BRITISH STANDARD

BS EN 14373:2005

Explosion suppression systems

The European Standard EN 14373:2005 has the status of a British Standard

ICS 13.230

British Standards

National foreword

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The UK participation in its preparation was entrusted to Technical Committee FSH/23, Fire precautions in industrial and chemical plant, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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EUROPEAN STANDARD

NORME EUROPÉENNE

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EN 14373

October 2005

ICS 13.230

English Version

Explosion suppression systems

Systèmes de suppression d'explosion

Explosionsunterdrückungs-Systeme

This European Standard was approved by CEN on 16 August 2005.

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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 Central Secretariat has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This European Standard (EN 14373:2005) 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of an identical text or by endorsement, at the latest by April 2006, and conflicting national standards shall be withdrawn at the latest by April 2006.

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

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

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1 Scope

This European Standard describes the basic requirements for the design and application of explosion suppression systems. This European Standard also specifies a method for evaluating the effectiveness and the scale up of explosion suppression systems against defined explosions. It gives the criteria for alternative test apparatus used to undertake explosion suppression efficacy tests and criteria to be applied in defining the safe operating regime of an explosion suppression system.

It covers:

— general requirements for explosion suppression components;

— evaluating the effectiveness of an explosion suppression system;

— evaluating the scale up of an explosion suppression system;

— evaluation and development of design tools for explosion suppression systems;

— instructions for installation of an explosion suppression system;

— maintenance instructions for an explosion suppression system.

This European Standard is applicable only to explosion suppression systems intended for the protection of closed, or essentially closed, enclosures in which an explosion may result as a consequence of ignition of an explosible mixtures, e.g. dust-air mixtures, gas(vapour)-air mixtures, dust-gas(vapour)-air mixtures and mists.

This European Standard is not applicable for explosions of materials listed below, or for mixtures containing some of those materials:

— unstable materials that are liable to dissociate;

— explosive materials;

— pyrotechnic materials;

— pyrophoric materials.

NOTE For the listed materials expert advice is required.

2 Normative references

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

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 explosion pressure rise*

EN 14034-1, *Determination of explosion characteristics of dust clouds — Part 1: Determination of the maximum explosion pressure* p_{max} *of dust clouds*

prEN 14034-2, *Determination of explosion characteristics of dust clouds — Part 2: Determination of the minimum rate of explosion pressure rise* $(dp/dt)_{max}$ *of dust clouds*

prEN 14034-3, *Determination of explosion characteristics of dust clouds — Part 3: Determination of the lower explosion limit LEL of dust clouds*

EN 14034-4, *Determination of explosion characteristics of dust clouds - Part 4: Determination of the limiting oxygen concentration LOC of dust clouds*

prEN 14491, *Dust explosion venting protective systems*

prEN 14994, *Gas explosion venting protective systems*

EN 26184-3, *Explosion protection systems — Part 3: Determination of explosion indices of fuel/air mixtures other than dust/air and gas/air mixtures (ISO 6184-3:1985)*

3 Terms and definitions

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

3.1
HRD-suppressor
appliance containing an explosion suppressant, which can be expelled by the action of internal pressure

NOTE 1 This pressure may be stored pressure, or may be obtained by a chemical reaction such as the activation of an explosive or pyrotechnic device.

NOTE 2 HRD is the abbreviation of High Rate Discharge.

3.2
suppressant
substance contained in the HRD-suppressor which, when dispersed into a volume to be protected, can arrest or prevent a developing explosion in that volume

NOTE Three categories of suppressants are in general use, separately or in combination:

- powder suppressant;
- water suppressant;
- chemical suppressant.

3.2.1
powder suppressant
powder with recognised flame extinguishing properties such as products based on monoammonium phosphate, potassium bicarbonate or sodium bicarbonate

NOTE Such suppressants may contain additives to improve their flow properties and their effectiveness.

3.2.2
water suppressant
water, cold or hot, used as an explosion suppressant

NOTE Additives may be included to provide frost protection, and/or to improve the suppressant effectiveness.

3.2.3
chemical suppressants
chemical suppressants with recognised flame-extinguishing properties

3.3
dispersion agent pressure
p_s
maintained pressure in a stored pressure-type suppressor at which the suppressant is dispersed, e.g. dry gas, chemical reaction or the application of heat

3.4
suppressant charge
M_s
mass or volume of the suppressant contained within the suppressor

3.5
explosion sensor
device which is responsive to the changes, caused by a developing explosion, in one or more of the parameters such as pressure, temperature and/or radiation

3.6
explosion detector
device or arrangement of apparatus, containing one or more explosion sensors, that responds to a developing explosion by providing an explosion detection signal

3.7
activation pressure
p_a
pressure threshold, above the pressure at ignition of the reactants (p_i), at which a detection of the explosion is deemed to have occurred

3.8
reduced (suppressed) explosion pressure
p_{red}
explosion overpressure, above the pressure at ignition of the reactants (p_i), recorded in a suppressed explosion event

3.9
maximum reduced (suppressed) explosion pressure
$p_{red,max}$
maximum explosion overpressure, above the pressure at ignition of the reactants (p_i), recorded in a suppressed explosion event at optimum fuel concentration

3.10
explosion suppression
technique by which burning in an explosive atmosphere is detected and arrested during incipient stages, restricting development of pressure

3.11
explosion suppression system
composite arrangement of devices to detect automatically the onset of an explosion and initiate the deployment of suppressant so as to limit the destructive effects of the explosion

3.12
control and indicating equipment
CIE
explosion protection equipment which controls, records and monitors the explosion sensors/detectors and the explosion protection devices

NOTE On detection of an incipient explosion, the CIE activates the explosion protection devices and initiates alarm systems.

3.13
dispersion device
device fitted on a HRD-Suppressor and designed to spread the suppressant throughout the volume to be protected

3.14
enclosure

3.14.1
compact enclosure
cubic enclosure
enclosures having a length (height) to diameter ratio of less than 2

3.14.2
elongated enclosures
enclosures with length (height) to diameter ratio of 2 to 10

3.14.3
pipe
construction with a ratio length (height) to diameter greater than 10

3.15
combination systems

3.15.1
suppression combined with venting
system combining the technology of explosion suppression with explosion venting

3.15.2
venting combined with suppression
system designed to minimise flame ejection out of an explosion vent

3.15.3
reduced oxygen concentration combined with suppression
system where a reduced oxygen concentration is used to minimise the explosion intensity and suppression is used to suppress the reduced explosion intensity

3.16
design strength of enclosure *p* (plant strength)

3.16.1
explosion resistant enclosures
enclosures and equipment, inclusive of attached pipelines, which are designed in accordance with CEN-regulation, such that the expected explosion pressure can be withstood without permanent deformation

3.16.2
explosion shock resistant enclosures
enclosures and equipment, inclusive of attached pipelines, which are designed in accordance with CEN-regulation such that they will resist the anticipated overpressure of an explosion. Unlike the criteria for explosion resistant enclosures, with explosion shock resistant enclosures some plastic deformation is allowable. In designing these enclosures, a higher utilisation of the strength of the material of construction is assumed

3.17
hazard sector
three dimensional space for which the explosion suppression system is designed to be active

3.18
LOAEL
lowest concentration at which an adverse toxicological or physiological effect has been observed

NOTE LOAEL is the abbreviation of Lowest Observable Adverse Effect Level.

3.19
model
mathematical calculation which predicts the course of an explosion, the action of the suppression system and its interaction with the explosion, in order to enable an accurate design of explosion suppression systems

3.20
NOAEL
highest concentration at which no adverse toxicological or physiological effects have been observed

NOTE NOAEL is the abbreviation of No Observable Adverse Effect Limit.

3.21
obstructed volume
volume element containing internal obstructions

3.22
occupied space
three dimensional expanse in which personnel may be or are present

3.23
segregated volumes
three dimensional space that is set apart from others or from the main volume

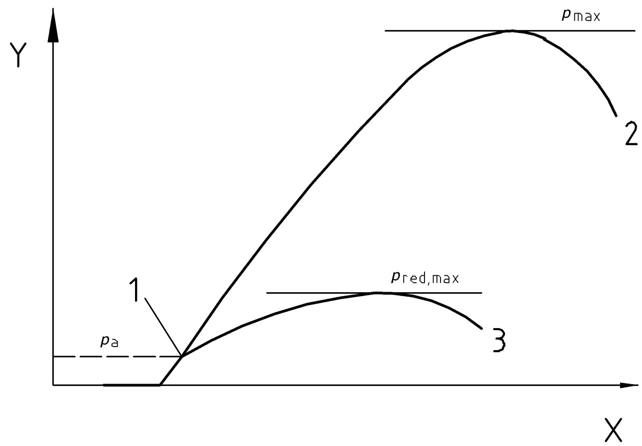
3.24
threshold dose
dose level below which no adverse toxicological or physiological effects have been observed

4 Explosion suppression

4.1 General

Explosion suppression is a technique by which combustion of an explosive atmosphere in a closed or essentially closed volume is detected and arrested during incipient stages, restricting development of damaging pressures.

