Gas explosion venting protective systems

The European Standard EN 14994:2007 has the status of a British Standard

ICS 13.230; 13.240

British Standards

National foreword

This British Standard was published by BSI. It is the UK implementation of EN 14994:2007.

The UK participation in its preparation was entrusted to Technical Committee FSH/23, 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.

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

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 29 June 2007

ISBN 978 0 580 54508 5

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14994

February 2007

ICS 13.240

English Version

Gas explosion venting protective systems

Systèmes de protection par évent contre les explosions de gaz

Schutzsysteme zur Druckentlastung von Gasexplosionen

This European Standard was approved by CEN on 15 December 2006.

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 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 Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 14994:2007: E

Contents

Page

Figures

Tables

Foreword

This document (EN 14994:2007) 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 August 2007, and conflicting national standards shall be withdrawn at the latest by August 2007.

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 94/9/EC, see informative Annex ZA, which is an integral part of this document.

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

1 Scope

This European Standard specifies the basic design requirements for the selection of a gas explosion venting protective system. This European Standard, EN 14797 and EN 14460 form a series of three standards which are used together.

NOTE 1 These three standards together represent the concept of gas explosion venting.

NOTE 2 To avoid transfer of explosions to other communicating equipment one should also consider applying prEN 15089.

This European Standard is applicable to:

- vent sizing to protect against the internal pressure effects of a gas explosion;
- flame and pressure effects outside the enclosure;
- recoil forces;
- influence of vent ducts;
- influence of initial temperature and pressure.

This European Standard does not provide design and application rules against effects generated by detonation reactions or runaway exothermic reactions including decomposition in the gas phase.

This European Standard is not applicable to:

- fire risks arising either from materials processed, used or released by the equipment or from materials that make up equipment and buildings;
- design, construction and testing of explosion venting devices, which are used to achieve explosion venting[1];
- protection against overpressures caused by events such as overfilling, overpressurisation, fire engulfment, overheating etc.

NOTE 3 Protection by venting against dust and hybrid explosions is specified in EN 14491.

2 Normative references

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

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

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

---

1) This is covered by EN 14797.

EN 13673-1, *Determination of the maximum explosion pressure and the maximum rate of pressure rise of gases and vapours — Part 1: Determination of the maximum explosion pressure*

EN 13673-2, *Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours — Part 2: Determination of the maximum rate of explosion pressure rise*

EN 14797:2006, *Explosion venting devices*

3 Terms and definitions

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

3.1
atmospheric conditions
conditions of the surrounding medium where the atmospheric pressure can vary between 80 kPa and 110 kPa and the temperature between – 20 °C and 60 °C

3.2
gas
for the purpose of this European Standard, gas, vapour or any mixture thereof at atmospheric conditions

3.3
compact enclosures
enclosures having a length (height) to diameter ratio of less than 2

[EN 14373:2005, 3.14.1]

NOTE The length L is calculated along the axis parallel to the main flow during the explosion, with D being the diameter measured perpendicular to this axis. For non-circular cross-sections, D is the diameter of a circle with the same area as the actual cross-sectional area.

3.4
elongated enclosures
enclosures with length (height) to diameter ratio of 2 to 10

[EN 14373:2005, 3.14.2]

NOTE The length L is calculated along the axis parallel to the main flow during the explosion, with D being the diameter measured perpendicular to this axis. For non-circular cross-sections, D is the diameter of a circle with the same area as the actual cross-sectional area.

3.5
pipe
construction with a ratio length (height) to diameter greater than 10

[EN 14373:2005, 3.14.3]

NOTE The length L is calculated along the axis parallel to the main flow during the explosion, with D being the diameter measured perpendicular to this axis. For non-circular cross-sections, D is the diameter of a circle with the same area as the actual cross-sectional area.

3.6
explosion venting device
device which protects a vessel or other closed volume by explosion venting

[EN 14797:2006, 3.4]

NOTE Examples of such devices are: bursting discs, vent panels and explosion doors.

3.7
effective vent area
$\boldsymbol{A_E}$
product of the geometric vent area A_d and the venting efficiency E_f for the venting device.

NOTE It is the effective vent area that should be used in making up the vent area for explosion venting

[EN 14797:2006, 3.2]

3.8
gas explosion constant
$\boldsymbol{K_G}$
maximum value of the pressure rise per unit time $(dp/dt)_{max}$ during the explosion of a specific explosive atmosphere in a closed vessel under specified test conditions normalised to a vessel volume of 1 m^3 multiplied by $V^{1/3}$

3.9
static activation pressure
$\boldsymbol{p_{stat}}$
differential pressure at which the retaining element activates such that the venting element is able to open

[EN 14797:2006, 3.11]

3.10
turbulence
motion of a fluid having local velocities and pressures that fluctuate randomly

NOTE Turbulence is a very effective transporter and mixer, and generally causing an overall increase of combustion rates.

3.11
turbulence inducing elements
obstructions inside protected enclosures at which during an explosion turbulence is generated increasing the combustion rate

3.12
venting efficiency
$\boldsymbol{E_f}$
dimensionless number used to define the efficiency of the explosion venting device

[EN 14797:2006, 3.14]

4 Venting of enclosures

Explosion venting is a protective measure preventing unacceptable high explosion pressure build-up inside enclosures.

Weak areas in the walls of the enclosure open at an early stage of the explosion, releasing un-burnt gas/vapour and combustion products from the opening so reducing the overpressure inside the enclosure.

Normally the explosion venting is applied such that the maximum reduced explosion pressure shall not exceed the known design pressure of the enclosure. All parts of the enclosure e.g. valves, sight-glasses, man-holes and ducts, which are exposed to the explosion pressure shall be taken into account when estimating the design pressure of the enclosure.

The vent area is the most important factor in determining the maximum reduced explosion pressure. Information required for calculation of the vent area includes the design pressure of the enclosure, the explosion characteristics of the gas, the shape and size of the enclosure, presence of turbulence inducing elements (including congestion) inside the enclosure, the static activation pressure and other characteristics of the venting device, and the condition of the explosive atmosphere inside the enclosure.

Venting does not prevent an explosion, it limits the explosion pressure. Flame and pressure effects outside the enclosure and flying debris shall be expected and in practice accounted for.

