Explosion isolation systems

ICS 13.230

British Standards

National foreword

This British Standard is the UK implementation of EN 15089:2009.

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.

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Explosion isolation systems

Système d'isolation d'explosion

Explosions-Entkopplungssysteme

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Foreword

This document (EN 15089:2009) 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of an identical text or by endorsement, at the latest by September 2009, and conflicting national standards shall be withdrawn at the latest by September 2009.

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1 Scope

This European Standard describes the general requirements for explosion isolation systems. An explosion isolation system is a protective system, which prevents an explosion pressure wave and a flame or only a flame from propagating via connecting pipes or ducts into other parts of apparatus or plant areas. This European Standard specifies methods for evaluating the efficacy of the various explosion isolation systems, and methods for evaluating design tools for such explosion isolation systems when applying these in practice.

This European Standard also sets out the criteria for alternative test methods and interpretation means to validate the efficacy of explosion isolations.

It covers e.g.:

a) general requirements for the explosion isolation components;

b) evaluating the effectiveness of an explosion isolation system;

c) evaluating design tools for explosion isolation systems.

This European Standard is applicable only to the use of explosion isolation systems that are intended for avoiding explosion propagation between interconnected enclosures, in which an explosion may result as a consequence of ignition of an explosive mixtures e.g., dust-air mixtures, gas-(vapour-)air mixtures, dust-, gas-(vapour-)air mixtures and mists.

In general explosion isolation systems are not designed to prevent the transmission of fire or burning powder either of which can initiate an explosion in downstream plant items. It is necessary to take this situation into account in risk assessments.

This European Standard is only applicable for gas and dust explosions of chemically stable substances and mixtures of these (flame propagating at subsonic velocity).

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

i) chemically unstable substances that are liable to decompose;

ii) explosive substances;

iii) pyrotechnic substances.

This European Standard does not cover flame arresters. For these devices refer to EN 12874.

2 Normative references

The following reference 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 12874:2001, *Flame arresters – Performance requirements, test methods and limits for use*

EN 13237, *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 rate of 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*

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

EN 14373, *Explosion suppression systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13237, EN 14373 and the following apply.

3.1
indicating equipment
IE
explosion protection equipment, which monitors the explosion sensors/detectors and the explosion protection devices

3.2
closing time
time needed for closing an isolation device

3.3
closing time of the system
sum of the activation time of sensor, activation time of isolation device and closing time of the isolation device

3.4
design strength of enclosure p (plant strength)

3.4.1
explosion-pressure-resistant
property of vessels and equipment designed to withstand the expected explosion pressure without becoming permanently deformed

[EN 13237:2003, 3.31]

3.4.2
explosion-pressure-shock-resistant
property of vessels and equipment designed to withstand the expected explosion pressure without rupturing, but allowing permanent deformation

[EN 13237:2003, 3.32]

3.5
explosion
abrupt oxidation or decomposition reaction producing an increase in temperature, pressure, or in both simultaneously

[EN 13237:2003, 3.28]

3.6
explosion diverter
mechanical device, which will divert the explosion to a safe area

NOTE It prevents flame jet ignition and pressure piling but cannot effectively stop explosions from travelling.

3.7
explosion isolation system

3.7.1
active explosion isolation system
system which is designed to stop explosions from travelling through pipelines or limit the associated destructive effects of the explosion and is activated by detectors and a control and indicating equipment (CIE), which are parts of the system

3.7.2
passive explosion isolation system
system which is designed to stop explosions from travelling through pipelines or limit the associated destructive effects of the explosion and does not require detectors and a control and indicating equipment (CIE)

3.8
explosion isolation valve
fast acting valve able to stop explosions from travelling through pipelines

3.9
explosion proof interlocked double valve arrangement
device, which will act in closed position as isolation valve

3.10
explosion isolation flap
hinged door which is kept in open position by the air flow and closes by gravity when the air flow is interrupted

3.11
extinguishing barrier
system that is used to discharge suppressant agent into ductwork to isolate a flame and keep it from propagating to other process areas

3.12
extinguishing distance
needed distance behind an extinguishing barrier to guarantee a proper isolation of the flame of an explosion

