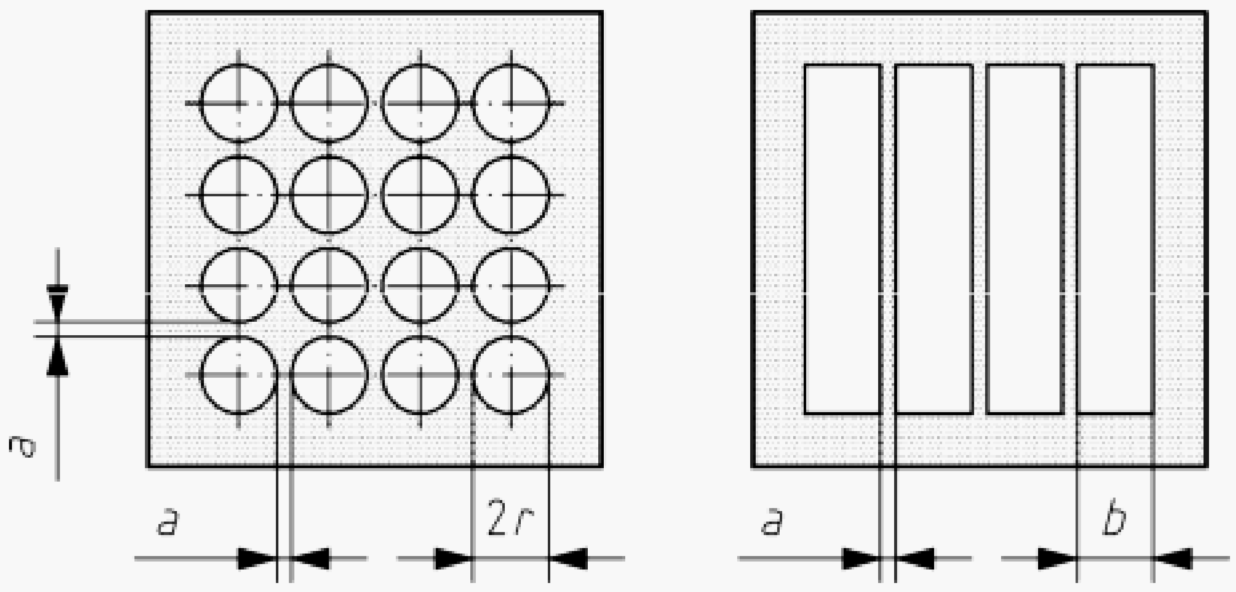
h) periodic inspection
Periodic inspection checks to ensure that the explosion venting capability does not deteriorate and complies with the original design in the event of an explosion.

i) extraordinary inspection
If an explosion occurs an inspection of the equipment is necessary. After completion of any repairs and before the equipment goes back into service, it is the responsibility of the user to satisfy himself that the equipment is safe and the explosion venting precautions are suitable for the equipments intended use.

Annex A
(informative)

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.



Key

a distance between two filter elements

b width of envelope or pocket filters

r radius of filter element

NOTE Left-hand side: bag, candle or cartridge filter elements; right-hand side: pocket, flat bag, cassette filter elements or disk filters.

Figure A.1 — Various filter element arrangements ($a \leq r$; $a \leq b$)

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

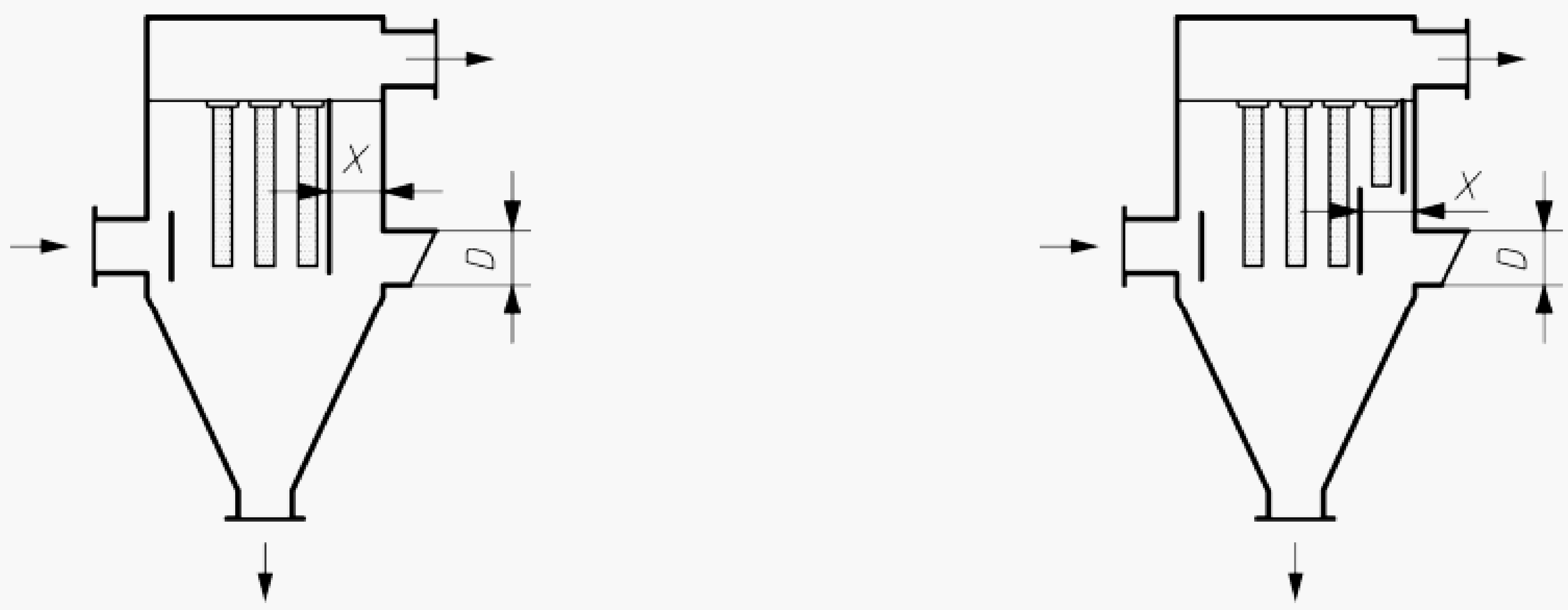
A key assumption is that the clean air volume is essentially free of fuel. With this statement being true, the vent panel will be calculated for the dirty air volume and be installed on the dirty air section. This requires that the structural integrity of the elements that separate the clean air volume 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.

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 A.2) should be such that the passage area directly in front of the venting device at least equals that of the venting device.

For an example of the calculation of L/D ratios of filters, see Figure C.8.