In a system consisting of two connected enclosures, a gas explosion ignited in one can propagate into the second. The propagation of this explosion generates turbulence, can cause pre-compression and can act as a large ignition source in the second enclosure. This combination can enhance the violence of the secondary explosion (see 5.6).

Turbulence inducing elements such as shelves in a drying oven may cause considerably more violent gas explosions. This will increase the venting requirements. As this mechanism is not covered by the general method presented in this standard, more intricate methods may need to be applied. In the informative Annex A rules are given when to apply the general method of the present standard and when one shall use more intricate methods if turbulence inducing elements are present. A general description of intricate methods is given in the informative Annex A together with requirements for the experimental validation of these methods.

5 Venting of isolated compact enclosures

5.1 General

Venting devices shall comply with the requirements of EN 14797. Two principle venting device parameters are p_{stat} and E_f, which is affected by values of vent cover inertia and enclosure volume.

Accurate sizing of vents is the most important aspect of vent design. Venting requirements depend in practice on the combustion characteristics of the gas, the state of the flammable mixture (concentration, turbulence, distribution), and the geometry of the enclosure (including the presence of turbulence inducing elements).

Combustion characteristics of flammable gases shall be measured according to appropriate methodologies. In this European Standard the combustion characteristics gas explosion constant K_G and maximum explosion pressure p_{max} are used. The gas explosion constant is derived from the maximum rate of pressure rise $(dp/dt)_{max}$. The latter characteristic and the maximum explosion pressure p_{max} shall be determined according to EN 13673-2 and EN 13673-1 respectively.

5.2 Venting of isolated compact enclosures

A method to size vent openings of compact enclosures is presented. The method applies to isolated enclosures essentially free from turbulence inducing elements (see 5.3.5). Appropriate measures (explosion isolation) shall have been taken to prevent explosion propagation to/and from other enclosures.

The method assumes that the explosive atmosphere inside the enclosure is essentially quiescent at the time of ignition.

According to this method the vent area shall be calculated using the following equation:

$$A = \left\{ \left[\left(0{,}1265 \lg \left(K_G\right) - 0{,}0567\right) p_{red}^{-0{,}5817} \right] + \left[0{,}1754\ p_{red}^{-0{,}5722} \left(p_{stat} - 0{,}1\,bar\right) \right] \right\} V^{2/3} \quad (1)$$

$$A_V = \frac{A}{E_f} \quad (2)$$

where

A is the geometrical vent area (E_f = 1), in m²;

A_v is the vent area of an explosion venting device with efficiency E_d < 1, in m²;

K_G is the gas explosion constant, in bar·m·s^{-1};

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

p_{stat} is the static activation pressure of explosion venting device, in bar;

E_f is the venting efficiency of explosion venting device;

V is the volume, in m³.

Equations (1) and (2) are valid for:

— isolated enclosures essentially free from turbulence inducing elements;

— $K_G \leq 550$ bar·m/s;

— 0,1 bar $\leq p_{stat} \leq$ 0,5 bar;

— $p_{red} \leq$ 2 bar;

— $p_{red} > p_{stat}$ + 0,05 bar;

— $V \leq$ 1 000 m^3;

— $L/D \leq 2$;

— initial conditions: atmospheric;

— E_f = 1 for explosion venting devices with an area specific mass of less than 0,5 kg/m^2;

— E_f = 1 for explosion venting devices with an area specific mass greater than 0,5 kg/m^2 and smaller or equal to 10 kg/m^2 provided $A_v/V^{0,753}$ < 0,07, where A_V is the vent area and V the vessel volume. This is valid for $p_{stat} \leq$ 0,1 bar and 0,1 bar < p_{red} < 2 bar;

— for all other conditions and for explosion venting devices with an area specific mass greater than 10 kg/m^2 the efficiency E_f has to be determined by tests (see EN 14797).

5.3 Situations outside the constraints of the basic method (turbulence inducing elements, partially filled enclosures)

5.3.1 General

The methods proposed in 5.3.2 to 5.3.4 apply to isolated compact enclosures essentially free from turbulence inducing elements.

5.3.2 Elevated initial pressure

The following equation shall be used for estimating reduced explosion pressures when the initial pressure is above atmospheric pressure:

$$p_{red2} = p_{red1}\left(p_2 + 1\right)^{\gamma} \quad (3)$$

where

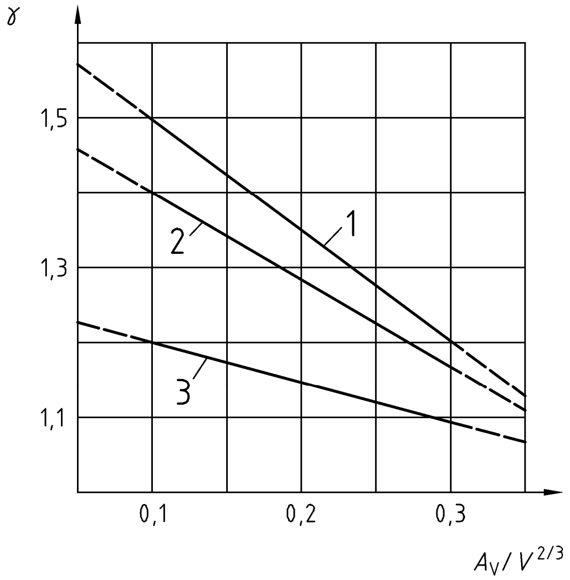
p_2 is the elevated initial gauge pressure, in bar;

p_{red1} is the reduced explosion pressure calculated by the method given in 5.2 for atmospheric conditions, in bar:

p_{red2} is the actual reduced explosion pressure for elevated initial pressure p_2, in bar;

γ is the exponent, a function of vent area and vessel volume.

The value of the exponent γ varies inversely with $A_V/V^{2/3}$, where A_V is the vent area and V the vessel volume. Plots of γ versus $A_V/V^{2/3}$ are given in Figure 1 for propane, ethylene and hydrogen.