3.13
flame arrester
device fitted to the opening of an enclosure or to the connecting pipework of a system of enclosures and whose intended function is to allow flow but prevent the transmission of flame

[EN 12874:2001, 3.1.1]

3.14
flame velocity
S_f
velocity of a flame front relative to a fixed reference point

3.15
installation distance

3.15.1
maximum installation distance
longest distance from the outlet of the enclosure with the potential explosion to the isolation system, which is limited by the explosion resistance of the isolation device or pipe but still guaranteeing a successful isolation

3.15.2
minimum installation distance
shortest distance from the outlet of the enclosure with the potential explosion to the isolation system guaranteeing a successful isolation

3.16
minimum ignition energy
MIE
lowest energy which is sufficient to effect ignition of the most easily ignitable explosive atmosphere under specified test conditions

[EN 13237:2003, 3.85]

3.17
minimum ignition temperature of an explosive atmosphere
MIT
ignition temperature of a combustible gas or of a vapour of a combustible liquid or the minimum ignition temperature of a dust cloud under specified test conditions

3.18
response time
time necessary for actuation of the system after a detection of an explosion

4 Explosion isolation systems

4.1 General

Explosion isolation is achieved by a protective system, which prevents an explosion pressure wave and a flame or only a flame from propagating via connecting pipes or ducts into other parts of apparatus or plant areas. Systems providing complete isolation by operation of the isolation device(s) prevent the propagation of the flame as well as pressure effects. Systems providing partial isolation only isolate the flame propagation. This distinction is important for practical application, because it is not necessary in all cases to achieve a complete isolation of flame and pressure. In some cases it is sufficient to achieve only flame isolation.

4.2 Isolation types

4.2.1 Passive isolation type

Passive isolation systems do not require the addition of detection and control and indicating equipment to function.

4.2.2 Active isolation type

Active isolation systems require detection and control and indicating equipment to function. Detection systems are systems usually based on optical or pressure sensors.

5 Requirements of explosion isolation components

5.1 General

To prevent an explosion occurring in a protected installation from spreading through a pipeline to another part of the installation, explosion isolation measures shall be implemented. Therefore isolation is normally installed into a pipe which connects two enclosures. It can also be located immediately after equipment e.g., a rotary valve underneath the cone of a filter or silo.

As explosions are generally propagated by flames and not by the pressure waves, it is especially important to detect, extinguish or block this flame front at an early stage, i.e. to isolate the explosion.

5.2 Detection devices

5.2.1 General

To initiate an active explosion isolation system one or more detectors are used to detect either an explosion pressure wave or flame of a propagating explosion. Each detector provides a signal to the CIE unit. It is important to locate the detector in its correct position, to ensure sufficient time for the isolation system to detect and activate the isolation device to stop the explosion.

NOTE In many cases it is favourable to use a combination of a pressure detector in the enclosure and an optical detector in the pipe, and they should be switched in an OR-type of logic for activating the isolation device.

5.2.2 Optical detection

Detection of a flame can be achieved using UV, IR or visible radiation sensors. It is important to mount the detector so that the angle of vision allows it to cover the full area to be monitored. The performance of an optical sensor will also be affected by any obstacles within its vision, which can be overcome by the introduction of more detectors. It shall be assured that the optical lenses of the sensors are kept clean, e.g. by air shields.

5.2.3 Pressure detection

Threshold detectors provide a signal when a pre-set overpressure – p_a (the systems activation pressure) – is exceeded.

Dynamic detectors have rate-of-pressure rise triggering points and may include additional pressure threshold triggering points. 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 geometry.

5.2.4 Other actuation

Bursting discs, vent panels or explosion doors can be fitted with switches or break wires, which actuate an isolation system.

5.3 Indicating equipment (IE) and control and indicating equipment (CIE)

5.3.1 General

Whether control and indicating equipment (CIE) or so-called indicating equipment (IE) is to be used on an isolation device/system is dependant on the type of protection device. IE will only indicate the status of the device; CIE will actively control the operation of the protection device and provide status indication of the device and is therefore critical for the correct functioning of the device/system.

5.3.2 Indicating equipment

Indicating equipment (IE) monitors and provides the status indication only of the isolation device/system.