a) filter bags removed

b) filter bags shortened

Key

X distance between the first arrays of filter elements and the venting device

D diameter of venting device

Figure A.2 — Filter elements in front of the venting device

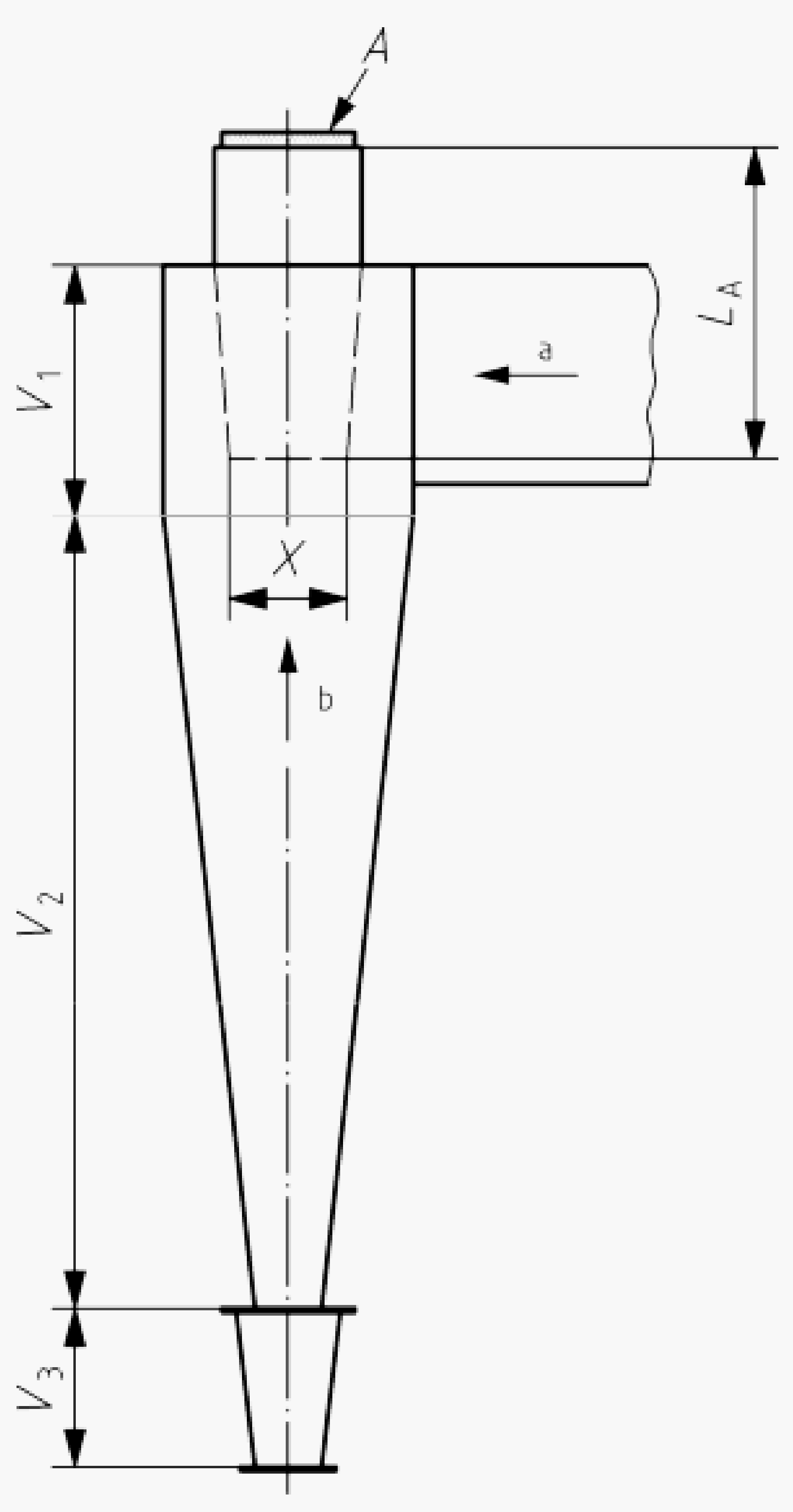
Annex B
(informative)

Explosion venting of cyclones

For calculating the explosion venting device of a cyclone (see Figure B.1), 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.



Key

a inlet

b outlet

Figure B.1 — Cyclone with settling chamber

Annex C
(informative)

Estimating the *L*/*D* ratio when calculating vent areas for elongated enclosures

The length-to-diameter ratio (L/D) of an elongated enclosure is needed if Formula (2) is to be applied. This value of L/D depends on the shape of the enclosure and the position of the vent, and need not necessarily equal the physical value of L/D evident from the design of the enclosure.

The worst case condition to which Formula (2) can be applied is an enclosure with a vent at one end, because the flame can travel the entire length of the enclosure before it vents. If in such a case, the enclosure is cylindrical for example, then the value of L/D can be calculated directly from physical dimensions. If the enclosure does not have a simple shape however, or the vent is not at one end, the appropriate value of L/D can only be obtained by estimating, based on the enclosure design, the maximum distance a flame can travel inside the enclosure before venting and the volume through which the flame travels.

A simple procedure has been devised for calculating L/D ratios for any shape of elongated enclosures and for any vent position:

a) estimate the maximum possible flame path along the central axis of the volume along which the flame can travel up to the higher edge of the pressure venting device, H;

b) calculate the volume of that part of the enclosure through which the flame can pass as it travels along the maximum flame path, V_{eff}[2];

c) divide V_{eff}[2] by H to produce an effective enclosure area, A_{eff} (ratio of the total free volume of an enclosure to its height);

d) calculate an effective enclosure diameter from A_{eff} , D_{eff}.

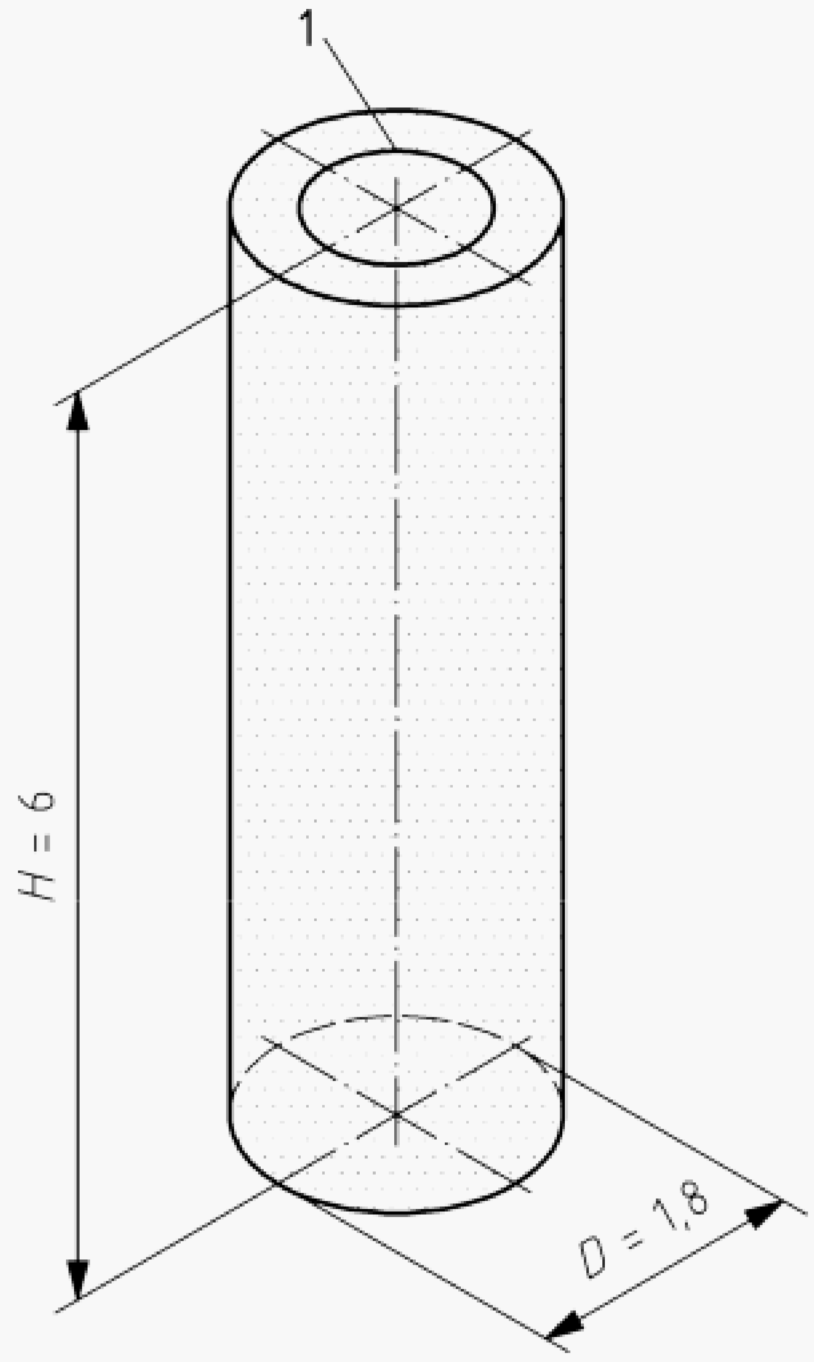
Examples of L/D calculations are given in Figures C.1 to C.8.

NOTE 1 Since flames do not spread in an optimum way in conical or pyramid shaped enclosures, the flame length inside such sections is taken as 1/3 of the height of the section when calculating H. Similarly, only 1/3 of the volume of such shapes is included when calculation V_{eff}. Note that these factors will not generally represent equivalent physical locations for calculating H and V_{eff}. For worked examples see C.3, C.5 and C.8.

NOTE 2 Figures C.3 to C.6 do not apply to filters directly because of the presence of filter elements. See Annex A and Figure C.8 for further information.

2) V_{eff} is not always the volume that should be used in calculating the vent area.