Key

1 propane

2 ethylene

3 hydrogen

γ exponent

Figure 1[2)] — Value of exponent γ as a function of $A_V/V^{2/3}$

Figure 1 is valid for initial pressures of up to an overpressure of 3 bar. The solid lines for propane and hydrogen were developed from experimental data. The line for propane shall be used for gases that have K_G-values no higher than 1,3 times that for propane. The line for ethylene represents an untested interpolation. The extension of broken lines represents extrapolation.

In applying Equation (3) the value used for p_2 shall be chosen to represent the maximum pressure at which the protected installation can be operating at the time of the ignition.

5.3.3 Effect of initial turbulence

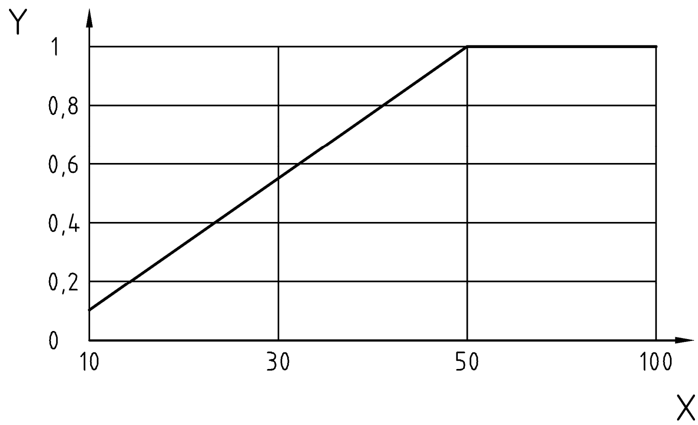
Experimental evidence shows that initial turbulence is important and its effect on the reduced explosion pressure cannot be ignored. However, at present there is insufficient information available to be able to quantify its effects for the type of practical applications for which explosion relief is used.

---

2) Reprinted with permission from NFPA 68 Guide for Venting of Deflagrations. Copyright© 1998 National Fire Protection Association, Quincy, MA 02269. This reprinted material is not the complete and official position of the National Fire Protection Association, on the referenced subject, which is represented only by the standard in its entirety.

5.3.4 Effect of partial filling

An estimate of the explosion pressures in compact enclosures provided with a vent and partially filled with an explosive mixture shall be made using Figure 2. Having calculated the vent size for an enclosure completely filled with an explosive gas atmosphere the reduced overpressure for a partially filled enclosure can be estimated. The figure shall only be applied for reduced overpressures below 1 bar for a 100 % filled enclosure. The figure is only valid for a static activation pressure of the venting device p_{stat} = 0,1 bar.



Key

X degree of filling (%)

Y ratio of maximum reduced overpressure to maximum reduced overpressure for 100 % filling

Figure 2 — Pressure reduction of partially filled enclosures as a function of filling ratio

5.3.5 Venting of enclosures containing turbulence inducing elements

The necessary venting requirements for enclosures containing turbulence inducing elements such as trays in drying ovens can normally not be calculated with the relationships mentioned above. The turbulence inducing elements may result in strong combustion rate increases during the explosion causing considerably higher pressures than anticipated on the basis of the relationship given in 5.2.

To judge whether another more intricate method shall be applied than the one described in 5.2 one can use the guidance given in Annex A.

5.4 Elongated enclosures

5.4.1 General

The equations given in this subclause apply to isolated elongated enclosures (with length to diameter/width ratios of between 2 and 10), containing quiescent gas mixtures that are essentially free of turbulence inducing elements (see 5.3.5) and do not contain any bends or changes of cross-section. The equations concern only gases or gas mixtures with a burning velocity close to that of methane or propane.

The aim in designing explosion relief for elongated enclosures is to minimise the reduced explosion pressure. This is done by ensuring that explosion vent areas are as large as is practicable and the static activation pressure is as low as is practicable in the prevailing process conditions. Vents shall be positioned, as far as is practicable, to minimise the distance between any potential ignition sources and the nearest vent; this may mean that vents are evenly distributed along the enclosure. Where multiple vents are fitted, each vent shall have the same area and open at the same static activation pressure.

The following equations for calculating the reduced explosion pressures are based on test results.

5.4.2 Venting of elongated enclosures vented at each end

When the elongated enclosure is vented at each end, either through end vents or side vents close to the end, then the reduced explosion pressure shall be taken to be the maximum value produced by application of Equations (4) to (6). These equations also apply when additional vents are spaced along the enclosure.

$$p_{red} = p_{stat} + \left(0{,}023\ S_{ui}^{2}\ K\ W\ (L/D)^{1/3}\right) / V^{1/3} \tag{4}$$

where

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

p_{stat} is the static activation pressure, in bar;

S_{ui} is the gas burning velocity, in m/s;

K is the vent coefficient (A_{cs}/A)

A_{cs} is the vessel cross sectional area, in m^2;

A is the total area of all vents, in m^2;

W is the weight per unit area of vent panel, in kg/m^2;

V is the enclosure volume, in m^3;

L is the enclosure length, in m;

D is the enclosure diameter, in m.

$$p_{red} = 0{,}015\ d\ K; \qquad \text{for } p_{stat} \le 0{,}06 \text{ bar} \tag{5}$$

$$p_{red} = 0{,}015\ d\ K + 0{,}15; \qquad \text{for } p_{stat} > 0{,}06 \text{ bar} \tag{6}$$

where

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

$d = x/D$, where x is the maximum possible distance that can exist between a potential ignition source and the nearest vent, and D is the diameter of the enclosure;

K is the vent coefficient (A_{cs}/A);

A_{cs} is the vessel cross sectional area, in m^2;

A is the total area of all vents, in m^2.

Equations (4) to (6) shall be used to estimate the vent areas and spacing necessary to limit the reduced explosion overpressure to given value.

Equations (4) to (6) are only valid for:

— atmospheric conditions;

— burning velocity S_{u} ≤ 0,46 m/s (i.e. burning velocity equal to or smaller than that of propane);

— volume $V \leq 200$ m^3;

— weight per unit area W: 0,5 kg/m^2 ≤ W < 5 kg/m^2;

— $p_{stat} \leq 0,1$ bar;

— $p_{red} \leq 1$ bar;

— $2 < L/D \leq 10$.