5.3.3 Control and indicating equipment

Control and indicating equipment (CIE) records and monitors the signals transmitted by the system detectors. Dependent on configuration, by interrogation and interpretation of the detector data the CIE selectively controls the actuation of protection device, process equipment shut down (direct or indirect) and all audible and visual alarms. System internal monitoring gives 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 implemented.

5.4 Safety integrity of control and indicating equipment (CIE)

5.4.1 General

The following requirements are intended to ensure the safety integrity for active systems.

5.4.2 Measures to avoid and control systematic faults

Systematic and transparent system analyses shall be made in all design stages to prevent potential defects. This methodical and comprehensible design approach ensures a clearly specified level of functional safety for any kind of product (see e.g. EN 15233).

5.4.3 Control of electric connections

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

a) detector(s);

b) protection isolation device(s).

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 explosion isolation system shall provide a fail-safe means to place the installation into a safe condition.

5.4.4 Indicators and messages on CIE

The activation and fault messages shall be shown and indicated at the CIE indicating its origin and nature. In case of activation of the explosion isolation device/system, the CIE shall provide a means to commence an emergency stop procedure of the protected installation.

5.4.5 Energy supply

For the energy supply of the CIE two independent energy sources shall be available. 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 hours. The power supply shall be independent and suitably protected, and shall not be de-activated by an emergency switch. After loss of the back-up power supply the CIE shall activate an emergency stop procedure of the protected installation.

5.5 Explosion isolation devices

5.5.1 General

The following is a list of explosion isolation devices.

The different objectives to be addressed can be summarized as follows:

Flame (F): objective is to stop flame propagation. The protected area is defined as the point beyond the isolation device, opposite to the ignition source.

Pressure (P): objective is to stop the pressure wave from travelling beyond the isolation device.

The explosion resistance of the equipment of the isolation device shall meet the expected pressure according to the intended use.

5.5.2 Explosion protection valve (active or passive) – F&P

To prevent flame and pressure propagation in pipes and ducts, valves or gates may be used which close in a sufficient short time. The closure can be affected by means of an actuating mechanism initiated by a pressure detector or a flame detector or a combination thereof or by the explosion overpressure itself.

NOTE Explosion protection valves need not be gas tight.

5.5.3 Extinguishing barrier (active) – F

The extinguishing medium is dispersed into the pipeline and the flame extinguished. The extinguishing medium shall be suitable for the specific explosive atmosphere.

5.5.4 Rotary valve (passive) – F

The effectiveness of the rotary valve against flame propagation and its explosion resistance shall be proven. Upon detection of an explosion the rotary valve shall be stopped automatically and instantaneously.

5.5.5 Explosion proof interlocked double valve arrangement (passive) – F&P

Enclosures that are explosion-resistant can be protected by at least two explosion proof process valves in series. By means of proper control, it shall be assured that at least one of the valves is always closed. Upon detection of an explosion the explosion proof interlocked double valve arrangement shall be stopped automatically and instantaneously.

5.5.6 Diverters, explosion isolation flaps and flame arresters

The isolation systems diverters, explosion isolation flaps and flame arresters are covered in separate standards (see upcoming diverters standard, explosion isolation flap standard and EN 12874).

6 System design

6.1 General

It is very important for explosion isolation systems that a detailed analysis of all relevant characteristics and conditions is made. This analysis shall include at least the following:

a) Specification of the physical characteristics of the connected equipment where the isolation device shall be installed, e.g.:

   1) type of connected equipment (pipe, belt, screw etc),

   2) strength of connected equipment,

   3) layout of connected equipment including length, bends, junctions,

   4) cross sections including changes in cross sections,

   5) presence of internal obstructions;

b) Specification of the relevant process conditions:

   1) indoors/outdoors,

   2) area classification (zones),

3) max/min temperature,

4) min/max pressure,

5) type of conveyed product: bulk, dense phase conveying, lean air/dust mixtures, gaseous mixtures,

6) flow rates and directions,

7) specific product properties (such as sticky material, moisture content, abrasive, corrosive, toxic, tendency for product built-up);

c) Specification of the explosion characteristics of the products involved, taking into account the influence of the process conditions for example pressure, temperature, etc.

d) Definition of the protection methods of the equipment to which the transportation system/pipe is interconnected;

e) Identification of potential ignition source location(s);

f) Definition of the protection objectives:

1) stop flame and burning particles from an explosion,

2) stop pressure wave;

Based upon the above elements, together with the specifications of the isolation system(s), the appropriate explosion isolation system can be chosen.