A control and indicating equipment, CIE initiates the discharge of the HRD-Suppressor and the suppressant is dispersed into the volume to be protected in as short a time as possible. An explosion is regarded as suppressed when it is possible either to restrict the maximum explosion pressure to a suppressed (reduced) explosion pressure, which is lower than the protected volume design strength, or to limit fireball propagation to a specified maximum size in unconfined spaces. The maximum explosion overpressure, p_{max} will therefore be lowered to a maximum reduced (suppressed) explosion overpressure $p_{red,\, max}$ of typically between 0,2 bar and 1 bar (Figure 1).



Key

1 Activation of the suppression system
2 Closed enclosure explosion
3 Suppressed explosion
Y Explosion overpressure *p*, in bar
X Time *t*, in s

Figure 1 — Pressure behaviour versus time for a normal and suppressed explosion

For most practical applications of explosion suppression the worst case maximum suppressed explosion pressure, $p_{red,\ max}$ that can result is determined. Provided that this suppressed explosion pressure is lower than the process equipment design strength and provided further that suppression is achieved with a sufficient margin of safety, effective explosion suppression can be assured.

4.2 Influencing factors

4.2.1 General

The effectiveness of an explosion suppression system depends on the parameters listed in 4.2.2 to 4.2.4.

4.2.2 The explosion hazard

a) Volume of enclosure (free volume, *V*);

b) shape of enclosure (surface area and length (height) to diameter ratio);

c) explosible material (gas, dust, flammable liquids, mixtures thereof);

d) homogeneity and intrinsic turbulence of the explosive atmosphere;

e) induced turbulence caused by interaction of the combustion wave with internal obstacles and reflected pressure waves;

f) initial pressure;

g) temperature condition;

h) explosibility parameters of explosible materials:

   1) maximum explosion overpressure, p_{max};

2) maximum explosion constant, K_{max};

3) burning velocity;

4) minimum ignition temperature, MIT.

4.2.3 The explosion suppressant

a) Type of suppressant agent;

b) mass of suppressant deployed;

c) suppression efficiency of the agent.

4.2.4 The suppression system

a) Detection - effective system actuation pressure, p_a;

b) HRD-suppressors:

1) number of HRD-suppressor(s), N_s;

2) volume of HRD-suppressor(s), V_s;

3) HRD-suppressor outlet diameter, D_s;

4) HRD-suppressor opening time, t_s;

5) suppressant charge in HRD-suppressor, M_s;

6) suppressant dispersion pressure, p_s;

7) HRD-suppressor dispersion device;

8) location of HRD-suppressor(*s*) on enclosure.

4.2.5 Interrelation

The relative importance of each of these parameters is dependent on the specific application. The determination of the efficacy of a given explosion suppression system requires systematic testing in which the following variables are changed independently:

— severity of the explosion (e.g. K_{max});

— threshold of explosion detection;

— bulk mass of deployed suppressant;

— suppressant dispersion pressure.

This procedure provides a base datum sufficient to assess the efficacy of the suppression system.

In principle, for a specific application of an explosion suppression system, either specific representative tests or appropriate interpolation from a representative test results database can provide the necessary surety.

In practice, design engineers depend on pertinent design guidance. Nomographs and scaling equations based on the cubic law, and more complex theoretical models that allow for the interdependence of all parameters, can be used as a base for system specification. Such nomographs, equations and models shall be substantiated on the basis of the minimum criteria of acceptance defined herein to give acceptable design guidance within the scope of this European Standard. The minimum criteria of acceptance for such guidance are specified in 6.4.

It should be noted that for some types of application additional information is required in order to determine system suitability. In the case of occupied areas the hazards associated with system activation are of paramount importance. The food industry demands that the system does not compromise hygiene. Applications that can result in suppressant release into the atmosphere require the use of environmentally friendly suppressants. Re-ignition risk, and post explosion fire protection requirements shall also be considered. Thus selection of the most appropriate explosion suppression system requires that the "fitness for purpose" of the system be fully evaluated.

5 General requirements for explosion suppression components

5.1 Detection

5.1.1 General

To initiate an explosion suppression system a detector is used to sense either an overpressure generated by, or a flame of, an incipient explosion. It is important to locate the detector in a position that ensures sufficient time for the suppression system to sense and activate the devices to extinguish the explosion.

5.1.2 Optical detection

Optical detectors shall be used in more open configurations where pressure build-up due to the incipient explosion is limited. Optical detectors shall not be used where high dust concentrations limit the reliability of the suppression system.

UV and IR detectors are available for optical detection. The use of daylight sensitive sensors shall be avoided to avoid spurious activation. The sensor shall be mounted such that the angle of vision allows it to cover all the protected hazard area. The performance of an optical detector will also be affected by any obstacles within its vision and this shall be overcome by the introduction of more detectors. Optical detectors shall be fitted with air shields to keep the optical lens clean.

5.1.3 Pressure detection

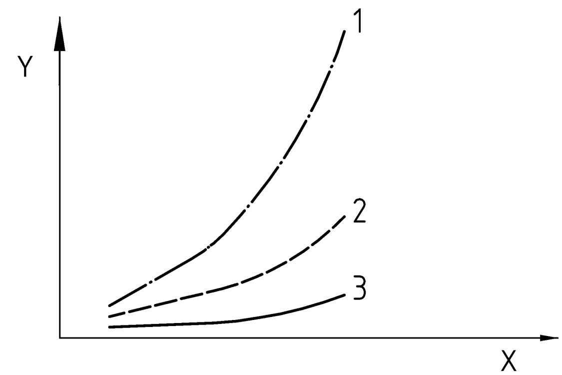
Pressure detection shall be used for closed enclosure applications.

Threshold detectors provide an electrical signal when a pre-set overpressure is exceeded.

Dynamic detectors provide an electrical signal to the system CIE unit. Typically they have both rate-of-rise and pressure threshold triggering points that can be configured specifically to the application conditions. Although this type of detector minimises spurious activation of the isolation system (due to pressure fluctuations other than explosion pressure rise), care shall be taken to set-up such detectors to meet appropriate detection response criteria for the particular application and protected enclosure geometry.

5.2 Suppressant

Suppressants deployed in suppression systems include water and dry and liquid chemicals. Apart from the effectiveness of the suppressant used, the compatibility of the suppressant with the process shall be considered. A suppressant is regarded as being very effective when an increase of the activation pressure p_a of the explosion suppression system leads to a small increase in the maximum reduced explosion overpressure $p_{red,\,max}$ (see Figure 2).



Key

1 Less effective suppressant

2 Effective suppressant

3 Very effective suppressant

X p_a (bar)

Y $p_{red, max}$ (bar)

Figure 2 — Effectiveness of suppressant

The application of a suppressant is dependent upon how effective it is at suppressing an explosion. Testing shall be used to determine the effectiveness and performance of the suppressant, thus quantifying the applicability of the suppressant. The following parameters shall be considered when selecting a suppressant:

a) any adverse reaction with the process products;

b) toxicity levels of the suppressant relating to occupational exposure limits;

c) temperature stability of the suppressant.

In addition the following properties shall be taken into account where necessary:

d) Will the suppressant have to be food compatible?

e) Will the suppressant cause the onset of corrosion?

f) Is the suppressant environmentally friendly?

g) Can the suppressant be easily removed from the process?

5.3 HRD-suppressors

HRD-suppressors are available in a range of sizes. Suppressant is stored in a container which is typically pressurised. A rapidly actuated container opening mechanism provides almost instantaneous unimpeded release for the suppressant, which is expelled by propelling agent and discharged through an appropriate dispersion device, if required, into the process equipment. HRD-suppressors that utilise a large diameter outlet have superior suppression capability over those that rely on high dispersion agent pressure alone to expel the suppressant agent. The HRD-suppressor and the dispersion system have an important influence on suppression effectiveness. The performance of HRD-suppressors with specific mounting adapters and dispersion system as appropriate shall be proven through tests (Clause 6). The number and distribution of HRD-suppressors are dependent upon the geometric size and shape of the enclosure to be protected and are crucial to achieving the best suppression performance. The application of HRD-suppressor(s) shall allow for the most effective discharge of suppressant, taking into account the following:

a) HRD-suppressor shall typically be mounted either on the top or the side of the process vessel, pipeline or enclosure to be protected.

b) HRD-suppressor shall be mounted onto the protected equipment so that proper discharge of the suppressant is ensured.

c) HRD-suppressor shall be fixed and supported on to the enclosure or to an available support in such a way as to allow for its weight and discharge recoil forces.

d) Application of explosion suppression on weak enclosures, vibrating equipment and high temperature process may require the HRD-suppressors to be supported off the enclosure.

Typically there are two types of dispersion devices, fixed and telescopic. Fixed spreaders protrude directly into the process equipment. A telescopic dispersion device remains outside the process equipment while inactive. On activation, the HRD-suppressor shall deploy the telescopic dispersion device forward (dislodging a protective cap/disc) into the protected equipment. The protective cap/disc positioned between the process and dispersion devices, shall prevent the ingress of process material into the dispersion device assembly.