Dimensions in metres



Key

1 vent

a) In this example, L/D equals the physical length to diameter ratio of the enclosure. H equals the vertical height of the enclosure;

b) $V_{eff} = \frac{\pi D^2}{4} \times H = \frac{\pi (1,8)^2}{4} \times 6 = 15,27 \text{ m}^3$;
V_{eff} is the shaded region in the diagram;

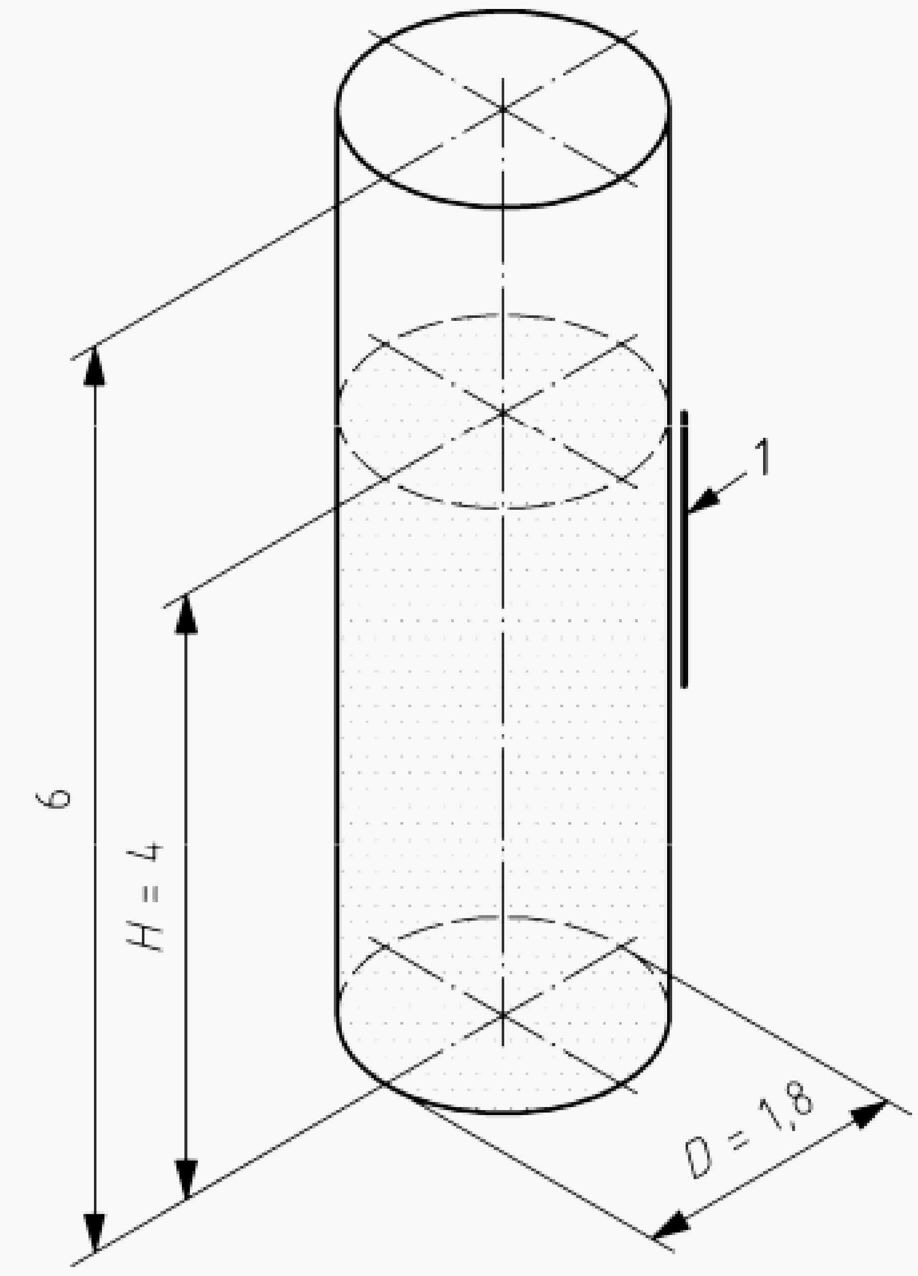
c) $A_{eff} = \frac{V_{eff}}{H} = \frac{15,27}{6} = 2,545 \text{ m}^2$;

d) $D_{eff} = \sqrt{\frac{4 A_{eff}}{\pi}} = \sqrt{\frac{4 \times 2,545}{3,142}} = 1,8 \text{ m}$;

e) $\frac{L}{D} = \frac{H}{D_{eff}} = \frac{6}{1,8} = 3,333$.

Figure C.1 — Cylindrical enclosure with a vent in the roof

Dimensions in metres



Key

1 vent

a) In this example, L/D does not equal the physical length-to-diameter ratio of the enclosure. H equals the distance from the enclosure floor to the top of vent, H = 4 m;

b) $V_{eff} = \frac{\pi D^2}{4} \times H = \frac{\pi \times (1,8)^2 \times 4}{4} = 10,18 \text{ m}^2$;
V_{eff} is the shaded region in the diagram;

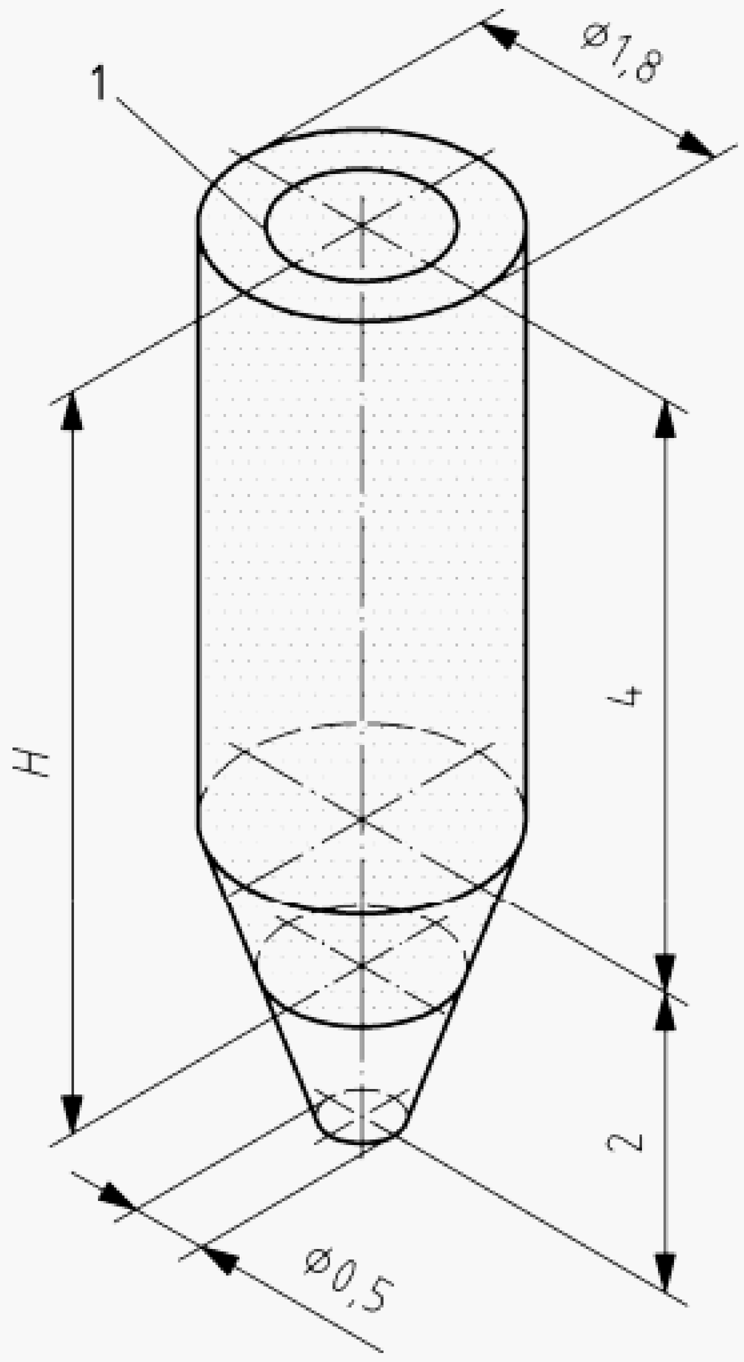
c) $A_{eff} = \frac{V_{eff}}{H} = \frac{10,18}{4} = 2,545 \text{ m}^2$;

d) $D_{eff} = \sqrt{\frac{4 A_{eff}}{\pi}} = \sqrt{\frac{4 \times 2,545}{3,142}} = 1,8 \text{ m}$;

e) $\frac{L}{D} = \frac{H}{D_{eff}} = \frac{4}{1,8} = 2,22$.