The distance between the protected equipment and the isolation system shall be such that:

i) the isolation system has operated before arrival of the pressure wave and/or flame;

ii) inadmissible flame accelerations leading to unacceptable high pressures are prevented.

6.2 Combination of explosion isolation systems with other explosion protection techniques

6.2.1 Explosion resistant design for the maximum explosion pressure – isolation

Because the explosion is allowed to run full course, high pressure and high temperatures will remain in the contained system for a long period of time. Therefore, the isolation system shall be able to withstand:

a) the highest pressures up to the location of isolation using explosion resistant design,

b) exposure to heat,

and the system’s integrity to be maintained during this period.

6.2.2 Venting – isolation

The isolation system shall be able to withstand:

a) the highest pressures up to the location of isolation using venting,

b) exposure to heat where applicable,

and the system’s integrity to be maintained during this period.

6.2.3 Suppression – isolation

Usually, the detection and the CIE of an explosion suppression system are at the same time used to trigger active isolation systems. If not, precautions shall be taken to activate the isolation system appropriately.

7 Experimental testing of the efficacy of an explosion isolation system

7.1 General

As a minimum, the following information shall be present prior to testing:

a) list of all used components,

b) process conditions (see 6.1),

c) explosive atmosphere type (K_{max}, p_{max}, S_u, MIT, MIE, MESG, metal dust yes/no),

d) Explosion resistance of the isolation device,

e) $p_{red,max}$ in the connected enclosure,

f) volume range of the connected enclosure,

g) safety function of the isolation device (pressure, flame or both),

h) diameter of the connection of the system to be isolated,

i) category of the components,

j) type of explosion detector,

k) type of explosion sensor,

l) location of the sensor, detector,

m) trigger point of the explosion isolation device,

n) location of the explosion isolation device.

7.2 Test Modules

7.2.1 General

The experimental testing consists of three different modules:

Module A: Explosion resistance testing

Module B: Flame transmission test

Module C: Functional testing.

The generation and the ignition of the explosive atmosphere are described in EN 14034-1 and EN 14034-2 for dusts and EN 13673-1 and EN 13673-2 for gases and vapours. However deviations from these standardized methods are necessary depending on the Module. These deviations have been specified in each of the Modules.

For experimental testing the efficacy of an explosion isolation system the following modules shall be applied for each explosion isolation device:

Table 1 — Type of modules as a function of type of isolation device

Type of isolation device	Type of Modules		
	Module A: Explosion resistance testing	Module B: Flame transmission test	Module C: Functional testing
Passive isolation valves	X	X	X
Explosion proof interlocked double valve arrangement	X	X	X
Active isolation valves	X	X	X
Extinguishing barriers	–	–	X
Rotary valves	X	X	X

7.2.2 Module A: Explosion resistance testing

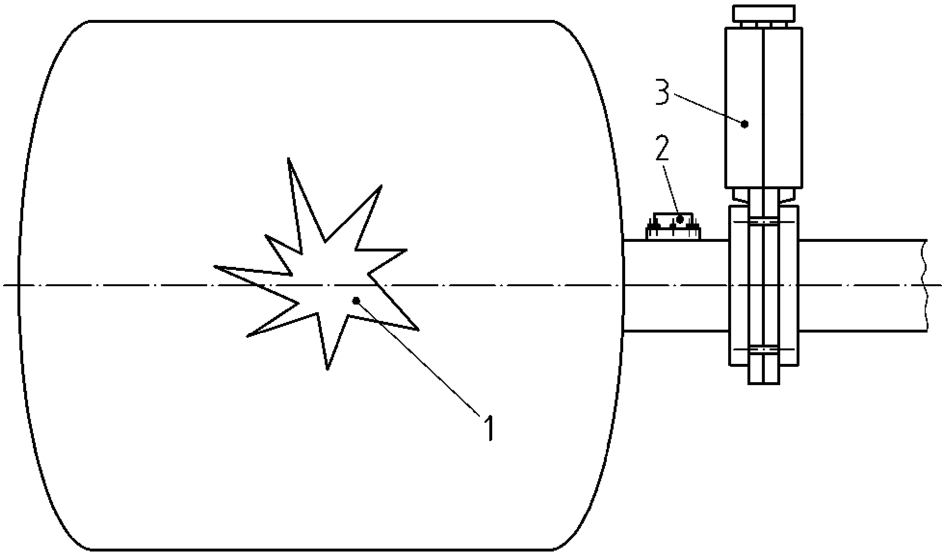
If an explosion resistance testing is necessary the following shall be used:

a) Test arrangement: Install the device according to Figure 1. The explosive atmosphere can be of any type, provided the pressure generated is sufficient to test the device‘s required explosion resistance.

b) Test assignment/records: The maximum allowable explosion overpressure to be specified for each individual device; recorded test pressure at least 10 % above design pressure or the average of three tests to be 100 %.

c) Number of tests: 1 for each size as a minimum.

d) Evaluation: Permanent deformation is allowed provided the isolation device does not fail in its function and will not give rise to dangerous effects to the surrounding.



Key

1 Location of ignition source (Z1)
2 Pressure transducer (Pt)
3 isolation device

Figure 1 — Test arrangement for explosion resistance testing and flame transmission testing at high pressure conditions

7.2.3 Module B: Flame transmission test

The testing of the isolation device according to Figure 1 or according to Figure 2 is specified by the intended use.

a) Test according to Figure 1 (High pressure conditions):

It shall be proven that the isolation device when exposed to high pressures and a flame simultaneously will stop a flame from propagating.

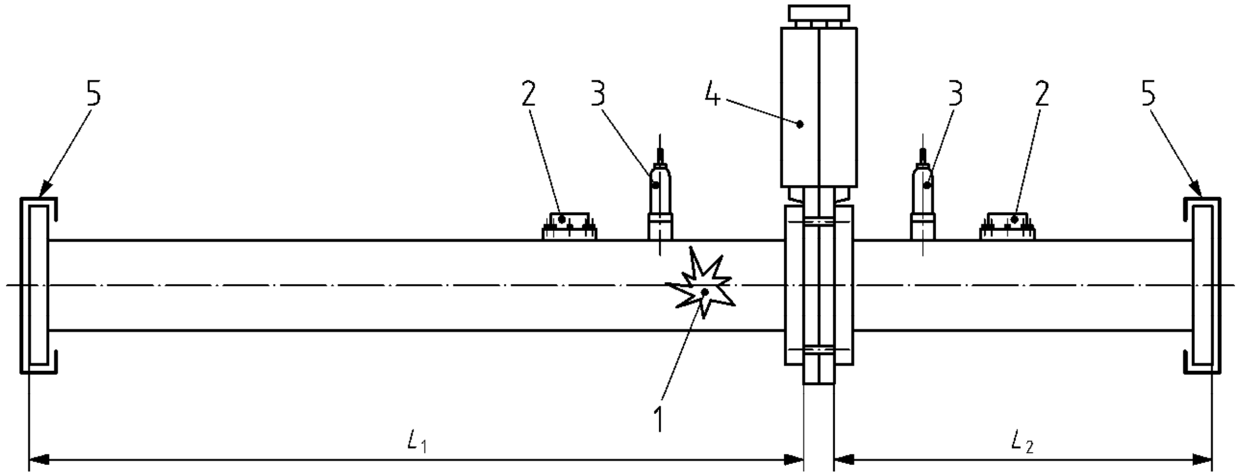
1) Testing:

   i) Test arrangement: See 7.2.2.

   ii) Test assignment/records: The presence of flame outside of the device (enclosure) shall be recorded.

   iii) Number of tests: Minimum 2 per device; smallest and largest size for devices constructed in the same way (with respect to the safe gap, sealing, thickness of the material etc.). If the number of sizes constructed in the same way exceed 5, an additional testing of a size (middle of range) is needed.

   iv) Evaluation: No explosion flame detection recorded outside of the enclosure at the position of the explosion isolation device. The explosion isolation device can be applied for any explosive atmosphere having a maximum experimental safe gap (MESG) equal to or larger than the explosive atmosphere used for testing.