5.4 Control and Indicating Equipment, CIE

A control and indicating equipment, CIE, shall record and monitor the signals transmitted by the system detectors. Dependent on configuration, by interrogation and interpretation of the detector/sensor data, the CIE shall selectively control the actuation of HRD-suppressors, other safety devices, process equipment shut down and all audible and visual alarms. System internal monitoring shall give fault indication in the event of device or field wiring defect, and alarm and fault relay contacts shall be connected as appropriate. Emergency standby power shall be facilitated such that full explosion protection is assured during any power failure. System isolation to facilitate safe working on or in a protected enclosure shall be standard.

6 Requirements for the design of an explosion suppression system

6.1 General

The explosion hazard presented by a given process shall be assessed by considering the parts of the process plant where explosive atmospheres or potentially explosive atmospheres are present. This analysis leads to the definition of hazard sectors within the process that shall be dealt with, as regards explosion prevention and protection, as discrete units essentially in isolation from each other. A hazard sector may include more than one enclosure and the pipes between, and its boundaries are often physical barriers such as rotary air locks or screw feeders. Any explosion event shall be fully contained within a hazard sector. It is normal practice when using explosion suppression to activate all the HRD-suppressors within a hazard sector. HRD-suppressors fitted to any other hazard sector are not activated unless an ignition occurs in that sector.

6.2 Hazard definition

For the purpose of this European Standard the explosion hazard shall be defined as the representative worst-case explosion event that can arise from an ignition in the hazard sector. The first step in determining the worst-case explosion shall be to measure the explosion characteristics of the fuel according to accepted test procedures as described in EN 13673, EN 14034 and EN 26218-3.

This test methodology establishes representative worst-case conditions of fuel concentration, homogeneity and turbulence expressed by the two principal explosion characteristics p_{max} and K_{max} which serve as a basis for assessing explosion suppression requirements.

The minimum criterion for effectiveness of an explosion suppression system shall be that the reduced suppressed explosion overpressure shall be less than the known pressure resistance of the weakest component of the equipment being protected.

6.3 Determination of the $p_{red, max}$ as a function of relevant influencing parameters

6.3.1 General

The tests shall be carried out in closed equipment using the procedures as described in EN 13673, EN 14034-1 and prEN 14034-2. The volume of the test apparatus shall be chosen such that 1 HRD-suppressor is just sufficient to suppress an explosion. To this end the highest reactivity fuel that can be encountered regarding the intended use of the explosion suppression system shall be chosen. Compact enclosures with a length-to-diameter ratio of 2:1 shall be used.

6.3.2 Validation by testing in one volume

6.3.2.1 Range of application of a new system

The efficacy of an explosion suppression system shall be determined by means of a series of tests in the chosen test volume. Measurement of the maximum reduced (suppressed) explosion overpressure ($p_{red, max}$) determines the minimum design strength of industrial plant to which such a system can be applied. Tests in accordance with the procedure described in 6.3.2 to 6.3.4 determine the range of applications of an explosion suppression system. From such tests the following shall be ascertained:

a) worst case explosion that can be suppressed by the system in that volume;

b) maximum detection pressure that can be used to suppress a defined explosion in that volume;

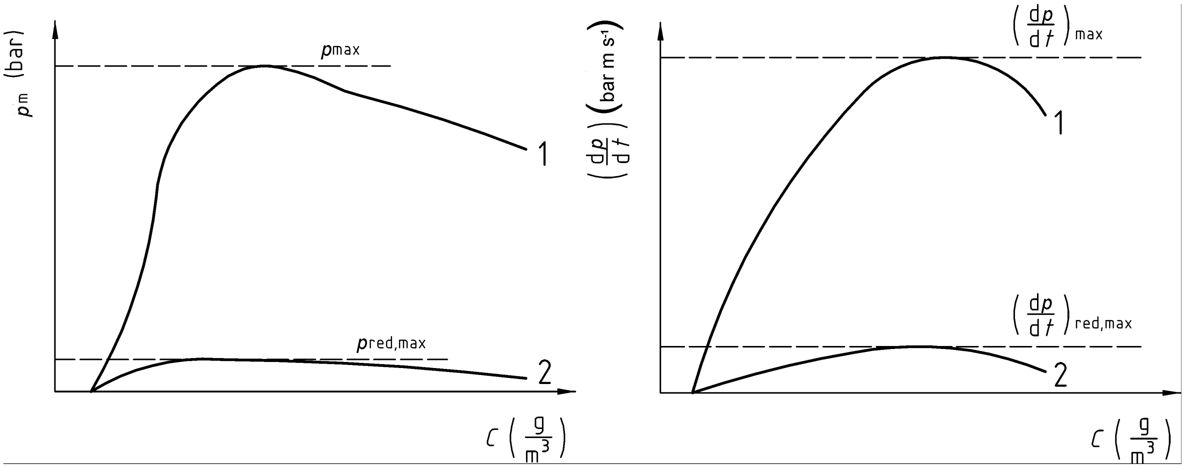
c) suppression system efficiency as determined by the $p_{red, max}$.

6.3.2.1.1 Variation of concentration of fuel, *C*

To determine the efficacy of a particular explosion suppression system against explosion hazards in a chosen test volume, a series of evaluations shall be undertaken. The maximum reduced (suppressed) explosion overpressure $p_{red, max}$ of a fuel shall be determined from the tests (see Figure 3). In practice it is necessary to measure p_{red} over a range of fuel concentrations to establish the optimum fuel concentration which gives the highest value of p_{red} Knowledge of the fuel concentration where p_{max} and $(dp/dt)_{max}$ occur is helpful here. Repeat tests at this optimum concentration shall be undertaken. The suppressed explosion indices, $p_{red, max}$ and $(dp/dt)_{red, max}$ shall be determined as the mean of at least three results at this optimum concentration.

EXAMPLE (assuming that the maximum of p_{red} is found at 500 g m^{-3} dust concentration)

1. series	250 g m^{-3},	500 g m^{-3},	750 g m^{-3}
2. series		500 g m^{-3}	
3. series		500 g m^{-3}	



a) **b)**

Key

1 unsuppressed explosion

2 suppressed explosion

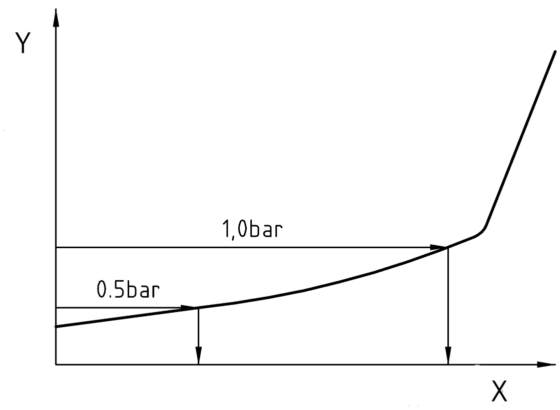
NOTE The activation pressure p_a and the number of suppressors (suppressant charge) are constant.

Figure 3 — Pressure behaviour and pressure rate of pressure rise versus concentration for a normal and suppressed explosion

The suppression system shall be prepared (dispersion agent pressure, suppressant charge) and installed on the test apparatus in accordance with the manufacturer‘s recommendations.

6.3.2.1.2 Variation of maximum explosion constant, K_{max}

To determine the range (limit) of application of a particular explosion suppression system against explosion hazards in a chosen test volume, a series of evaluations shall be undertaken against different explosions of increasing severity by varying K_{max} (see Figure 4).



Key

X $K_{max} \left(\frac{m \times bar}{s} \right)$

Y $p_{red,max}$ (bar)

NOTE The activation pressure p_a and the number of HRD-suppressors (suppressant charge) are constant.

Figure 4 — Maximum reduced explosion pressure, $p_{red, max}$ behaviour versus maximum explosion constant, K_{max}

The variation of K_{max} values shall be obtained as follows:

a) **Dust** as a fuel:

Using dusts with different K_{max} values or by using the same dust and varying the ignition delay time, t_v, and the concentration, *C,* to obtain different rates of pressure rise in order to simulate different K_{max} values.

b) **Gas** as a fuel:

Evaluating the performance of a suppression system in tests with propane will be satisfactory for vapours of many industrial solvents.

Where the burning characteristics of the gas or vapour are greater than that of propane, the performance of the suppression system shall be evaluated using a test gas or vapour with equal or higher explosion characteristics.

For turbulent conditions, the standard turbulence test method with turbulence varied by varying the ignition delay shall be used (see EN 26184-3).

c) **Hybrid** mixtures as a fuel:

For hybrid mixtures, the gas under turbulent conditions and the dust are investigated separately, and the worst case taken as the criterion for the efficacy of the suppression system (see EN 26184-3).