Figure C.2 — Cylindrical enclosure with a vent in the side

Dimensions in metres



Key

1 vent

a) Since the flame does not spread in an optimum way in the cone the flame length inside the vessel is 1/3 of the height of the cone plus the height of the cylindrical part = 1/3 cone height + height cylindrical part = 0,667 + 4 = 4,667 m;

b) V_{eff} equals the total free volume of the enclosure which consists of 1/3 of the cone volume and the volume of the cylindrical part.

The volume of the cylindrical part =

$$\frac{\pi\,(1{,}8)^2}{4} \times 4 = 10{,}18\ \text{m}^3$$

1/3 of the volume of the hopper =

$$\frac{\pi \times 2}{3}\left(\frac{0{,}9^2 + 0{,}9 \times 0{,}25 + 0{,}25^2}{3}\right) = 0{,}77\ \text{m}^3$$

$$V_{eff} = 0{,}77 + 10{,}18 = 10{,}95\ \text{m}^3\,;$$

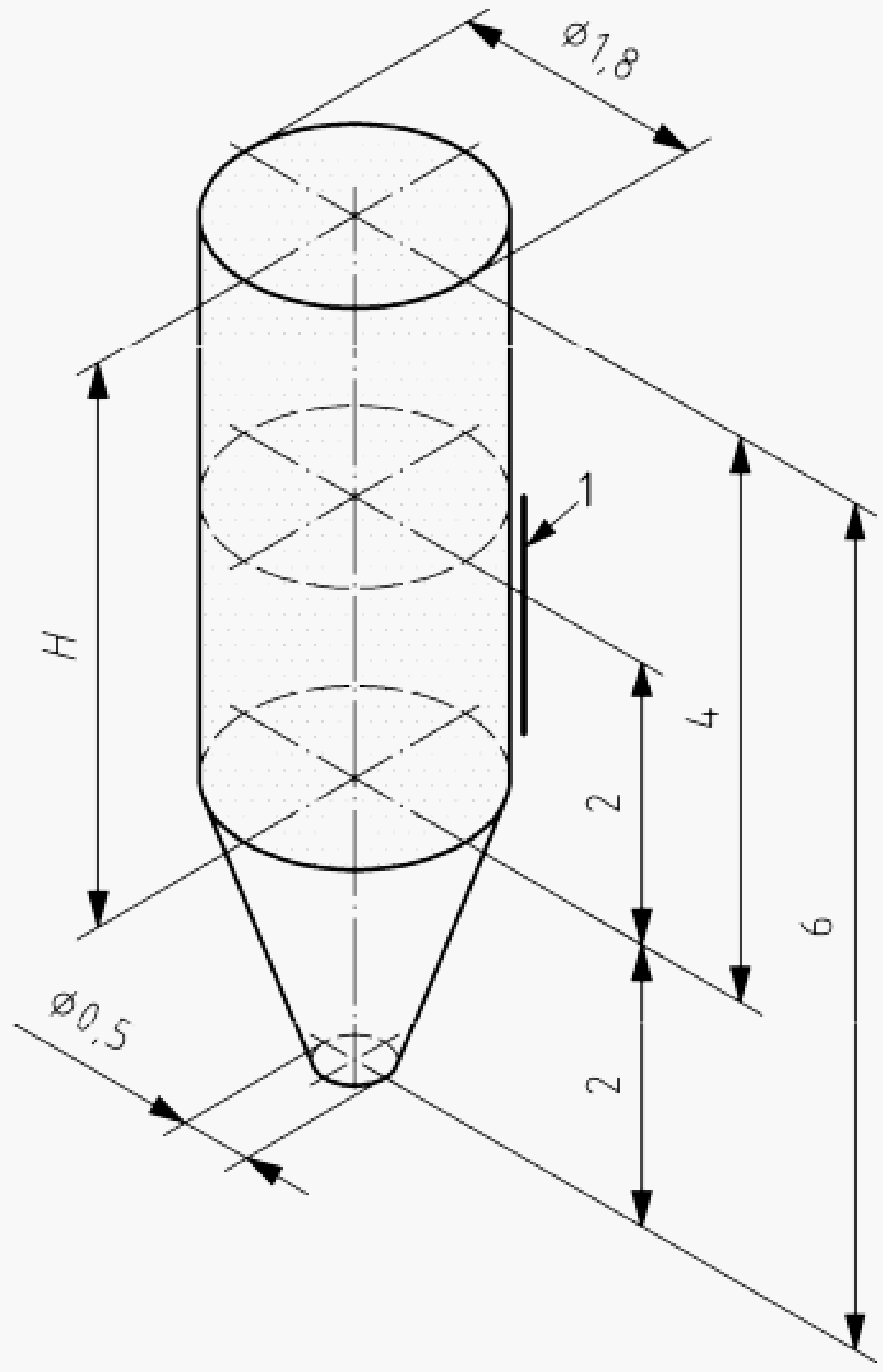
c) $$A_{eff} = \frac{V_{eff}}{H} = \frac{10{,}95}{4{,}667} = 2{,}346\ \text{m}^2\,;$$

d) $$D_{eff} = \sqrt{\frac{4\,A_{eff}}{\pi}} = 1{,}728\ \text{m}\,;$$

e) $$\frac{L}{D} = \frac{H}{D_{eff}} = \frac{4{,}667}{1{,}728} = 2{,}70\,.$$

Figure C.3 — Cylindrical enclosure with a hopper and vented in the roof

Dimensions in metres



Key

1 vent

a) H equals the vertical distance from the roof of the cylindrical part to the bottom end of the vent = 4 m;

b) V_{eff} equals the volume of the cylinder to the bottom end of the vent, i.e. the volume of the cylinder.

Volume of the cylindrical part =

$$V_{eff} = \frac{\pi\,(1{,}8)^2}{4} \cdot 4 = 10{,}18\ \text{m}^3\,;$$

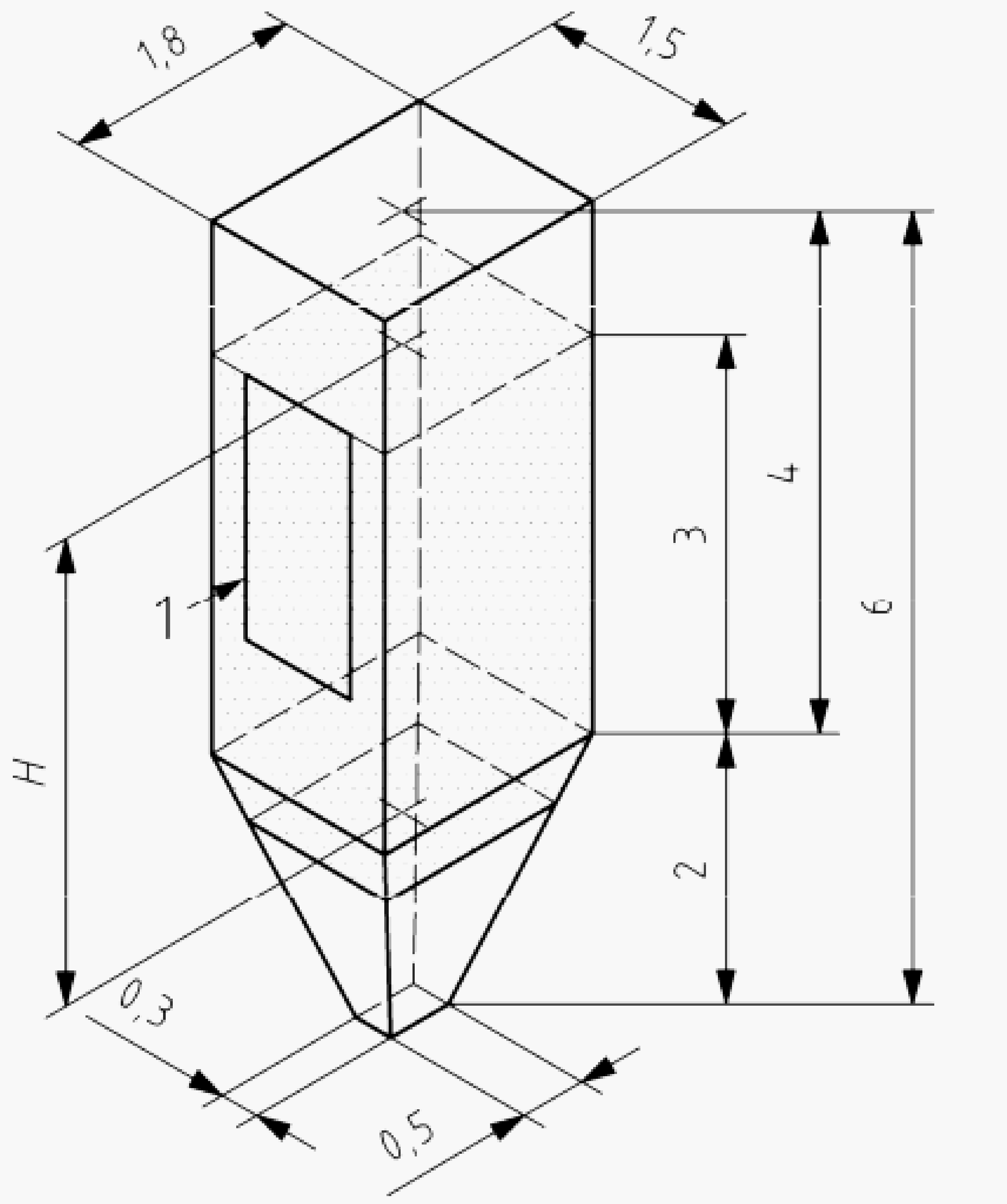
c) $$A_{eff} = \frac{V_{eff}}{H} = \frac{10{,}18}{4} = 2{,}55\ \text{m}^2\,;$$