5.4.3 Venting of elongated enclosures vented along the enclosure

When the elongated enclosure is not vented at each end but only by vents along the enclosure, then Equations (5) and (6) may significantly underestimate reduced explosion overpressures. In these circumstances, Equations (4), (7) and (8) shall be applied with the highest value that is calculated being used for the estimate of reduced explosion overpressure.

For methane:

$$p_{red} = p_{stat} + 0{,}070\ d\ K \tag{7}$$

For propane:

$$p_{red} = p_{stat} + 0{,}085\ d\ K \tag{8}$$

where

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

$d = x/D$, where x is the maximum possible distance that can exist between a potential ignition source and the nearest vent, and D is the diameter of the enclosure;

K is the vent coefficient (A_{cs}/A);

A_{cs} is the vessel cross sectional area, in m^2;

A is the total geometrical vent area, in m^2.

Equations (7) and (8) are only valid for:

— atmospheric conditions;

— burning velocity $S_u \leq 0,46$ m/s (i.e. burning velocity equal to or smaller than that of propane);

— volume $V \leq 200$ m^3;

— weight per unit area W: 0,5 kg/m^2 ≤ W < 5 kg/m^2;

— $p_{stat} \leq 0,1$ bar;

— $p_{red} \leq 1$ bar;

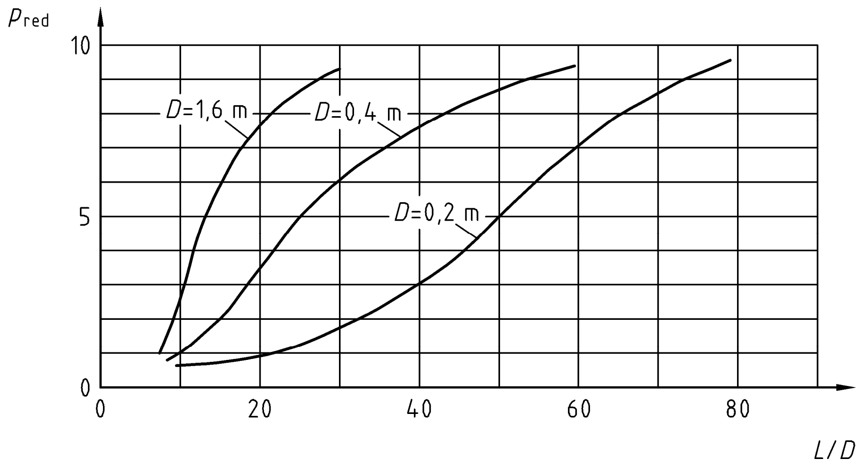
— $2 < L/D \leq 10$.

For gases more reactive than propane, enclosures with bends or changes of cross-section, or situations where the gas mixture is flowing no methods for estimating the explosion relief required are available.

5.5 Pipes

The method described in this subclause apply to pipes, enclosures with length to diameter ratios of greater than 10. In sizing explosion relief the gas flow through the pipe, which may be significant in industrial plant, needs to be taken into account. The long distances over which the explosion can propagate in pipe work systems can also lead to a detonation developing. The methods presented in this subclause apply to pipes essentially free from turbulence inducing elements (see 5.3.5) unless otherwise mentioned.

Figure 3 shall be used to estimate the maximum pressure developed in a smooth straight pipe, closed at one end and vented at the other (the size of the vent is equal to the cross-section of the pipe). It is valid for gases with a fundamental burning velocity of less than 0,6 m/s and for flow velocities of 2 m/s or less. The distance between the ignition source location and vent location is expressed as an *L/D* ratio. Reduced explosion overpressure for other pipe diameters shall be found by interpolation.



Key

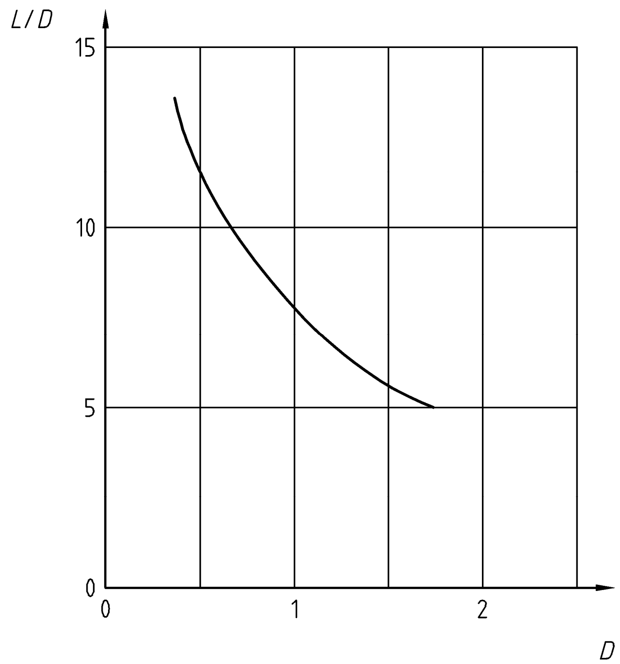
p_{red} reduced explosion overpressure, in bar

L/D ratio length (height) to diameter

Figure 3[3] — Maximum pressure developed during deflagration of propane-air mixtures flowing at 2 m/s or less in a smooth, straight pipe closed at one end

Figure 4 gives guidance for pipes with vents spaced at regular intervals along the length of the pipe. It shows the vent spacing required for propane to keep the reduced explosion overpressure below 0,2 bar for initial flow velocities of between 2 m/s and 20 m/s (the size of the vent is equal to the cross-section of the pipe).

[3] Reprinted with permission from NFPA 68 Guide for Venting of Deflagrations. Copyright© 1998 National Fire Protection Association, Quincy, MA 02269. This reprinted material is not the complete and official position of the National Fire Protection Association, on the referenced subject, which is represented only by the standard in its entirety.