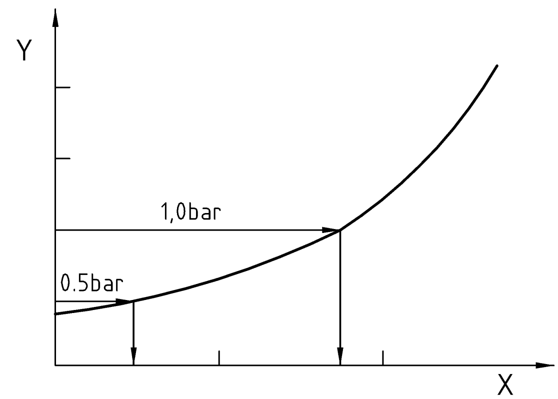
d) **Mists** as a fuel:

For mists a test procedure analogous to that used for dust shall be chosen. It is necessary to confirm that the test methodology used produces a mist with droplet size distribution equivalent to or smaller than occurs in the plant equipment for such testing to be considered valid (see also EN 26184-3).

For all fuel types mentioned above, the maximum reduced (suppressed) explosion overpressure, $p_{red, max}$, shall be determined from the tests. After the first test with a certain K_{max}, the same test shall be repeated twice. The suppressed indices $p_{red, max}$ are defined as the mean value of the three test results.

6.3.2.1.3 Variation of activation pressure p_a

To determine the range of application of a particular explosion HRD-suppressor fitted to a chosen test volume, the performance shall be evaluated against explosions of defined severity, using a range of activation pressures p_a (or equivalent sensor response). The maximum reduced (suppressed) explosion overpressure $p_{red, max}$ as a function of the activation pressure p_a shall be determined from the tests (see Figure 5). After the first test with a certain p_a, the same test shall be repeated twice. The suppressed indices $p_{red, max}$ are defined as the mean value of the three test results.



Key

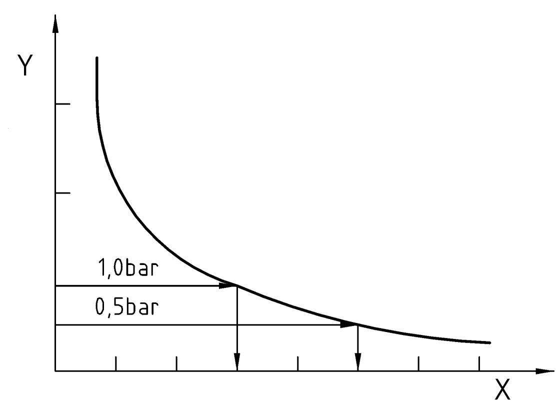
X p_a (bar)
Y $p_{red,max}$ (bar)

NOTE The explosion constant K_{max} and the number of HRD-suppressors (suppressant charge) are constant.

Figure 5 — Maximum reduced explosion pressure, $p_{red, max}$ behaviour versus activation pressure, p_a

6.3.2.1.4 Variation of number of HRD-suppressors

To determine the range of application of multiple explosion HRD-suppressor configurations fitted to a test volume, their performance shall be evaluated against defined explosion severity in the test volume (see Figure 6). The manufacturer shall specify the recommended amount of suppressant. After the first test with a specific number of HRD-suppressors, the same test shall be repeated twice. The suppressed indices $p_{red, max}$ are defined as the mean value of the three test results.



Key

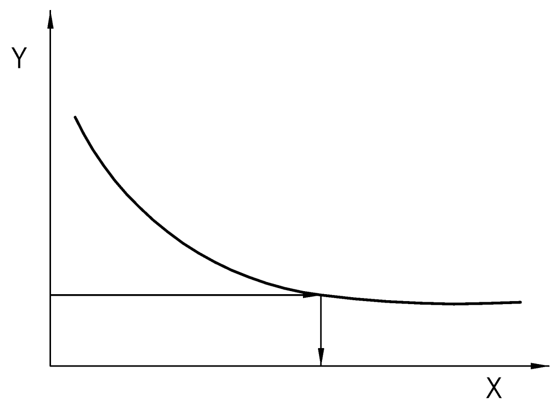
X HRDs
Y $p_{red,max}$ (bar)

NOTE The explosion constant K_{max} and the activation pressure p_a are constant.

Figure 6 — Maximum reduced explosion pressure, $p_{red, max}$ behaviour versus number of HRD-suppressors, HRDs

6.3.2.1.5 Variation of dispersion agent pressure p_s

For HRD-suppressors a variation of dispersion agent pressure p_s may occur (e.g. due to temperature, leakage). The influence of this varying dispersion agent pressure shall be investigated (see Figure 7). The dispersion agent pressure p_s shall be varied in a test by a range to the lower limit determined by the maximum deviation from $p_{red,\ max}$ allowed. Tests shall be repeated twice. The tests will determine the limits within which the system will function properly, e.g. it will specify the limit of the dispersion agent pressure p_s where the HRD-Suppressor shall be replaced.



Key

X p_s (bar)
Y $p_{red,max}$ (bar)

NOTE The activation pressure p_a, the explosion constant K_{max} and the number of HRD-suppressors are constant.

Figure 7 — Maximum reduced explosion pressure, $p_{red,\ max}$ behaviour versus dispersion agent pressure p_s

6.3.2.2 Suppression system for limited application

If the intended use of a suppression system is only for a specific (limited) range of application, then the efficacy of that suppression system shall be determined against explosions representative of that range of application, e.g. $K_{max} \leq 200$ m·bar·s^{-1}, $p_{max} \leq 10$ bar, $p_a \leq 0,05$ bar.

6.3.2.3 Fuel with unknown suppressability characteristics

The suppressability characteristics of a fuel describe how well an explosion involving this fuel can be suppressed. If an explosion suppression system is applied for a fuel with unknown suppressability characteristics (due to chemical composition or extreme process conditions) it shall be tested. If the explosibility characteristics of the fuel are not known they shall be determined.

The maximum reduced (suppressed) explosion overpressure $p_{red,\ max}$ of fuel shall be determined from the tests over a range of the fuel concentrations at an activation overpressure of typically $p_a = 0,1$ bar. Only the concentration range close to the observed maximum explosion overpressure p_{max} need be tested. p_{red} shall be measured at the most explosible fuel concentration, and then at higher and at lower fuel concentrations. The optimum fuel concentration, which gives the highest value of p_{red}, is thus established. Repeat tests at this optimum concentration shall be undertaken, and the suppressed explosion indices, $p_{red,\ max}$ defined as the mean of at least three results at this optimum concentration.

EXAMPLE (assuming that the maximum of p_{red} is found at 250 g·m^{-3} dust concentration)

1. series 125 g m^{-3}, 250 g m^{-3}, 500 g m^{-3}

2. series 250 g m^{-3}

3. series 250 g m^{-3}

If the obtained value for $p_{red,\ max}$ is not higher than the $p_{red,\ max}$ at which the design method is based the evaluation is completed. If the measured value is higher, a new assessment shall be undertaken as described in 6.3.2.

6.3.2.4 New components

To determine the efficacy of an existing suppression system where one of the components is replaced, e.g.:

a) new HRD-suppressor; or

b) new volume of HRD-Suppressor; or

c) new HRD-suppressor outlet diameter; or

d) new detector; or

e) new HRD-suppressor opening time; or

f) new suppressant charge in HRD-suppressor; or

g) new suppressant dispersion pressure; or

h) new HRD-suppressor dispersion device; or

i) new control and indicating equipment CIE.

The performance shall be evaluated according to 6.3.2. If it has only to be proven that the performance of a new component is at least equal to the old one, one series of three tests at worst conditions is sufficient.

If the new component should improve the performance of the explosion suppression system requiring new design guidelines the tests from 6.3.2.1 shall be repeated.

6.3.3 Validation by testing in a second volume

If the tests carried out in 6.3.2 have been completely successfully, tests shall be carried out in a second volume to investigate the effect of volume on the efficacy of the explosion suppression system. The size of the second volume depends on the size of the used HRD-Suppressor.

The tests that shall be performed are the same as described in the 6.3.2.1.1 to 6.3.2.1.5.

6.3.4 Elongated enclosures

For elongated enclosures the validation of the efficacy of a certain explosion suppression system shall be determined as for compact enclosures (see 6.2). However, the initial explosion in an elongated enclosure is more intense, and it is necessary to calculate an explosion intensity that is correspondingly greater than the standard measurement of K_{max} For dusts the following equation shall be used to determine the increase in the maximum explosion constant K_{max} as a function of enclosure length (height) to diameter ratio:

$$K_{max, el} = 0{,}95 \times 1{,}06^{H/D} \times K_{max} \quad (1)$$

where

$K_{max, el}$ is the elevated value in an elongated enclosure, in m·bar·s^{-1};

H/D is the length (height) to diameter ratio of the elongated enclosure;

K_{max} is the maximum explosion constant in, m·bar·s^{-1}.

Other validated methods for calculation of the enhanced K_{max} can be used. It is essential that the HRD-suppressors are distributed in such a way that effective suppressant distribution into the enclosure is ensured.