d) $$D_{eff} = \sqrt{\frac{4\,A_{eff}}{\pi}} = 1{,}80\ \text{m}\,;$$

e) $$\frac{L}{D} = \frac{H}{D_{eff}} = \frac{4}{1{,}80} = 2{,}22\,.$$

Figure C.4 — Cylindrical enclosure with a hopper and vented at the side

Dimensions in metres



Key

1 vent

a) H equals the flame length inside the vessel which is 1/3 of the height of the hopper plus the height of the rectangular part up to the top of the vent = 1/3 hopper height + height rectangular part = 0,667 m + 3 m = 3,667 m;

b) V_{eff} equals the 1/3 of volume of the hopper plus the volume of the rectangular vessel (to the top of the vent);

c) The volume of the rectangular part = 1,8 m × 1,5 m × 3 m = 8,1 m^3;

d) 1/3 of the volume of the hopper = 1/3 × 2,33 = 0,777 m^3
V_{eff} = 8,1 + 0,777 = 8,877 m^3;

NOTE A general formula for calculating the volume for a rectangular hopper is given with Figure C.7;

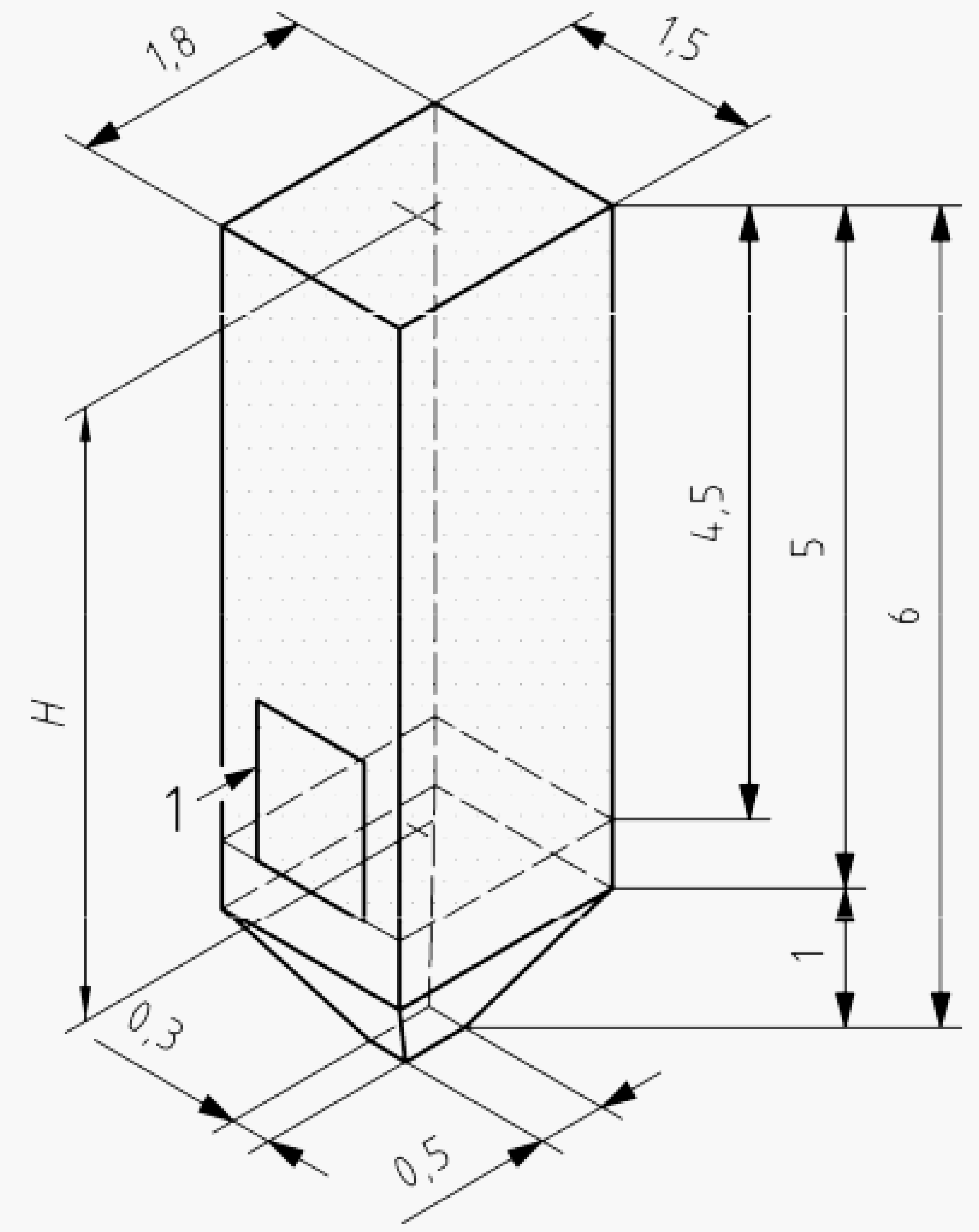
e) $A_{\text{eff}} = \frac{V_{\text{eff}}}{H} = \frac{8,877}{3,667} = 2,42 \text{ m}^2$;

f) $D_{\text{eff}} = \sqrt{\frac{4\ A_{\text{eff}}}{\pi}} = 1,756 \text{ m}$;

g) $\frac{L}{D} = \frac{H}{D_{\text{eff}}} = \frac{3,667}{1,756} = 2,089$.