Key

D diameter, in m

L/D ratio length (height) for diameter

Figure 4[4)] — Vent spacing needed to keep p_{red} from exceeding 0,2 bar for propane in pipes flowing at an initial velocity of between 2 m/s and 20 m/s

For gases, with fundamental burning velocity less than 1,3 times that of propane (< 0,6 m/s), the following equations shall be used to calculate the maximum pressure or the distance between vents required to keep the reduced explosion overpressure below 0,2 bar.

$$p_{red,x} = p_{red,p}\left(S_{u,x}/S_{u,p}\right)^2 \quad (9)$$

$$L_x = L_p\left(S_{u,x}/S_{u,p}\right)^2 \quad (10)$$

where

$p_{red,x}$	is the maximum reduced overpressure predicted for the gas, in bar;
$p_{red,p}$ = 0,2 bar	is the maximum overpressure for propane;
L_x	is the distance between vents for the gas, in m;
L_p	is the distance between vents for propane, in m;
$S_{u,x}$	is the fundamental burning velocity of the gas, in m/s;
$S_{u,p}$ = 0,46 m/s	is the fundamental burning velocity of propane.

4) Reprinted with permission from NFPA 68 Guide for Venting of Deflagrations. Copyright© 1998 National Fire Protection Association, Quincy, MA 02269. This reprinted material is not the complete and official position of the National Fire Protection Association, on the referenced subject, which is represented only by the standard in its entirety.

Higher reduced explosion overpressures can be generated if the pipe contains turbulence inducing elements, such as bends, valves, or any fitting that would cause a restriction to the gas flow through the pipe. In these cases it is required to fit a vent, with an area equal to the cross-sectional area of the pipe, on each side of the elements at a distance of no more than three pipe diameters (the size of the vent is equal to the cross-section of the pipe).

5.6 Interconnected enclosures

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

Interconnected enclosures are best protected by isolating each separate enclosure so that an explosion in one enclosure is stopped from propagating into a second one. Examples of isolation methods are flame arresters, fast-acting cut-off valves and suppression barriers.

No equations are available for vent sizing of interconnected enclosures.

5.7 Vent ducts

Vent ducts are used to discharge combustion products into safe areas (see 6.4) will reduce the effect of the vent and lead to an increase of the reduced overpressure. Using Equations (11) and (12) the effect on the reduced overpressure of vent ducts with lengths of respectively less than 3 m and 3 m to 6 m shall be estimated. Until more experimental data are available duct lengths shorter than 3 m shall be considered to be 3 m. No data are available for duct length longer than 6 m. For longer ducts the effect on the reduced overpressure shall be determined by appropriate tests.

The equations are as follows:

For duct lengths of less than 3 m:

$$p'_{red} = 1{,}24\ p_{red}^{\ 0{,}8614} \qquad (11)$$

where

p'_{red} is the maximum reduced overpressure with vent duct, in bar;

p_{red} is the maximum reduced overpressure without duct, in bar.

For ducts with lengths of 3 m to 6 m:

$$p'_{red} = 2{,}48\ p_{red}^{\ 0{,}5165} \qquad (12)$$

where

p'_{red} is the maximum reduced overpressure with vent duct, in bar;

p_{red} is the maximum reduced overpressure without duct, in bar.

The proposed method applies to isolated compact enclosures essentially free from turbulence inducing elements (see 5.3.5). The vent duct shall have a cross section at least as great as that of the vent itself. There is insufficient data available to quantify the effect of vent ducts with a cross section larger than that of the vent. Vent ducts shall be as straight as possible and free from obstructions. Bends in the vent ducts increase the pressure developed in the protected enclosure. There is no information to quantify these pressure increases.

6 Supplementary design aspects

6.1 General

Successful application of explosion venting involves a number of supplementary design aspects including the effect of the venting device, positioning and shape of the vents, the design of vacuum breakers and dealing effectively with the hazards that arise from the venting process, such as:

- flame;
- blast;
- recoil forces;
- flying debris.

Explosion venting shall not be performed if products or compounds are released, which are classified as poisonous, corrosive, irritant, carcinogenic, teratogenic or mutagenic. Both the gas and the combustion products can present this hazard to the immediate environment.

If there is no alternative to explosion venting of such compounds the consequences of such releases shall be taken into account assuring that people are not exposed to risks.

6.2 Positioning and shape of explosion vents

Explosion vents shall be positioned so that the effectiveness of the venting process is not impeded. If the enclosure is small and relatively symmetrical, one large vent is 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 necessary. One shall also assure that nearby plant and personnel will not be at risk from flames, blast and flying debris. Recoil forces shall be taken into account when considering the location and distribution of the vent.

Rectangular vents are as effective as square or circular vents of equal area.

6.3 Choice of venting device

Under certain circumstances the vent opening can be left open, and this provides the ideal situation. However, generally vent openings are closed by some form of venting device. This closure shall be designed, constructed, installed and maintained so that it opens readily and moves out of the way of the combustion products. Besides, no parts shall fly away that could endanger people.

Venting devices can take many different forms, from thin rupturing membranes to re-usable hinged doors to structural elements of the enclosure. The choice of the venting device depends on the operating conditions. Regardless of the type of venting device, it shall be able to function reliably as an explosion vent.

An ideal venting device opens without adverse effect on the combustion process and completely when required. In reality, the operation of venting device is affected by factors such as the weight of the device (causing inertia) and restraining devices. This means that, where these effects are significant, an efficiency factor shall be assigned to a particular device depending on conditions of its application.

The explosion vent areas calculated using the methods in this European Standard are the required “effective” vent areas. Where necessary the physical size of the venting device shall be adjusted to obtain the required effective area.

When using explosion doors or spring loaded systems the use of vacuum breakers shall be considered to avoid underpressure in the protected enclosure and thereby damage. Design rules for vacuum breakers are presented in EN 14491.

If venting devices are used, that are designed, built and tested according to prEN 14797 the requirements described above are met.

6.4 External effects

6.4.1 General

The venting event will in most cases be accompanied by ejection of burned and unburned gases and flames. Measures shall therefore be taken to ensure that nearby plant and personnel will not be at risk from the venting action.

The venting of the explosion shall be such that the area in which the explosion by-products are vented is sufficiently distant from other process equipment, and personnel shall not be allowed to enter this area when an explosion hazard is present.

6.4.2 Flame effects

Flames ejecting from a vent opening will spread in all directions but especially in the main lateral venting direction due to inertia. Moreover the flames will represent a minor radiation hazard.