6.3.5 Pipes

Design of explosion protection in pipes by explosion suppression (as distinct from explosion protection by the use of extinguishing barriers) is an extension of the design basis used for elongated enclosures. The worst-case explosion hazard is ignition at the closed end of a pipe.

For pipelines detectors and suppressors shall be deployed along the entire length of the pipe, since it is assumed that an ignition can occur anywhere along the pipe length. The response from any one detector location shall be used to actuate all of the HRD-suppressors installed on the pipe.

Detectors shall be located along the pipe length with sensitivity sufficient to ensure that the explosion is detected and suppressant deployed before explosion pressures exceed the pipe internal design strength.

If the pipeline is connected to an explosion suppression of a pipeline alone is not a valid safety measure unless the enclosure is protected by venting or suppression.

6.3.6 Occupied spaces

Explosion suppression can be deployed to mitigate the consequence of an explosion in spaces where personnel may be present. Protection of such spaces imposes specific design constraints on the suppression system such that the suppressed explosion event is survivable.

Validation of the efficacy of any proposed explosion suppression system in occupied areas follows exactly the criteria described in Clause 6 for closed enclosures or essentially closed enclosures, but with the following additional constraints:

a) **Suppressant toxicology:** the deployed suppressant concentration shall be lower than NOAEL or LOAEL.

b) **Suppressant discharge:** the means of deploying the suppressant into the space envelope such that the blast (pressure effects) of the discharge shall not be injurious to personnel - with or without eye and ear protection as appropriate; the noise of the discharge shall not result in temporary loss of hearing; visual impairment arising from the discharge shall not be so extreme that personnel cannot see their route to an exit.

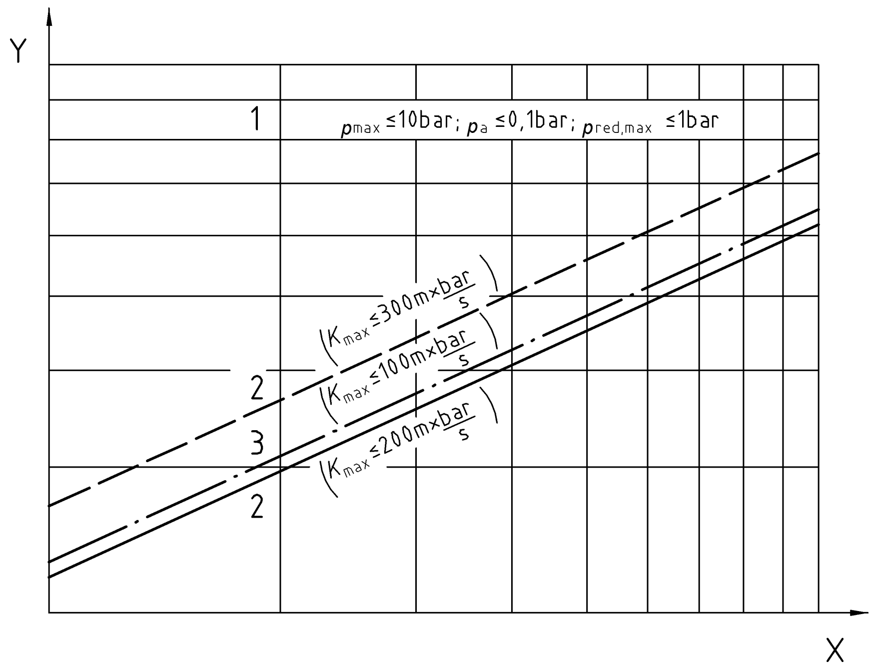
6.4 Validation of system design guidelines

6.4.1 General

System design guidelines are used by the manufacturer to predict an explosion suppression system's specification in a particular application. The minimum number of HRD-suppressors, for instance, is an essential safety requirement for ensuring the efficacy of a system when evaluating a practical situation. System design guidelines shall be validated by appropriate tests. These tests shall be carried out in the range of enclosure sizes that will occur in practice. The most common design guidelines are the simple nomograph type and the more advanced mathematical model type.

6.4.2 Design nomograph

The nomograph is the simplest type of design method and is based on tests from a minimum of two compact enclosures having different volumes. The method predicts the number of HRD-suppressors needed to suppress explosions in a certain volume for a given activation pressure p_a of the suppression system, a certain desired maximum reduced overpressure, $p_{red,\,max}$ and fuel reactivity (K_{max}). An example of such a nomograph is shown in Figure 8.



Key

1 Specific type of HRD-suppressor
2 Organic dust
3 Gas quiescent
Y Minimum numbers of HRDs, N_s
X Vessel volume V, in m³

Figure 8 — Design nomograph for a specific explosion suppression system

The method inherently takes several properties of the suppression system into account such as delays within the detector and the CIE and the time for a cloud of extinguishing powder to be deployed.

For a combination of other components or for another activation pressure, maximum reduced overpressure or fuel reactivity, new tests shall be performed to develop a new nomograph (see Annex A).

The nomograph shall be validated by performing tests with the relevant explosion suppression system components. The tests shall be carried out in a volume no greater than 1,33 times the smallest volume of the volume range over which the nomograph is valid and a volume greater than 0,25 the maximum volume of the volume range. The fuel reactivity for the tests shall be equal (K_{max}, p_{max}) to the fuel reactivity for which the nomograph is valid. If more than one reactivity is indicated (as in Figure 8) tests shall be carried out with representative fuels for each of the reactivities. The tests shall be carried out with the relevant activation pressure p_a.

The maximum reduced overpressure $p_{red,\,max}$ shall not exceed the equivalent predicted value when using the number of indicated HRD-suppressors.

6.4.3 Mathematical model for design

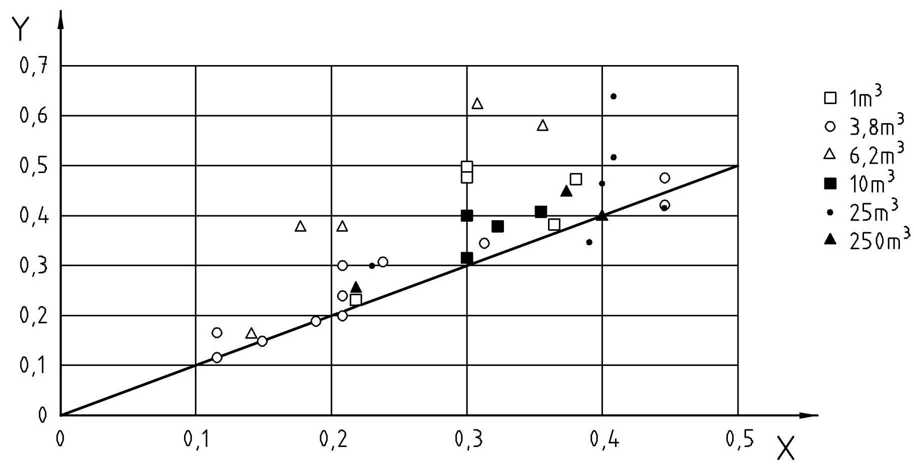
A mathematical model can be used for the design of explosion suppression systems. Such a model describes the course of the explosion in a specified geometry and the interaction of the suppression system with the explosion. The parameters of the different system components essential for the modelling shall be determined. Examples of such parameters are: the delay time of the detection system, the throw of the suppressant as a function of time. These determinations do not necessarily have to involve explosion testing.

However, the mathematical model shall be validated with explosion testing (see 6.3.2.1).

Each dependent parameter used in the mathematical model shall be tested to validate applicability. Dependent factors shall be tested at the extremes of their range. In total a minimum of 100 tests shall be performed in at least 4 different test volumes.

a) Evaluation for $p = p_{red,\,max} \leq 0{,}5$ bar:

As a minimum 95 % of all calculated reduced (suppressed) explosion pressures shall be equal to or higher than those measured by experimental tests (Figure 9):



Key

Y $p_{red,max}$ calculated, in bar

X $p_{red,max}$ measured, in bar

Figure 9 — Calculated maximum reduced explosion overpressure versus measured maximum reduced explosion overpressure for $p_{red,\,max}$ values up to 0,5 bar

Such models shall be considered valid only for the test enclosure volumes and the scope of the parameters under which they have been validated (fuel type, V, p_{max}, K_{max}, p_a, p ($p_{red,\,max}$)). An extrapolation beyond the test volumes is possible under the following conditions:

Minimum volume $V_{min} = 0{,}75 \times V_{min,\,test}$

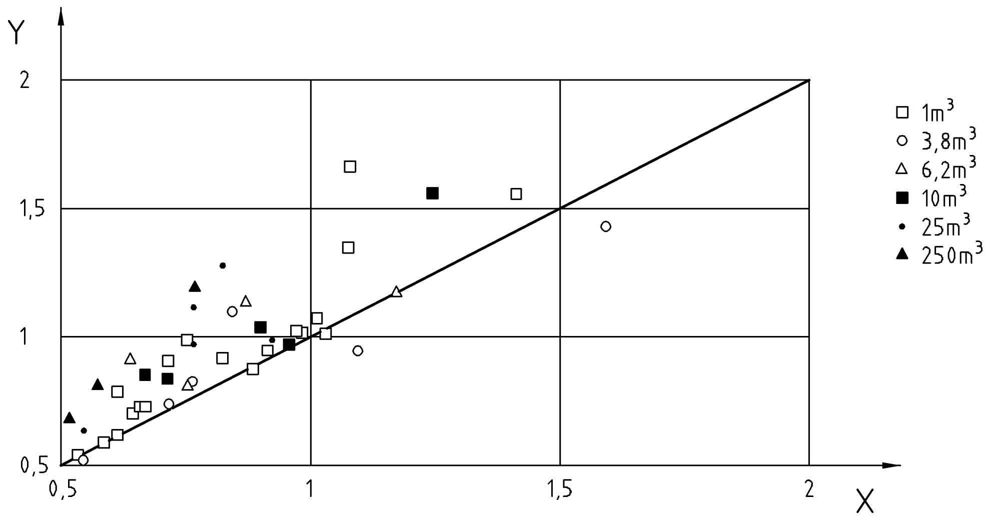
Maximum volume $V_{max} = 4{,}00 \times V_{max,\,test}$

For applications outside these limits expert advice shall be sought. In some circumstances, extrapolation beyond the stated volume range limits is admissible, but only if it can be proven by unambiguous scientific interpretation that such an extrapolation is valid.