Figure C.5 — Rectangular enclosure with a hopper and vented at the side

Dimensions in metres



Key

1 vent

a) H equals the vertical distance from the top of the rectangular vessel to the bottom of the vent. H is the longest flame path possible because the vent is closer to the hopper bottom than it is to the vessel top = 4,5 m;

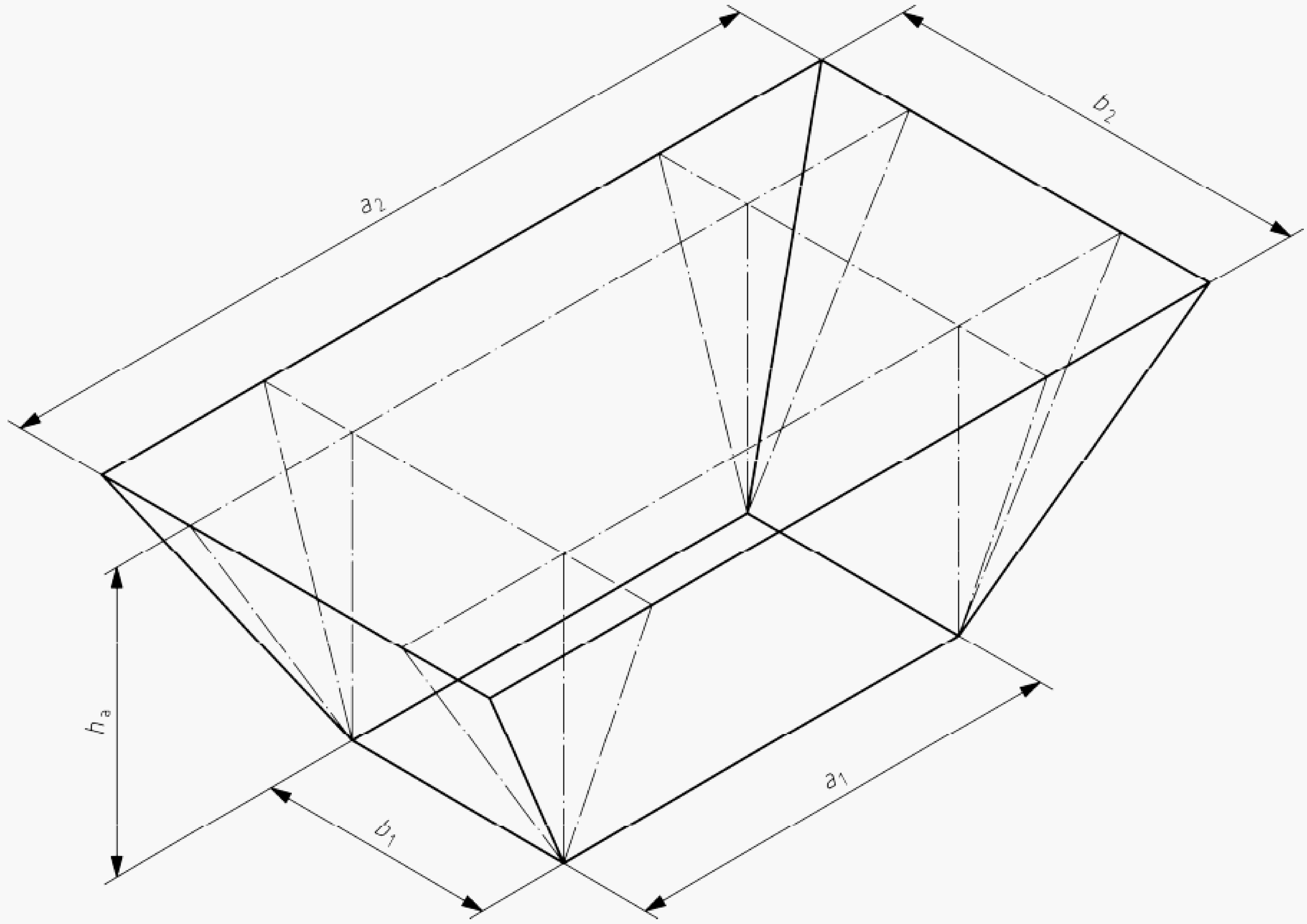
b) V_{eff} equals the volume from the top of the rectangular vessel to the bottom of the vent = 4,5 m × 1,8 m × 1,5 m = 12,15 m^3
V_{eff} is the shaded region in the Figure;

c) $A_{\text{eff}} = \frac{V_{\text{eff}}}{H} = \frac{12,15}{4,5} = 2,7 \text{ m}^2$;

d) $D_{\text{eff}} = \sqrt{\frac{4\ A_{\text{eff}}}{\pi}} = 1,854 \text{ m}$;

e) $\frac{L}{D} = \frac{H}{D_{\text{eff}}} = \frac{4,5}{1,854} = 2,427$.

Figure C.6 — Rectangular enclosure with a hopper and vented at the side, close to the hopper



$V = h_a/3\ (a_1\ b_1 + (a_1\ b_1\ a_2\ b_2)^{0,5} + a_2\ b_2)$;

Key

a_1 length of the base
b_1 width of the base
h_a height of the rectangular hopper
a_2 length of the top
b_2 width of the top
V Volume

Figure C.7 — Calculation of a volume of a rectangular hopper

For a conical hopper, V is:

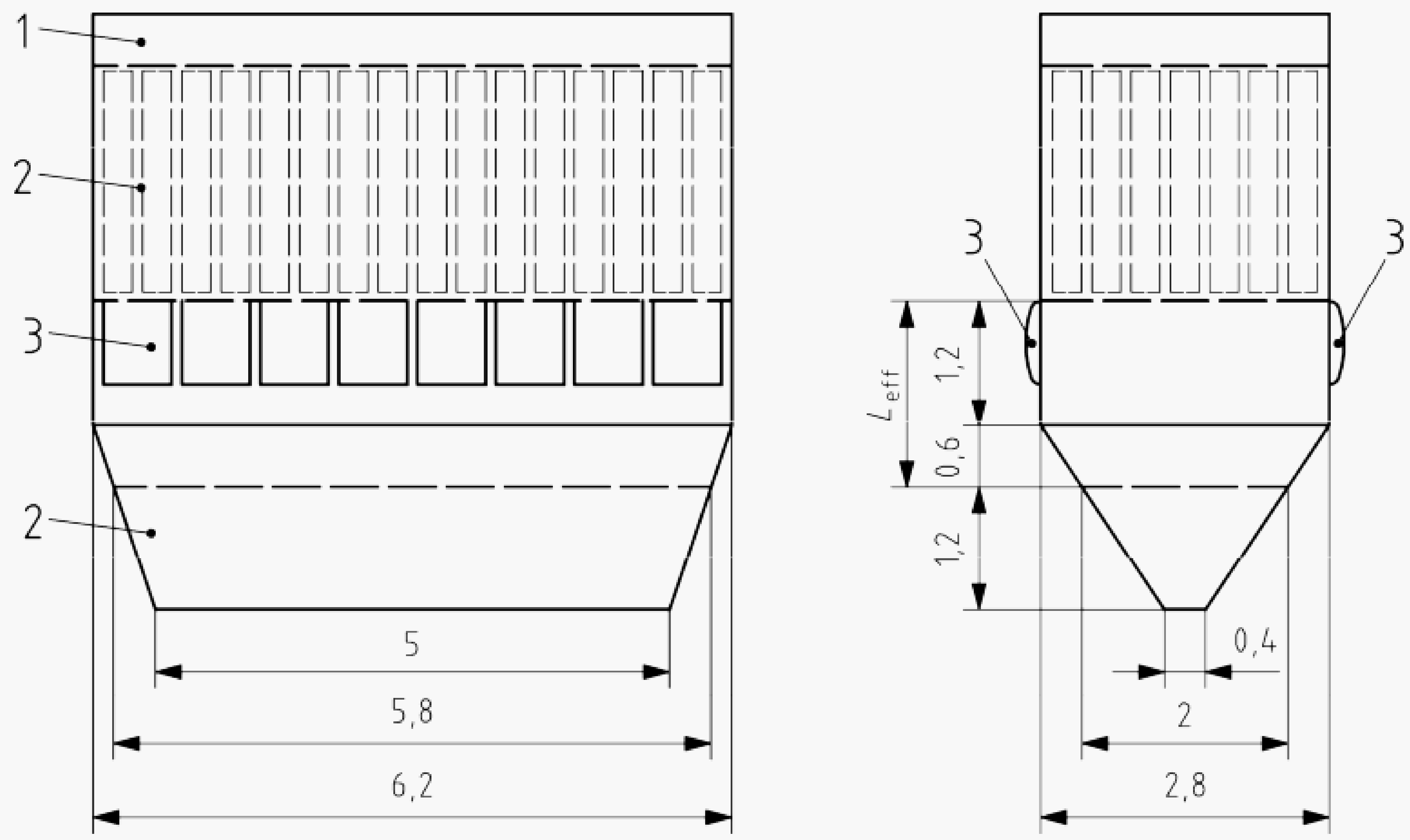
$$V = \pi\,(h)\left(D_1^2 + D_1\ D_2 + D_2^2\right)/12$$

where

D_1 is the diameter of the base;

D_2 is the diameter of the top.

Dimensions in metres



Key

1 clean air side

2 dirty air side

3 explosion venting devices

Figure C.8 — Rectangular filter with a hopper and vented at the side, close to the hopper

In this particular example, the construction of the filter elements is such that the upper part of the filter (the enveloping volume of the filter elements) can be neglected in the volume calculations (see Annex A). Therefore the effective flame path will always be in the lower part of the filter.