Estimates for flame length in the lateral direction shall be calculated using the following equations:

$$L_F = 5\, V^{1/3} \tag{13}$$

where

L_F is the flame length in lateral direction, in m;

V is the volume of protected enclosure, in m^3.

Equation (13) is valid for:

- compact enclosures free from turbulence inducing elements and provided with a single vent opening;
- enclosure volume, V: $0{,}1\ m^3 \le V \le 50\ m^3$;
- static activation pressure of vent, p_{stat}: $p_{stat} \le 0{,}1$ bar;
- maximum reduced explosion overpressure, p_{red}: $0{,}1$ bar $< p_{red} \le 1{,}0$ bar; $p_{red} > p_{stat}$;
- maximum explosion pressure, p_{max}: $p_{max} \le 9$ bar;
- gas explosion constant, K_G: $K_G \le 100$ bar·m/s;
- length-to-diameter ratio, L/D: $L/D < 2$.

6.4.3 Pressure effects

Pressure and blast effects external to a vent arise from pressures generated by the vented explosion inside the enclosure and the explosion of an explosive gas cloud generated in the area outside the vent.

The following estimate can be made for the maximum external peak pressures for gas/air mixtures ignited in a compact enclosure:

$$p_{ext} = \left[1{,}24\ p_{red}\left(\sqrt{A/R}\right)^{1{,}35}\right] \Big/ \left[1 + (\alpha/56)^2\right] \tag{14}$$

where

p_{ext} is the maximum overpressure external to the vent, in bar;

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

A is the vent area, in m^2;

R is the distance to vent opening, in m;

α is the angle (in degrees) between the connection line and the centre of the vent opening (α = 0° is right in front of the vent opening; α = 90° is sideways of the vents).

Equation (14) is valid for:

— enclosure volume: 0,1 m^3 $\leq V \leq$ 250 m^3;

— static activation pressure: $p_{stat} \leq$ 0,1 bar;

— reduced explosion overpressure: 0,1 bar < $p_{red,max} \leq$ 1,0 bar;
maximum explosion overpressure: $p_{max} \leq$ 9 bar;

— K_G-value: $K_G \leq$ 200 bar · m/s;

— length to diameter ratio: $L/D \leq$ 2;

— maximum overpressure external to the vent, p_{ext}: 0,2 bar $\leq p_{ext} \leq$ 1,0 bar;

— angle between connection line and centre of vent opening, α: 0° to 180°.

Equation (14) only applies to enclosures without turbulence inducing elements.

6.4.4 Deflectors

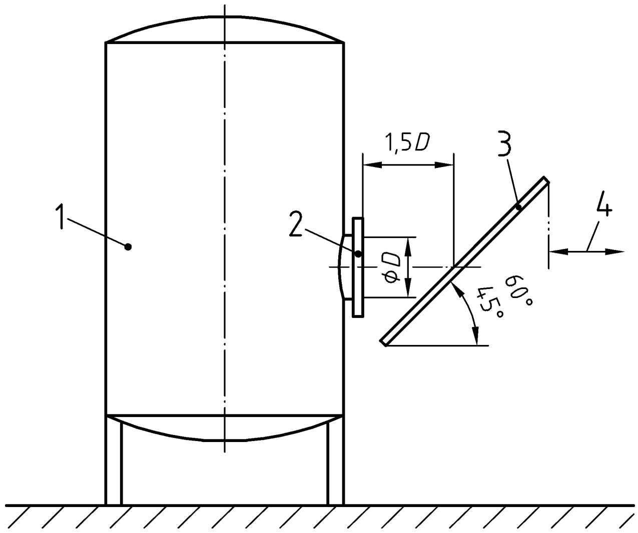
The hazards of external flames can be limited by deflectors. These can be designed and installed to direct the flame to safe areas. A possible design of a deflector plate, and its installation, is shown in Figure 5.

The area of the plate shall be at least three times the area of the vent, and its dimensions shall be at least 1,75 times the dimensions of the vent. The plate shall be inclined 45° to 60° to the vent axis to deflect the ejected flame. The plate shall be installed at 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 reduced explosion pressure inside the enclosure. Neither shall the plate be installed at too great a distance; the distance of 1,5 D given in Figure 5, where D is the equivalent diameter of the vent, has been shown to be satisfactory in explosion trials. The plate shall be mounted so that it can withstand the force exerted by the vented explosion, which can be calculated by multiplying the reduced explosion pressure by the area of the plate.

The plate limits the length of the flame in the ejection direction. Explosion trials show that, a deflector plate positioned as in Figure 5 approximately halves the length of the flame compared to that given by Equation (13). A safe distance beyond the deflector shall be specified from which the personnel are excluded while the plant is operating. The plate deflects the flame sideways and the extent of the safe area should be sufficient to avoid harm from the sideways deflection.

The design only applies to compact enclosures without turbulence inducing elements.

The influence of deflectors has only been investigated for enclosure volumes up to 20 m^3 and shall therefore not be installed when the enclosure volume is greater.



Key

1 protected enclosure

2 explosion venting device

3 strongly mounted deflector plate

4 safety distance

Figure 5 — Design of a flame deflector plate (basic principles)

6.5 Recoil forces[5)]

The flux of momentum connected to the discharge of material during venting causes recoil. If the enclosure vents upwards, the recoil force shall be absorbed by the foundation. The foundation shall be designed to withstand this recoil force. If the vent(s) is (are) situated at side walls, the recoil causes a sideways force on the enclosure. The mounting of the enclosure shall be designed to resist this recoil force.

If more than one vent opening is used, placing the vents opposite to each other will reduce the resulting recoil.

The maximum recoil force shall be calculated by Equation (15).

$$F_{R,\mathrm{max}} = 119\ A\ p_{red} \tag{15}$$

where

$F_{\mathrm{R,max}}$ is the maximum recoil force, in kN;

A is the total vent area, in m^2;

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

The duration of action of the recoil force Δt_{R} shall be estimated by Equation (16).

$$\Delta t_R = 10^{-4} \times K_G\ V/(A\ p_{red}) \tag{16}$$

5) It is emphasised that the design rules given in this subclause is based on tests performed with dust explosions.

where

Δt_R is the duration of recoil force, in s;

K_G is the gas explosion constant, in bar·m/s;

A is the total vent area, in m^2;

V is the enclosure volume, in m^3;

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

To estimate the static load on a structure caused by recoil forces (F_R) the following approximation shall be applied:

$$F_R = 0{,}52\ F_{R,\text{max}} \tag{17}$$

where

F_R is the static load due to recoil forces, in kN;

$F_{R,max}$ is the maximum recoil force, in kN.