In addition the calculated maximum (suppressed) explosion overpressures shall be in average at least 5 % higher than those measured, demonstrating that the model calculation errors are on the side of safety.

b) Evaluation for $p = p_{red,\,max} > 0{,}5$ bar:

As a minimum 90 % of the calculated reduced (suppressed) explosion pressures shall be equal to or higher than those measured by tests (Figure 10). For each variable allowed in the model, tests shall be done over the range of the applicability, in compact enclosures having different volumes:



Key

Y $p_{red,max}$ calculated, in bar

X $p_{red,max}$ measured, in bar

Figure 10 — Calculated maximum reduced explosion overpressure versus measured maximum reduced explosion overpressure for $p_{red,\,max}$ values above 0,5 bar

Such models shall only be considered valid for the test enclosure volumes and the scope of the parameters under which they have been validated (fuel type, V, p_{max}, K_{max}, p_a, p ($p_{red,\,max}$)). An extrapolation beyond the test volumes is possible under the following conditions:

Minimum volume $V_{min} = 0{,}75 \times V_{min,\,test}$

Maximum volume $V_{max} = 4{,}00 \times V_{max,\,test}$

For applications outside these limits expert advice shall be sought. In some circumstances, extrapolation beyond the stated volume range limits is admissible, but only if it can be proven by unambiguous scientific interpretation that such an extrapolation is valid.

In addition the calculated maximum (suppressed) explosion overpressures shall be in average at least 5 % higher than those measured, demonstrating that the model calculation errs on the side of safety.

6.5 Special applications

6.5.1 Suppression combined with venting

Suppression combined with venting is typically used on applications where the plant strength cannot be protected by either suppression or venting techniques alone. Where the primary protection means is explosion suppression, the addition of vents results in a lowering of the achievable reduced explosion pressure. The explosion venting system shall be set to activate above the explosion suppression activation pressure - typically twice (2×) as high. The efficacy of the combined system shall be validated by testing of the particular application. Sufficient suppression shall be present to avoid any secondary explosions inside the enclosure.

6.5.2 Venting combined with suppression

The combination of venting/suppression is typically used on applications where flame ejection from the enclosure is to be avoided. On detection of the incipient explosion, the suppression system injects suppressant into the enclosure near to the vents minimising any flame jet release from the vent closure. This application can be used on process vessels that are venting into a designated area of the buildings, where personnel are working.

The degree of venting shall be determined according to prEN 14491 and prEN 14994. The efficacy of the combined system shall be validated by testing of the particular application.

The HRD-suppressor shall be located so that the suppressant is deployed across the vent aperture before and during the duration of the fireball ejection.

6.5.3 Suppression combined with reduced oxygen concentrations

For those explosion hazards where, effective explosion protection by suppression is not practicable, the K_{max} can be reduced by replacing part of the oxygen by inert gas. The efficacy of the combined system shall be validated by testing of the particular application. The oxygen concentration shall be monitored to ensure that the allowed oxygen concentration is not exceeded.

6.5.4 Partial volumes

Where it can be unambiguously proven that an explosion is possible only in part of the volume and layers of flammable dusts are absent under both normal and abnormal operating conditions, it is admissible to design and deploy an explosion suppression system for this limited volume only. This may be appropriate for spray dryers.

Figure 11 shows an example of an enclosure where an explosible concentration prevails only in the lower section.

For such a situation a safety distance "*z*" shall be determined from a knowledge of the explosion flame speed, s_f, and the time from ignition to full explosion suppression, t_{supp}:

$$z = s_f \times t_{supp} \qquad (2)$$

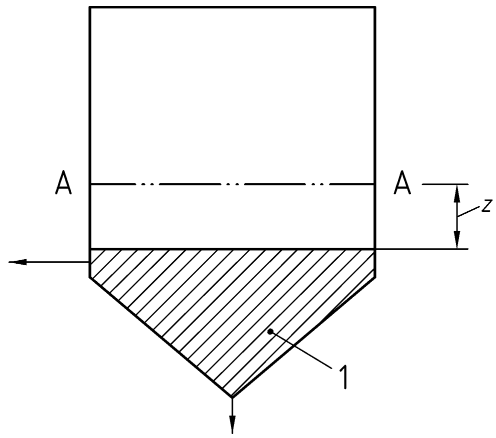
where

z is the safety distance, in m;

s_f is the flame speed, in m/s;

t_{supp} is the time from ignition to full explosion suppression, in s.

This dimension defines a boundary limit (in Figure 11) AA above which deployment of explosion suppressant is not required. Note that such partial volume protection is only valid for applications where there is no risk of explosion propagation from any interconnected pipe/enclosure site to the non-explosible volume element.



Key

1 Explosive atmosphere

Figure 11 — Example of an enclosure where an explosive concentration prevails only in the lower section

6.5.5 Segregated volumes

In some process equipment the volume is divided by an effective membrane/plenum into a clean volume element where no explosible concentration exists, and a dirty volume element where explosive atmospheres can be expected.

For such equipment (filters, bed driers etc.) it is a sufficient requirement to install an explosion suppression system to protect only the explosible (dirty) volume element - provided only that the pressure shock resistance across the membrane/plenum is greater than the corresponding suppressed/reduced explosion pressure expected from an ignition in the dirty volume. If the integrity of the membrane/plenum cannot be assured then the total volume of the enclosure shall be protected by the explosion suppression system.

6.5.6 Obstructed volumes

In some circumstances it is not possible to ensure deployment of suppressant into the total volume of the enclosure because of internal obstructions within the enclosure. The obstructions can be pocket filter elements or filter bags on support baskets. The effect of this unprotected volume element shall be taken into account. The resultant suppressed maximum explosion overpressure, $p_{red,\ max}$ in the enclosure can be estimated from:

$$p_{\text{red,max}} = p^{*}_{\text{red}} + \left[\frac{V_0 \times T_u \times p_{\text{max}}}{V \times T_b} \right] \quad (3)$$

$(V_0 \leq 0{,}5\ V)$

where

p^*_{red} is the expected suppression explosion pressure that would result if there were no internal obstructions, in bar;

V_0 is the volume element (volume of the obstructions) of the total volume V that is not effectively covered by deployed suppressant, in m³;

T_u is the initial temperature (unburned), in K;

T_b is the adiabatic flame temperature (burned), in K;

p_{max} is the maximum explosion overpressure of the explosion, in bar.

The calculation does not apply to circumstances where rapid flame acceleration can occur due to the presence of repeated obstacles.

6.6 Test report

The test report shall include the following information:

a) Product characteristics:

- nature of the sample;
- sample pre-treatment;
- characteristics data for particle size distribution and moisture content;
- explosion properties (p_{max}, K_{max}) according to EN 13673, EN 14034 and EN 26184-3.

b) Characteristics of the test apparatus:

- dimensional sketch of the test enclosure;
- enclosure volume, aspect ratio surface area;
- dust-dispersion system for producing homogeneous or inhomogeneous fuel clouds;
- unsuppressed explosion parameters of the fuel (sample) in the test enclosures.

c) Characteristics of the explosion suppression system:

- type of suppressant;
- detection system;
- dispersion device;
- type of HRD-suppressors;
- number and location of the HRD-suppressors;
- dispersion propelling pressure;
- suppressant charge in each of HRD-suppressors.

d) Results:

- data of test;
- ignition delay time (turbulence index);
- detection pressure;
- comparison of the results with the nomographs or with a computer model.

e) In addition:

- report shall include all pertinent observations and information which may not be fully described above;
- deviations from the defined test procedure are permissible when necessary, provided that such deviations are exactly described in the test report;
- test reports shall be certified on behalf of the testing establishment, numbered and dated.