If (part of) the upper volume needs to be taken into account for example due to large distances between filter elements (see Annex A), the entire volume should be used for L/D calculations.

Effective flame path:

$$L_{\text{eff}} = 1{,}8\,\text{m}$$

Effective flame volume:

Rectangular part: $1{,}2\,\text{m} \times 6{,}2\,\text{m} \times 2{,}8\,\text{m} = 20{,}83\,\text{m}^3$

Rectangular hopper (see Formula below Figure C.7): $16{,}56\,\text{m}^3$

$$V_{\text{eff}} = 20{,}83\,\text{m}^3 + \frac{16{,}56\,\text{m}^3}{3} = 26{,}35\,\text{m}^3$$

Effective cross-sectional area:

$$A_{eff} = \frac{V_{eff}}{L_{eff}} = \frac{26{,}35\,m^3}{1{,}8\,m} = 9{,}41\,m^2$$

Effective diameter:

$$D_{eff} = \sqrt{\frac{4\ A_{eff}}{\pi}} = \sqrt{\frac{4 \times 9{,}41}{\pi}} = 3{,}46\ m$$

Effective length/diameter ratio:

$$\frac{L_{eff}}{D_{eff}} = \frac{1{,}8\ m}{3{,}46\,m} \longrightarrow 1 \left(since\ \frac{L_{eff}}{D_{eff}} \leq 1 \right)$$

The calculation shows that the explosion venting area shall be designed with a ratio of L_{eff}/D_{eff} = 1. This only holds for elongate filter systems if the explosion vents are evenly distributed over the length of the filter systems.

Annex D
(informative)

Protection of buildings

D.1 General

There can be several reasons for a dust explosion inside a building, such as:

a) a controlled vented explosion into the building from process equipment;

b) an uncontrolled explosion into the building from process equipment;

c) either a) or b) followed by a secondary explosion in the building itself; or

d) an explosion starting in the building.

The course of an explosion in buildings will be affected by several parameters such as the shape of the building, the presence of equipment and structural elements, the possibility of propagation from room to room and the presence of flammable dust left to lie on surfaces such as window sills, pipework and floors etc. The dust explosion can be limited to a small part of the total volume. Pressure development will vary according to circumstances and a wide range of dust explosion loads can be expected.

Where a room is much greater in volume than the vessel which is situated in it, a primary explosion venting into the building will cause only a marginal pressure increase in the room. If the vent is close to a wall or roof panel, however, significant local overpressures can result.

Where a vented vessel occupies a substantial proportion of the room, for example some spray drying plants, an explosion from the vessel can cause a significant overpressure in the room as a whole.

Sometimes a vessel vulnerable to an explosion (like a mill) is located in a especially strong room which has its own explosion vent in the building outside wall. The access door shall be strong enough to take the expected overpressure. Access to this room can then be prevented while the plant is in operation.

Wherever a building is vulnerable to an explosion, the primary requirement is that an explosion inside the building should not cause progressive collapse of the building, by displacement of load bearing walls or columns. A secondary requirement is that the consequences of an explosion in the building should cause least risk to people outside the building. Both these requirements imply a strong preference for steel framed buildings with lightweight panel walls, rather than masonry construction.

For buildings $p_{\text{red,max}}$ should always exceed p_{stat} by at least 0,02 bar. The vent area should be distributed as symmetrically and as evenly as possible over the available surface.

Vent areas on buildings should be distributed uniformly over the wall and roof areas. In estimating $p_{\text{red,max}}$ care should be taken to ensure that the weakest structural element, as well as any equipment or other devices that can be supported by structural elements, is identified. All structural elements and supports should be considered. For example, floors and roofs are not usually designed to be loaded from beneath. However, a lightweight roof can be considered sacrificial, provided its movement can be tolerated and provided ice or snow does not hinder its movement.

D.2 Calculating the vent area

The recommended venting formula for buildings is as follows:

$$A = C \cdot A_S \cdot p_{\text{red,max}}^{-0,5} \tag{D.1}$$

where

A is the required vent area, in square-metres (m^2);

A_v is the geometric vent area $A_v = A/E_f$, in square-metres (m^2);

E_f is the venting efficiency;

C is the venting formula constant:

$0 < K_{St} \leq 100$: C = 0,018 $bar^{0,5}$;
$100 < K_{St} \leq 200$: C = 0,026 $bar^{0,5}$;
$200 < K_{St} \leq 300$: C = 0,030 $bar^{0,5}$;

A_s is the internal surface area of enclosure, in square-metres (m^2);

$p_{red,max}$ is the maximum explosion overpressure developed in a vented enclosure during a vented deflagration, in bar. $p_{red,max}$ in this application, is not to exceed an overpressure of 0,1 bar.

The form of the venting formula is such that there are no dimensional constraints on the shape of the room, provided the vent area is not applied solely to one end of an elongated room. The vent area should be applied as evenly as possible over the available wall area; but if it is restricted to the end of an elongated room, the ratio of length-to-diameter of the room should not exceed 3. For cross sections other than those that are circular or square, the effective diameter should be taken by 4 (A_c/L_p), where A_c is the cross-sectional area normal to the longitudinal axis of the space and L_p is the perimeter of the cross section. Therefore, for rooms with venting restricted to one end, the application of the venting formula is constrained as follows:

$$L < 12 \cdot A_c \cdot L_p^{-1} \tag{D.2}$$

where

L is the longest dimension of the building, in metres (m);

A_c is the cross-sectional area normal to the longest dimension, in square-metres (m^2);

L_p is the perimeter of cross section, in metres (m).

D.3 Calculation of internal surface area

The internal surface area, A_s, is the total area that constitutes the perimeter surfaces of the enclosure that is being protected. Non-structural internal partitions that cannot withstand the expected overpressure are not considered to be part of the enclosure surface area. The enclosure internal surface area, A_s, includes the roof or ceiling, walls, floor, and vent area and can be based on simple geometric figures. Surface corrugations are neglected, as well as minor deviations from the simplest shapes. Regular geometric deviations such as saw-toothed roofs can be "averaged" by adding the contributed volume to that of the major structure. The internal surface of any adjoining rooms should be included. Such rooms include adjoining rooms separated by a partition incapable of withstanding the expected overpressure.

The surface area of equipment and contained structures should be neglected.

Increasing the value of $p_{red,max}$ can reduce A or A_v, the calculated vent area. The value of $p_{red,max}$ should not be increased above 0,1 bar for the purpose of design under this clause.

Annex E
(informative)