Key

1	location of ignition source (Z1)	5	Foil cover
2	Pressure transducer (Pt)		
3	Flame transducer (Ft)	L_1	Length of pipe: $L_1 \geq 20 \times$ DN
4	isolation device	L_2	Length of pipe: $L_2 \geq 1$ m

Figure 2 — Test arrangement for flame transmission test

b) Test according to Figure 2 (Low pressure conditions):

It shall be proven that the isolation device when tested in a long pipe will stop a flame from propagating along the ductwork.

1) Testing:

i) Test arrangement: Device mounted in standard position between flanges of a long pipe (see Figure 2). Device is set in the closed position; ignition source close to the device (about one diameter). The pipe is filled with appropriate fuel air-mixture (typically propane) on both sides of the device. A foil covers both ends of the pipe.

ii) Test assignment/records: The presence of flame before and after the device shall be recorded. It is recommended to measure also the pressure before and after the device.

iii) Number of tests: Minimum 2 per device; smallest and largest size for devices constructed in the same way (with respect to the safe gap, sealing, thickness of the material etc.). If the number of sizes constructed in the same way exceeds 5, an additional testing of a size (middle of range) is needed.

iv) Evaluation: No explosion flame detection recorded on the isolated side of the explosion isolation device. The explosion isolation can be applied for any explosive atmosphere having a maximum experimental safe gap (MESG) equal to or larger than the explosive atmosphere used for testing.

7.2.4 Module C: Functional testing

7.2.4.1 General

The main objective of the functional testing is the determination/verification of the minimum/maximum installation distance of the isolation device dependent on the method of the detection and to assess the efficacy of the device/system as an explosion isolation device/system according to the intended use as specified by the manufacturer.

7.2.4.2 Passive explosion protection valve

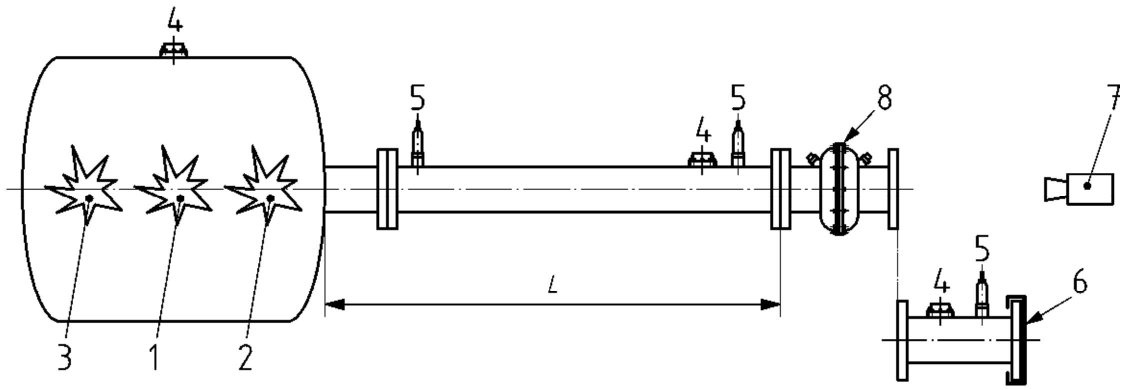
a) Aim of the functional testing

The test will assess the efficacy of the device and the minimum and maximum installation distance. This shall be determined by varying the location of the ignition source in the test enclosure and other influencing parameters e.g., enclosure volume, maximum explosion overpressure in the enclosure according to the intended use.

b) Test set-up

The test rig consisting of a compact enclosure (with a length (height) to diameter ratio of less than 2) in combination with a pipe (see Figure 3) shall reflect the specified intended use (orientation of the isolation valve, presence of restrictions, elbows, volume of enclosure). Depending on the intended use, the enclosure is explosion proof, vented or suppressed. The generation of the explosion characteristics in the test enclosure shall reflect the explosion characteristics required.