7 Safety integrity of explosion suppression systems

7.1 General

The following requirements shall ensure an agreed level of safety integrity.

7.2 Measures to avoid and control systematic faults

An appropriate group of technologies and measures shall be used that are designed to prevent the introduction of faults during the design and development of the hardware.

An appropriate group of technologies and measures shall be used during the design and development of the software.

The design shall protect against:

a) any residual design faults in the hardware;

b) adverse environmental conditions, including electromagnetic disturbance (EN 50130-4);

c) mistakes by the operator;

d) any residual design faults in the software.

The reliability of the explosion suppression system shall be such that the probability of failure on demand, resulting from random hardware failures, meets the target failure measures according to the stated level of safety integrity.

7.3 Control of electric connections

As a minimum, the electronic connections for the following equipment shall be monitored for short circuit, open circuit and earth faults:

- sensors;
- HRD-suppressors.

For the connection to HRD-suppressors short circuit monitoring is not a requirement.

In case of an identifiable fault such that the safety function of the system cannot be guaranteed to the agreed level of safety integrity, the suppression system shall provide a fail-safe means to place the installation into a safe condition.

7.4 Indicators and messages CIE

Any activation and fault message shall be shown and indicated at the CIE, indicating its origin and nature. In case of activation of the suppression system, the CIE shall provide a means to commence an emergency stop procedure of the protected installation.

7.5 Energy supply

For the energy supply of the CIE two independent available energy sources shall be applied. Where batteries are applied they shall be suitable for the local operation and maintain a sufficient charge.

Batteries, where used as a back-up power supply, shall supply a minimum of 4 h.

The power supply shall be independent and suitably protected, and shall not be de-activated by an emergency switch.

8 Instructions for installation, commissioning and maintenance

8.1 General

The installation of an explosion suppression system shall be undertaken by a competent installer according to the current operation manuals.

8.2 Installation of cables

The cable specification, which is specified by either the manufacturer or supplier, shall be adhered to. Modifications to the cable specification can only be undertaken by written consent from the manufacturer or supplier.

Cables for explosion protection systems shall be segregated and routed away from power cables. See supplier recommendations.

8.3 Assembling

8.3.1 General

The location of the components that comprise the explosion protection system shall be determined by the system design. Modifications shall be undertaken after written agreement from the manufacturer or supplier.

8.3.2 Assembly

The end user shall approve all the explosion suppression equipment which comes into contact with processes.

The end user shall provide the manufacturer or supplier with information regarding product accumulation, increased type of protection, corrosive products or particular climatic conditions.

8.4 Commissioning

8.4.1 General

The commissioning of explosion protection equipment shall be undertaken by a competent person.

8.4.2 Commissioning phase

During the commissioning phase a minimum number of procedures shall be completed according to the supplier’s recommendations.

8.4.3 Instruction

The end user or an authorised person in charge of the operation (typically two persons) shall be instructed or provided with information by the manufacturer or supplier how to operate and control the explosion protection equipment.

The complete documentation bearing the unique system no. (see 9.3) (in the user's specified language) shall be supplied to the end user. This documentation shall contain all information about the system performance, design, application and operating instructions, and significant safety information, which is required for the explosion protection equipment operation and, as far as necessary, the technical basic documentation about feature performances and data limit values.

The end user or authorised persons in charge of operating the suppression equipment shall be informed about their duties as operators.

8.4.4 Commissioning report

A commissioning report signed by the person(s) responsible for the acceptance test shall be supplied.

8.4.5 Safety

Users shall be fully informed of the operational and safety aspects of the explosion protection system.

The explosion protection equipment shall be disarmed (connected in an inactive position) before undertaking maintenance work on the protected installation. It is recommended that the explosion protection equipment be interlocked with the process control system of the protected installation, in order that any restart of the processing operation is impossible, as long as the explosion protection equipment is not armed (active).

Entry by operators into protected enclosures is strictly forbidden when the explosion protection equipment is active and shall be prevented by taking internal measures (access authorisation and interlocking for example).

Handling and inspection of HRD-suppressors shall be undertaken only by the competent staff of the manufacturer or supplier or somebody who has previously been instructed and authorised by the same system design authority.

8.5 Maintenance

8.5.1 General

Explosion suppression systems shall be inspected by a competent person at least once a year. More often is depending on the process and/or environment conditions.

8.5.2 Servicing

Servicing comprises:

— Care of installation parts, exchange of components having a limited service life, adjustments, new adjustments and balancing of components and devices, and execution of functional tests.

— All incidents that occur, with indications as to their origins and, if possible, reasons - as well as all necessary measures concerning maintenance and modifications - shall be continuously reported in an operation logbook, permanently at the disposal of personnel at the installation. This report shall be written by the user or by the user's instructed persons, in charge of the operation.

9 Marking and packaging

9.1 General

Each component of the explosion suppression system shall be marked in accordance with 9.2 except as permitted in 9.4.

The explosion suppression system shall be uniquely referenced in accordance with 9.3.

The markings shall be permanent and shall not impair the performance of the explosion suppression system, and, where applicable, shall be such that they are visible after installation.

Explosion suppression system components shall be packed to prevent any damage which may impair their performance.

9.2 Explosion suppression system components

Each component part of the explosion suppression system shall be permanently marked, preferably on an identification label securely attached to the component and clearly visible.

The marking shall include as a minimum the following:

a) Detector/sensor:

1) operating temperature rating;

2) part number and type;

3) serial number;

4) equipment category;

5) ingress protection (IP) rating;

6) CE-marking where relevant.

b) HRD-suppressors:

1) operating temperature rating;

2) pressure rating and setting;

3) contents of the HRD-suppressors (type of powder and type of gas);

4) label indicating "pressurised enclosure:

   i) π if according to Directive 1999/36/EC (TPED);

   ii) CE-marking if according to Directive 97/23/EC (PED);

5) part number and type;

6) serial number;

7) identification for use in classified areas;

8) IP rating.

c) CIE:

1) operating temperature rating;

2) part number and type;

3) serial number;

4) identification for use in classified areas where appropriate;

5) IP rating;

6) CE-marking where relevant.

9.3 Explosion suppression system

The job number shall refer to the current operating manuals.

Also the complete system shall be CE marked and Ex marked. The marking shall include as a minimum the following:

— name and address of supplier;

— system CE-type examination certificate number;

— reference to explosion suppression system.

An example is shown below:

Logo of supplier Explosion Suppression System
Marking suppression system: Ex-sign, application range (G for gas, D for dust), notified body (NB), notified body identification number, ATEX, number of certificate, specific conditions Example: **GD NB 4444 ATEX 1234X**
Name and address of manufacturer

9.4 Omission of markings

Where the size and shape of the explosion suppression system component does not allow inclusion of all the required marking, or when marking may affect the performance, as many of the marking requirements as practical shall be met.

The marking shall always include a unique reference, which relates the item to the certificate, or document that contains the relevant information omitted from the marking requirement.

Annex A
(informative)

Development of nomograph type design guidelines

A.1 General

System design guidelines are used by the manufacturer to predict an explosion suppression system's specification in a particular application. The minimum number of HRD-suppressors, for instance, is an essential safety requirement for ensuring the efficacy of a system when evaluating a practical situation. The most common type of design guideline is the simple nomograph type enclosure. In this annex the development of such a nomograph is described.

A.2 Design nomograph

For this design nomograph the minimum number of a type of HRD-suppressors, N_s, required to suppress an explosion of defined explosion intensity in e.g. a compact enclosure of volume V can be determined by reference to the equation:

$$N_s = c \times V^{2/3} \tag{A.1}$$

where

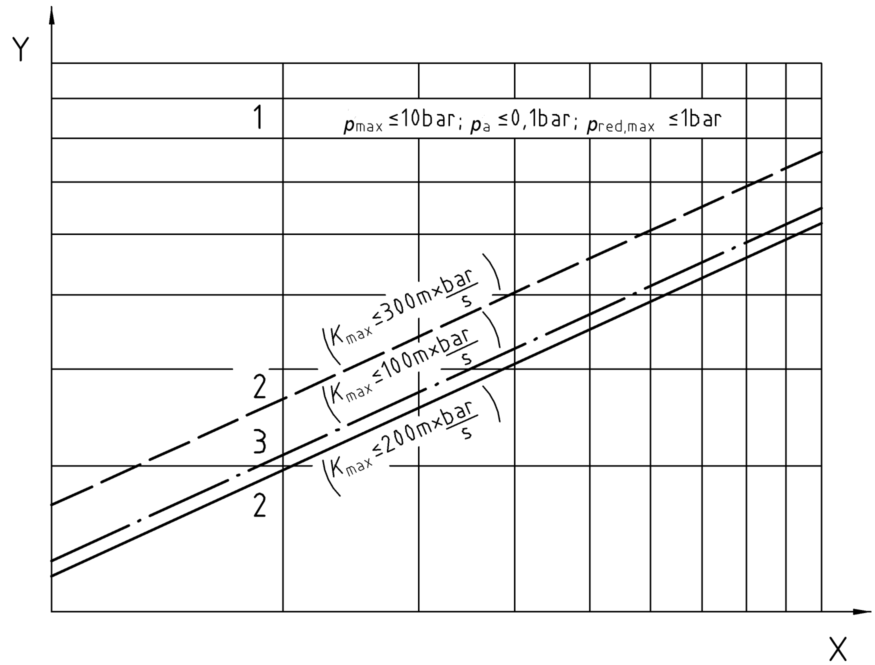
N_S is the minimum number of a type of HRD-suppressors;

c is a constant, in m^{-3};

V is volume of enclosure, in m^3.