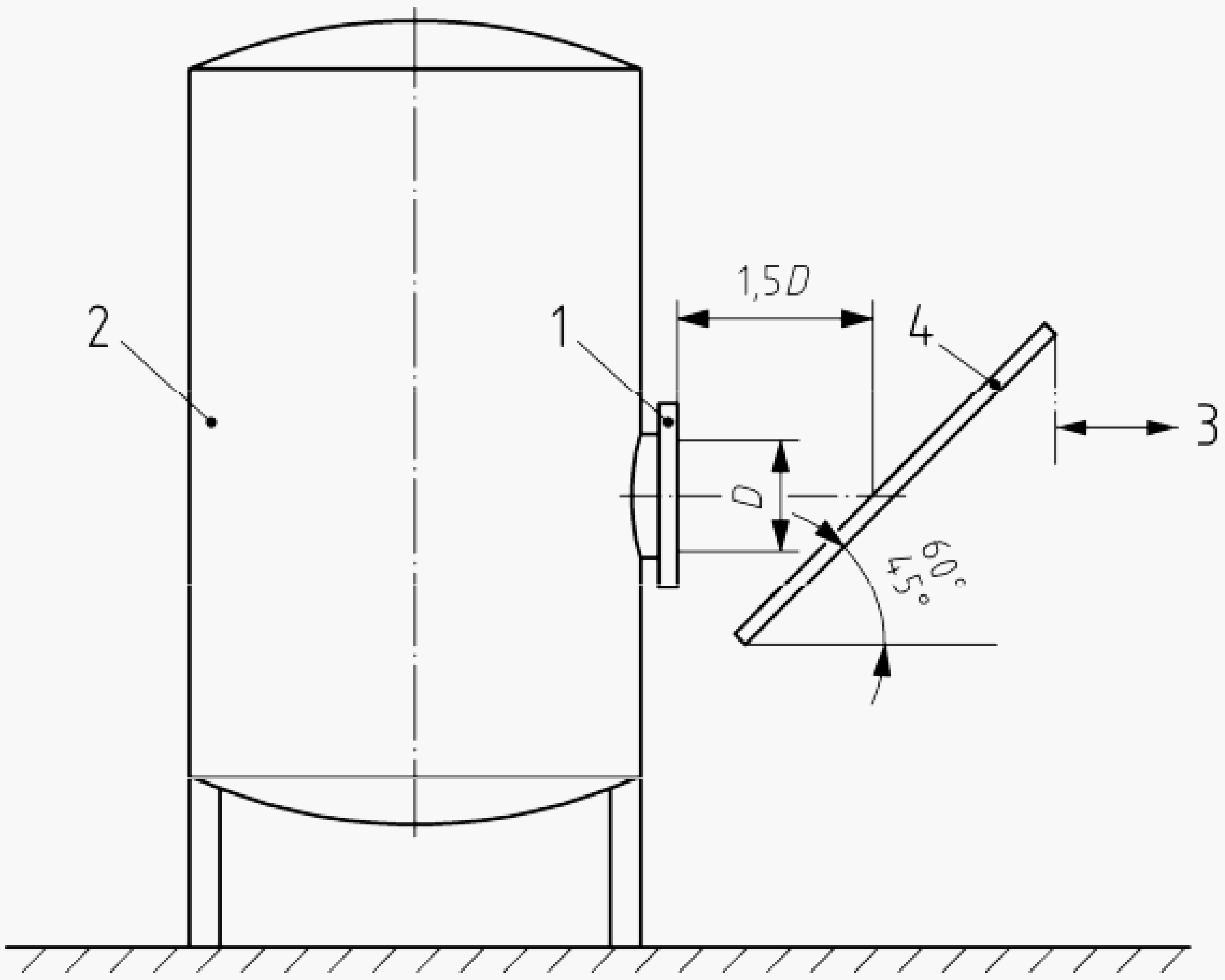
Deflectors

Deflectors can influence the external flame produced by a vented explosion. A possible design of deflector plate, and its installation, is shown in Figure E.1. The plate limits the length of the flame along the axis of the vent. Explosion trials show that a deflector plate, positioned as in Figure E.1, approximately halves the length of the flame compared to when the plate is absent. A hazardous area should be specified beyond the deflector from which personnel are excluded while the plant is operating. The plate deflects flame sideways and the lateral extent of the hazardous area should be sufficient to avoid harm from this sideways deflection. Flames can curl around the deflector. Therefore also the area directly behind the deflector cannot be considered safe.

NOTE It is expected that external overpressures are hardly affected by this type of deflector.

The area of the plate should be at least three times the area of the vent, and its dimensions should be at least 1,6 times the dimensions of the vent. The plate should be inclined at least 45° to 60° to the horizontal to deflect the ejected flame upwards. The axis crossing the centre of the vent opening should also cross the centre of the deflector plate. The plate should be installed at a sufficient distance from the vent to ensure that it does not act as an obstacle to the venting process and so cause an increase in the maximum reduced explosion overpressure inside the enclosure. Neither should the plate be installed at too great a distance from the vent; the distance of 1,5 D given in Figure E.1, where D is the hydraulic diameter of the vent, has been shown to be satisfactory in explosion trials, but may need to be modified in practice, depending on circumstances. The plate should be mounted so that it can withstand the force exerted by the vented explosion, which can be calculated by multiplying the maximum reduced explosion overpressure by the area of the plate.

The presented design criteria should only be used for enclosure volumes up to 20 m^3.



Key

1 explosion venting device

2 enclosure

3 distance to hazardous area

4 strongly mounted deflector plate

Figure E.1 — Design of a blast deflector plate

Annex F
(informative)

Significant changes between this European Standard and EN 14491:2006

This European Standard supersedes EN 14491:2006.

The significant changes with respect to EN 14491:2006 are listed below.

		Type		
Significant Changes	Clause	Minor and editorial changes	Extension	Major technical changes
Addition of normative references	2	X		
Correction of definitions and introduction of new definitions	3	X		
Former Clause 6 moved to Clause 4, renumbering of following clauses	4	X		
Rearrangement of formulae in Clause 5 and the whole document, renumbering of subsequent formulae	5	X		
New introduction and replacement of 5.3	5.3.1		X	
Additional information and requirements for pneumatic conveying with axial release into vessels and silos (Reduction of requirements for specific conveying conditions)	5.3.2		X	
Additional information and requirements for pneumatic conveying of the product with tangential release into vessels and silos (Reduction of requirements for specific conveying conditions)	5.3.3		X	
New subclause on free fall filling (Reduction of requirements for specific conveying conditions)	5.3.4		X	
Revision of requirements for interconnected pipes	5.4	X		
Correction of formulae for pressure in pipes	5.5	X		
Introduction of revised formulae for description of effect of vent ducts.	5.6		X	
Addition of new subclause 5.7 "Design of vent ducts"	5.7		X	
Additional explanation and clarification on hybrid mixtures	5.8	X		

		Type		
Significant Changes	Clause	Minor and editorial changes	Extension	Major technical changes
Subclause 6.2.3 restructured	6.2.3	X		
New formula (24) introduced	6.2.3.2		X	
Former formula (17) modified and moved to new subclause 6.2.3.3	6.2.3.3	X		
Former subclause 6.2.5 "Effects of flameless explosion venting devices" has been replaced by reference to upcoming standard on flameless explosion venting devices	6.2.5	X		
Annex A (informative) on the influence of the filter elements on the explosion venting has been added.	Annex A		X	
Annex B (informative) on the design of explosion venting of cyclones has been added	Annex B		X	
Former Annex A moved to Annex C, Examples recalculated.	Annex C	X		
New example and Figure C.8 added.	Annex C		X	
Former subclause 5.5 moved to new informative Annex D "Protection of buildings"	Annex D	X		
Former subclause 7.2.4 moved to new informative Annex E "Deflectors" with editorial modifications	Annex E	X		
Annex F with the significant changes with regard to the previous version added.	Annex F	X		
New bibliography added.	Bibliography	X		
NOTE **The technical changes referred to include the significant technical changes from the EN revised but is not an exhaustive list of all modifications from the previous version.**				

Explanations:

Minor and editorial changes

clarification
decrease of technical requirements
minor technical change
editorial corrections

Changes in a standard classified as "Minor and editorial changes" refer to changes regarding the previous standard, which modify requirements in an editorial or a minor technical way. Changes of the wording to clarify technical requirements without any technical change are also classified as "Minor and editorial changes".

A reduction in the level of existing requirements is also classified as "Minor and editorial changes".

Extension addition of technical options

Changes in a standard classified as "extension" 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 "extensions" will not have to be considered for products in conformity with the preceding edition.

Major technical change addition of technical requirements
increase of technical requirements

Changes in a standard classified as "Major technical change" refer to changes regarding the previous standard, which add new or increase the level of existing technical requirements, in a way that a product in conformity with the preceding standard will not always be able to fulfil the requirements given in the standard. "Major technical changes" shall be considered for products in conformity with the preceding edition. For every change classified as "Major Technical Change" additional information is provided.

NOTE These changes represent current technological knowledge[3]. However, these changes should not normally have an influence on equipment already placed on the market.

3) See also ATEX Guide 10.3 and Annex ZA.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 94/9/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 94/9/EC Equipment and protective systems intended for use in potentially explosive atmospheres (ATEX).

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Directive 94/9/EC

Clause(s)/sub-clause(s) of this EN	Essential Requirements (ERs) of Directive 94/9/EC		Qualifying remarks/Notes
whole document	1.0.1	Principles of integrated explosion safety	
8	1.0.3	Special checking and maintenance conditions	
7	1.0.5	Marking	
8	1.0.6	Instructions	
whole document	1.2.1	Technological knowledge of explosion protection for safe operation	In combination with EN 14797
4, 6	1.4.1	Safe functioning	In combination with EN 14797, EN 16009
	1.4.2	Mechanical and thermal stresses and withstanding attack by existing or on foreseeable aggressive substances	In combination with EN 14797
5, 6	3.0.1	Dimension of protective systems safety level	In combination with EN 14797
4, 5	3.0.2	Design and position	

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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