For determination of flame break-through a flame sensor (only possible when a pipe is connected to the test set-up downstream of the isolation device) or alternatively cameras can be used. The length of the pipe downstream of the isolation device if used shall be at least 1 m or at least 2 times the diameter.



Key

1 Location of ignition source, *Z1*, 50%
2 Location of ignition source, *Z2*, 10%
3 Location of ignition source, *Z3*, 90%
4 Pressure transducer (Pt)
5 Flame transducer (Ft)
6 Foil cover with low opening pressure (< 0,1 bar)
7 camera
8 passive explosion protection valve
L Installation distance

Figure 3 — Test arrangement for functional testing for passive explosion protection valves

c) Measuring technique

The following parameters shall be measured:

1) Pressure, minimum one transducer (Pt) in the enclosure and one directly in front of the explosion isolation device and one after, in case a pipe downstream of the explosion isolation device is used. This transducer shall be mounted with a maximum distance of 100 mm from the connecting flange.

2) Flame, minimum one detector (Ft) at the beginning of the pipe with a maximum distance of 100 mm from the connecting flange and one in front and after the explosion isolation device if a pipe downstream is used with a maximum distance of 100 mm from the connecting flange.

3) Alternatively, two cameras can be used instead of a flame detector in the downstream pipe.

d) Execution of test

1) Explosive atmospheres

Dust: The highest K_{max} as specified by the intended use and a K_{max} with a value of 30 % of the highest K_{max}, but minimum K_{max} = 50 bar · m · s^{-1}.

Gas: The highest K_{max} as specified by the intended use and a K_{max} with a value of 30 % of the highest K_{max}, but minimum K_{max} = 50 bar · m · s^{-1}.

Hybrid mixtures: The highest K_{max} as specified by the intended use and a K_{max} with a value of 30 % of the highest K_{max}, but minimum K_{max} = 50 bar · m · s^{-1}.

2) Location of the explosive atmospheres

For gases the explosive atmosphere shall extend throughout the enclosure and the entire pipe. This accounts also for dusts unless:

$$L < 0{,}5 \cdot (D_B / D_R)^2 \cdot L_B$$

where

L is the length of the pipe between the enclosure and the isolation device in metres (m);

D_B is the diameter of the closed enclosure in metres (m);

D_R is the diameter of the pipe between the enclosure and the isolation device in metres (m);

L_B is the length of the enclosure in metres (m).

For these geometrical conditions it is sufficient to generate an explosive dust atmosphere in the enclosure only. The dust cloud needs to be generated in the pipe if the ignition is effected close to the pipe entry, this in spite of agreeing to the relationship mentioned above.

One initial test shall be carried out (with valve open) to ensure that the extend of the explosive atmosphere is sufficient to guarantee that the flame passes the valve for all ignition source positions used.

3) Determination of the minimum and maximum installation distance

Table 2 shows all test conditions which shall be used for verification/determination of the minimum installation distances.

The higher value found for the test conditions to be used for verification/determination of the minimum installation distance shall be used as the minimum installation distance.

The maximum installation distance shall be determined by varying the distance from the enclosure to the isolation device until the pressures are equal to the resistance of the device determined under Module A. The tests shall be performed with an explosive atmosphere with K_{max} and location of ignition source far from the pipe inlet $Z3$ (90 %).

Table 2 — Location of ignition source for verification/determination of the minimum installation distance

Ignition source location in enclosure	K_{max} (p_{max} or $p_{red,max}$)	30 % of K_{max} or minimum 50 bar·m·s^{-1} (p_{max} or $p_{red,max}$)
close to pipe ($Z2$)	–	X
centre ($Z1$)	–	–
opposite to pipe ($Z3$)	–	X
p_{max} for design for the maximum explosion overpressure $p_{red,max}$ for venting or suppression NOTE The ignition source locations $Z1$, $Z2$ and $Z3$ are all located on the axis trough the connected pipeline. $Z1$ is located at a distance of 50 % of the distance between pipe entrance and opposite side of the test vessel from the pipe entrance. $Z2$ is located at a distance of 10 % of the distance between pipe entrance and opposite side of the test vessel from the pipe entrance and $Z3$ is located at a distance of 90 % of the distance between pipe entrance and opposite side of the test vessel from the pipe entrance.		