The impulse transmitted by the recoil force shall be calculated by:

$$I_R = F_R \cdot \Delta t_R \tag{18}$$

where

I_R is the impulse transmitted by recoil force, in kN·s;

F_R is the static load due to recoil forces, in kN;

Δt_R is the duration of recoil force, in s.

7 Information for use

7.1 Marking

All products protected against the consequences of internal gas explosions by explosion venting designed according to this European Standard shall be marked on the main part in a visible place. This marking shall be legible and durable taking into account possible chemical corrosion.

Marking shall include:

a) name and address of the manufacturer;

b) manufacturer's type identification;

c) year of construction;

d) serial number.

7.2 Accompanying documents

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

a) the information marked on the product;

b) all details of operational requirements;

The venting of the explosion shall be such that the area in which the explosion by-products are vented is sufficiently distant from other process equipment, and personnel shall not be allowed to enter this area when an explosion hazard is present.

c) the method used to assess the vent area;

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

e) the upper value of the vent static activation overpressure p_{stat}, in bar;

f) the upper limit of the explosibility characteristics p_{max}, in bar and K_G in bar·m·s^{-1};

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

In addition the instructions for maintenance shall include:

h) periodic inspection;

Periodic inspection checks should be made to ensure that the explosion venting capability does not deteriorate and would continue to react as originally designed 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)

Assessment of the level of congestion in rooms containing turbulence including elements

The necessary venting requirements for enclosures containing turbulence inducing elements such as equipment in the forms of piping, vessels and structural elements in industrial buildings and trays in drying ovens can normally not be calculated with the relationships presented above. The turbulence inducing elements may result in strong combustion rate increases during the explosion causing considerably higher pressures than anticipated on the basis of the equations given in 5.2.

To judge whether another more sophisticated method should be applied than the one described in 5.2 one can use the following guidance.

The influence of turbulence inducing elements is closely related to the size, number, shape and position of these elements. The guidance offered aims at describing the turbulence inducing elements, which may be present in the enclosure, according to several important parameters. The relative importance of these parameters is described by a single relationship.

To assess the level of congestion inside an enclosure with turbulence inducing elements the following parameters are used:

Number of rows n with turbulence inducing elements, area blockage b by the turbulence inducing elements and a complexity factor c. In addition to that the laminar burning velocity S_{ui} and expansion ratio E are used to describe the varying sensitivity of fuels to turbulence inducing elements.

The equipment in the enclosure is organised in rows in the main flow direction, i.e. the direction of the flow in the enclosure towards the vent. On the basis of the defined rows the following properties are determined:

— the number of rows with turbulence inducing elements in the main flow direction: n;

— the average blockage area ratio b in these rows;

— the distance l between the vent opening and the point furthest away in the enclosure.

An appropriate value of the complexity factor c is chosen using the following guidance:

— Level 1: idealised arrangements of obstructions of the same diameter or very few obstructions of significant different dimension than the dominant obstruction diameter;

— Level 2: rather more complex than level 1, for example with two obstruction sizes an order of magnitude apart;

— Level 3: much more like real plant but without many smaller items;

— Level 4: full complexity of typical congested chemical or petro-chemical installations.

Table A.1 — Values for the complexity factor *c*

Complexity level	Complexity factor *c*
1	1
2	1,7
3	2,8
4	4,0

Next the value of the vent area A is calculated according to the method described in 5.2. If this vent area is smaller than the expression given on the right side of the Equation (A.1) the method given in 5.2 can be used for estimating the size of vents in the considered enclosure where turbulence inducing elements are present:

$$A \le \left[75 \times 10^{-3} F_{fuel}\, c \left(\frac{2{,}1\, l - 2\, V^{1/3} + 1}{V^{1/3}} \right)^{0{,}55} n^{1{,}33} \exp(3{,}8\, b) + 0{,}885\, (p_{stat} - 0{,}1) \right]^{-0{,}577}$$

$$V^{2/3} \left[0{,}12651 \lg (K_G) - 0{,}0567 + 0{,}1754 (p_{stat} - 0{,}1) \right] \tag{A.1}$$

where

$$F_{fuel} = \frac{\left[S_{0,fuel} \left(E_{fuel} - 1 \right) \right]^{2{,}71}}{\left[S_{0,propane} \left(E_{propane} - 1 \right) \right]^{2{,}71}} \tag{A.2}$$

E is the expansion coefficient;

$S_{0,\text{fuel name}}$ is the burning velocity at initial conditions, in m/s:

n is the number of rows with turbulence inducing elements in the main flow direction;

b is the average blockage ratio in rows (= ratio of total area of cross section blocked by turbulence inducing elements and total cross section);

l is the length between the vent opening and the point furthest away in the enclosure;

c is the complexity factor.

If, however, A is larger than the equation given above more sophisticated methods shall be used.

Example of assessment of congestion level:

Consider a storage room for solvents. The room is 2,5 m high, 7 m long and 3 m wide. Inside the room there are five racks positioned parallel to each other. Each rack is open with 4 shelves running along the entire length of the rack. The racks are 2 m long and are positioned at equal distances from each other. The racks run from one of the long walls parallel to the short walls.

Each rack can be filled with containers with solvent. The containers are 0,3 m high and have a diameter of 0,3 m. In the calculation it is assumed that all shelves are filled with containers to simulate a worst case condition.

A vent opening is planned in one of the short walls. The room can withstand a pressure of 0,2 bar. The static activation pressure of the vent cover is chosen to be 0,1 bar.

Assessing the level of congestion in the room it can be seen that the number of rows with obstructions n is 4. Considering the entire cross section of the room (which is 2,5 m × 3 m = 7,5 m^2) the blockage by each filled rack can be calculated: 4 shelves with 0,3 m high containers which are 2 m long block: 4 × 0,3 m × 2 m implying a blockage ratio of b = 0,32. The length l between the vent opening and the back wall of the enclosure is l = 7 m.