Extensive series of experimental tests with a range of specific HRD-Suppressors should establish equations to determine the constant c.

An example of one such design nomograph is shown in Figure A.1.



Key

1 Specific type of HRD-suppressor

2 Organic dust

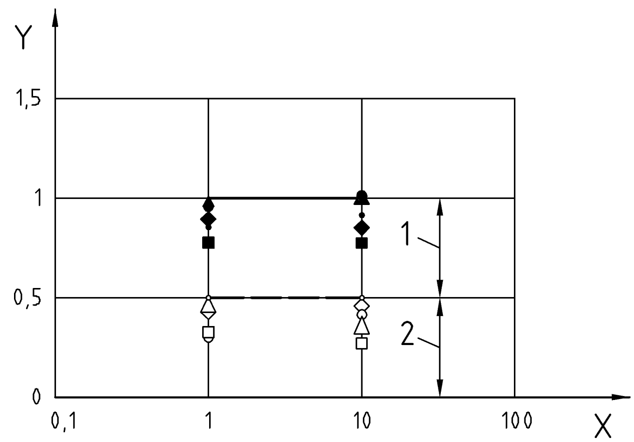
3 Gas quiescent

Y Minimum numbers of HRDs, N_s

X Vessel Volume *V*, in m³

Figure A.1— Design nomograph for a specific explosion suppression system

Design nomograph (see Figure A.1) for a given plant strength *p* and for a given type of HRD-suppressor and a constant activation pressure p_a can be used for estimation of the minimum number of HRD-suppressors N_s providing that it has been proven with experimental tests that the measured maximum reduced explosion overpressure $p_{red,\ max}$ is not higher than the $p_{red,\ max}$ at which the design nomograph is based. The tests to develop the nomograph should be carried out for each nomograph equation using a minimum of two enclosures having different volumes with at least five explosions test at optimum concentration (see Figure A.2) for one gas type or two tests at optimum concentration for each dust having different explosion indices (p_{max}, K_{max}) in each of the following fuel ranges.



Key

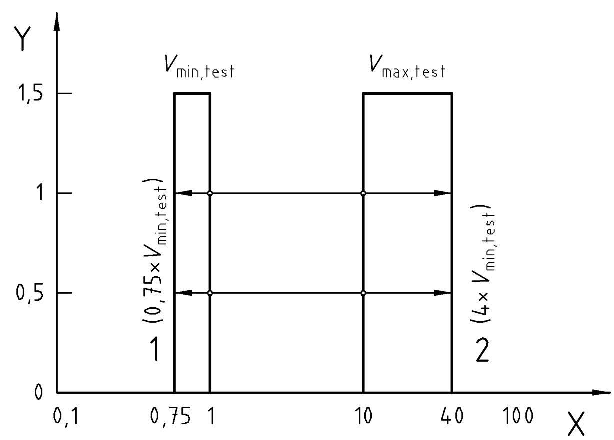
1 Range 2: $N = C_2 \times V^{2/3}$ for $p = p_{red,\,max}$ = 1 bar

2 Range 1: $N = C_1 \times V^{2/3}$ for $p = p_{red,\,max}$ = 0,5 bar

Y $p_{red,\,max}$, in bar

X Vessel Volume V, in m³

Figure A.2 — Design guideline for a fuel range



Key

1 Lower limit of enclosure volume

2 Upper limit of enclosure volume

Y $p_{red,\,max}$, in bar

X Vessel Volume V, in m³

Figure A.3 — Volume limits of the design guideline for a fuel range

a) **Dust** as a fuel:

— Range 1: up to K_{max} = 200 m·bar·s^{-1};

— Range 2: 200 m·bar·s^{-1} < K_{max} ≤ 300 m·bar·s^{-1};

— Range 3: 300 m·bar·s^{-1} < K_{max} ≤ 800 m·bar·s^{-1};

The number of dusts used for the validation depends upon the range used:

— Range 1: Three different dusts having completely different chemical compositions, e.g. natural, plastics, and dyestuff with p_{max} = 10 bar ± 2 bar and K_{max} = 200 m·bar·s^{-1} ± 40 m·bar·s^{-1};

— Range 2: Two different dusts with p_{max} = 10 bar ± 2 bar and K_{max} = 300 m·bar·s^{-1} ± 60 m·bar·s^{-1};

— Range 3: Two different dusts with p_{max} and K_{max} values depending on the intended use.

b) **Gas** as a fuel:

Where the K_{max} or the fundamental burning velocity of the gas or vapour is greater than that of propane, the performance of the suppression system should be evaluated using a test gas or vapour with equal or higher explosion characteristics (see EN 14034-1).

For turbulent conditions, the standard turbulence test method with turbulence varied by varying the ignition delay shall be used (see EN 26184-3).

c) **Hybrid mixtures** as a fuel:

For hybrid mixtures, the gas under turbulent conditions and the dust are investigated separately, and the worst case taken as the criterion for the efficacy of the suppression system (see also EN 26184-3).

In case where the suppression system is not used to suppress the explosion of all of the above mentioned fuels types in all explosibility ranges, then the validation of that suppression system can be limited to explosions within just the specific range(s).

The practical method of validating the nomograph equation for the tested suppression system with the two selected test volumes and the above fuel ranges is as follows:

1) Worst-case condition for explosion suppressability, in terms of the suppression system and the chosen test fuels, should be determined in the smaller of the two selected test volumes. These tests will determine the most difficult to suppress fuel in the fuel ranges, with the tested suppression system.

2) Most difficult to suppress fuels from each fuel range are then used in the larger of the two selected test volumes to complete validation of the nomograph equation for the tested suppression system.

Such design nomographs, and their equations for all fuels, should only be considered valid for the test enclosure volumes and the scope of the parameters under which they have been validated (fuel type, p_{max}, K_{max}, p_a, $p = p_{red,\,max}$). Interpolation between the volumes is allowable. An extrapolation is only allowed for the volumes under the following conditions (see Figure A.3):

— Minimum volume $V_{min} = 0{,}75 \times V_{min,\,test}$

— Maximum volume $V_{max} = 4{,}00 \times V_{max,\,test}$

For applications outside these limits expert advice should be sought. In some circumstances, extrapolation beyond the stated volume range limits is admissible, but only if it can be proven by unambiguous scientific interpretation that such an extrapolation is valid.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 94/9/EC of 23 March 1994

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 European 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 European 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 Directive 94/9/EC		**Clause(s)/sub-clause(s) of this EN**
General requirements	1.0	whole document
Principles of integrated explosion safety	1.0.1	whole document
Design considerations	1.0.2	6.4
Special checking and maintenance conditions	1.0.3	7, 8
Surrounding area conditions	1.0.4	6.3.5, 6.5.2
Marking	1.0.5	9
Instructions	1.0.6	8
Selection of materials	**1.1**	
Limits of operating	1.1.2	6
Design and construction	**1.2**	
Technological knowledge of explosion protection for safe	1.2.1	whole document
Requirements in respect of safety-related devices	**1.5**	
Independent function of safety devices of measurement and control. Fail safe principles for electric circuits. Safety related switches independent of software and command	1.5.1	7
Safety device failure	1.5.2	7.2, 7.3, 7.4
Emergency stop controls	1.5.3	7.2, 7.3, 7.4
Control and display units	1.5.4	7.4
Integration of safety requirements relating to the system	**1.6**	
Emergency shutdown system	1.6.2	5.4

Table ZA.1 (*concluded*)

Essential Requirements (ERs) of Directive 94/9/EC		**Clause(s)/sub-clause(s) of this EN**
Hazards arising from power failure	1.6.3	7.5
Hazards arising from connections	1.6.4	7.3
Requirements applicable to equipment in category 1 of equipment group II	**2.1**	
Explosive atmospheres caused by gases, vapours or hazes	2.1.1	whole European Standard
Explosive atmospheres caused by air/dust mixtures	2.1.2	whole European Standard
Supplementary requirements in respect of protective systems	**3**	
General requirements	3.0	whole European Standard
Dimension of protective systems safety level	3.0.1	6, 7
Protection systems operation in power failure situation	3.0.3	7.5
Failure of protective systems due to outside interference	3.0.4	7.2.3
Planning and design	**3.1**	
Pressure relief systems	3.1.5	6.5.1, 6.5.2
Explosion suppression systems	3.1.6	whole European Standard
Protective systems integrated into a circuit with an alarm	3.1.8	whole European Standard

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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