The complexity factor c can be chosen to be c = 1 since obstructions can be considered to be close to idealised rows of obstructions.

The solvents can be expected to have properties close to that of pentane, $S_{0,\text{pentane}}$ = 0,43 m/s and E_i = 8,06. K_G of pentane is K_G = 104 bar·m/s.

Using the simple method described in 5.2 the vent area can be calculated to be A = 7,1 m^2.

The factor F_fuel can be calculated to be F_fuel = 0,91.

Using the various factors given above the right side of the Equation (A.1) results in a value of 1,75 m^2 implying that the method described in 5.2 cannot be used to safeguard the solvent storage room. More sophisticated methods need to be applied.

Intricate venting calculation methods:

The intricate calculation methods mentioned above and in 5.3.5 are able to take the effect of obstructions on combustion during an explosion into account. This also includes the effect of the location of these obstructions, their shape, orientation, number etc. When applying the method all relevant obstructions shall be taken into account. Further, the methods shall be able to take the following effects into account: gas explosion properties of the flammable gas, vent location, ignition point location, effect of vent enclosure and when relevant the size of the flammable cloud and its position.

To be able to use one of the intricate methods for these types of applications, documentation shall be made available demonstrating that the method has been validated against experiments relevant for the application (geometry, level of congestion and gas reactivity). This documentation must be prepared following European guidelines [2].

References for Annex A

[1] Puttock, J. S., *Improvement in Guidelines for Prediction of Vapour Cloud Explosions*, International Conference and Workshop on Modelling the Consequences of Accidental Releases of Hazardous Materials, San Francisco, 1999

[2] EME, Gas explosion model evaluation protocol, version 5th September 1998

[3] Selby, C. and Burgan, B., *Blast and fire engineering for topside structures, Phase 2, Final summary report*, Steel Construction Institute, UK, SCI Publication, Number 253

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 of 23 March 1994 concerning equipment and protective systems intended for use in potentially explosive atmospheres.

Once this standard is cited in the Official Journal of the European Communities 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

Essential Requirements (ERs) of EU Directive 94/9/EC	Clauses of this EN	Qualifying remarks/Notes
1.0.1 Principles of integral explosion safety (third indent)	Whole document	
1.0.2 Design considerations	5, 6	
1.0.4 Surrounding area conditions	6.4	
1.1.2 Limits of operating	5, 6	
1.2.1 Technological knowledge of explosion protection for safe	Whole document	Reference to EN 14797
1.4.1 Safe functioning	6	
2.2.1 Explosive atmospheres caused by gases, vapours or mist	Whole document	
2.3.1 Explosive atmospheres caused by gases, vapours or mists	Whole document	
3.0.1 Dimensions of protective systems safety level	5, 6	Reference to EN 14797
3.1.5 Pressure relief systems	Whole document	

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

Bibliography

[1] Bartknecht, W., *Explosionsschutz. Grundlagen und Anwendung,* Springer-Verlag, 1993

[2] Moen, I. O., Lee, J. H. S., Hjertager, B. H., Fuhre, K. and Eckhoff, R. K., *Pressure development due to turbulent flame propagation in large methane-air explosions,* Comb. Flame, vol. 47, pp. 31 - 52, 1982

[3] Hansen, O. R., Storvik, I., Wingerden, van, K. *Validation of CFD-models for gas explosions, where FLACS is used as example; model description and experiences and recommendations for model evaluation.* Proceedings European Meeting on Chemical Industry and Environment III, Krakow, Poland, pp. 365 - 382, 1999

[4] Pappas, J. A., *Venting of large-scale volumes, Proc. Control and Prevention of Gas Explosions,* Oyez/IBC, 1993

[5] National Fire Protection Association (NFPA), *Guide for Venting of Deflagrations,* NFPA 68, 2002 Edition

[6] Pritchard, D. K., Allsopp, J. A. and Eaton, G. T., *Gas explosion venting in elongated enclosures*, www.safetynet.de, 2001

[7] Tite, J. P, Binding, T. M. and Marshall, M. R., *Explosion relief for long vessels*. Paper presented at Conference on Fire and Explosion Hazards, April 1991, Moreton-in-Marsh

[8] Wingerden, van, K., *Prediction of pressure and flame effects in the direct surroundings of installations protected by dust explosion venting,* J. Loss Prev. Process Ind., Vol. 6, No. 4, pp. 241 - 249, 1993

[9] Harmanny, A., *Pressure Effects from Vented Dust Explosions,* VDI-Bericht Nr. 160, 2002

[10] Harrison, A. J. and Eyre, J. A., *External explosions as a result of explosion venting,* Combust. Sci. and Techn. Vol. 52, pp. 91 - 106, 1987

[11] Schacke, H., Müller, R. and Siwek, R., *Gas Explosion Venting of a Structure. Proceedings of the* "7th Int. Symposium on Loss Prevention and Safety Promotion in the Process Industries", Volume 4: pp. 59, 4th - 8th May 1992, Taormina, Italy, 1992.

[12] Faber, M., *Rückstoßkräfte bei der Explosionsdruckentlastung*, Zement-Kalk-Gips, Vol. 36, No. 9, pp. 531 - 534, 1983

[13] EN 14373:2005, *Explosion suppression systems*

[14] EN 14460, *Explosion resistant equipment*

[15] EN 14491, *Dust explosion venting protective systems*

[16] prEN 15089, *Explosion isolation systems*

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: +44 (0)20 8996 9000. Fax: +44 (0)20 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: +44 (0)20 8996 9001. Fax: +44 (0)20 8996 7001. Email: orders@bsi-global.com. Standards are also available from the BSI website at http://www.bsi-global.com.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: +44 (0)20 8996 7111. Fax: +44 (0)20 8996 7048. Email: info@bsi-global.com.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: +44 (0)20 8996 7002. Fax: +44 (0)20 8996 7001. Email: membership@bsi-global.com.

Information regarding online access to British Standards via British Standards Online can be found at http://www.bsi-global.com/bsonline.

Further information about BSI is available on the BSI website at http://www.bsi-global.com.

Copyright

BSI
389 Chiswick High Road
London
W4 4AL