A minimum of two tests (see evaluation) are required for each test condition.

4) Evaluation

The test is successful if there is no occurrence of sparks/flames on the non-protected side of the isolation device.

The following shall be reported regarding the intended use:

a) maximum pressure on the protected side of the isolation device,

b) maximum of installation distance with reference to the strength of the device,

c) minimum of installation distance,

d) minimum conditions causing closing of the isolation device.

7.2.4.3 Active isolation valves

a) Aim of the functional testing

The test will assess the efficacy of the device and the minimum and maximum installation distance. This shall be determined by varying the location of the ignition source in the test enclosure and other influencing parameters e.g., enclosure volume, maximum reduced explosion overpressure in the enclosure, type of detector or sensor used or combinations of detectors and sensors, activation pressure, sensitivity of flame detector, all according to the intended use.

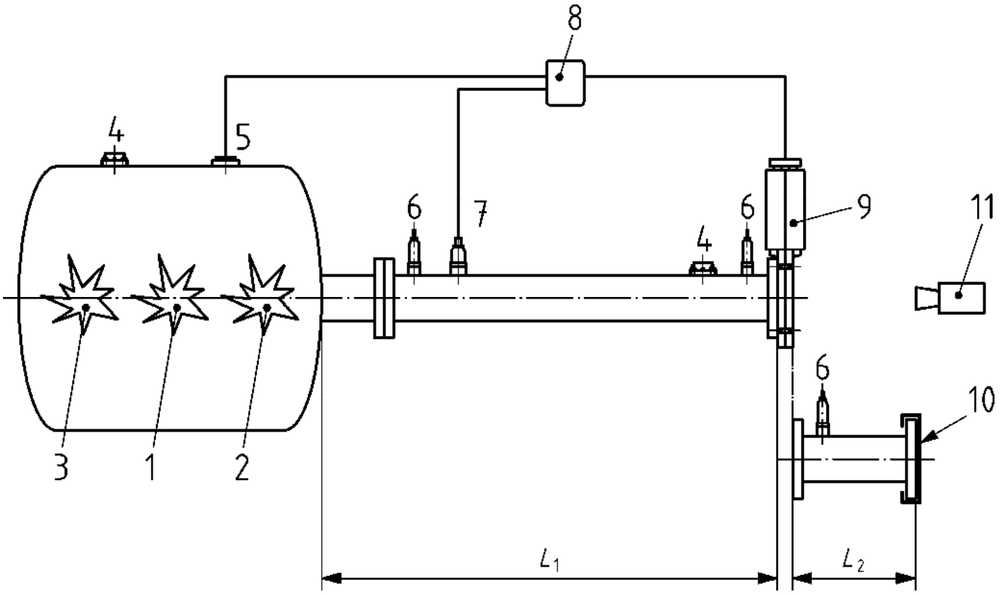
b) Test set-up

The test rig consisting of a compact enclosure (with a length (height) to diameter ratio less than 2) in combination with a pipe (see Figure 4) shall reflect the specified intended use (orientation of the isolation valve, presence of restrictions, elbows, volume of enclosure). Depending on the intended use, the enclosure is explosion proof, vented or suppressed. The generation of the explosion characteristics in the test enclosure shall reflect the explosibility characteristics required. For determination of flame break-through a flame sensor (only possible when a pipe is connected to the test set-up downstream of the isolation device) or alternatively cameras shall be used. If used the length of the pipe downstream of the isolation device shall be at least 1 m or at least 2 times the diameter.

The following recommendations are given in respect of detector location for triggering the isolation device:

1) For pressure the detector or sensor (Tp) is located on the interconnected enclosure, and not on pipeline;

2) For flame the detector or sensor (Tf) is located on the interconnected duct within 2 duct diameters from the duct entry.



Key

1	Location of ignition source, *Z1*, 50%	8	Control and indication equipment/ indication equipment (CIE/IE)
2	Location of ignition source, *Z2*, 10%	9	Isolation device
3	Location of ignition source, *Z3*, 90%	10	Foil cover
4	Pressure transducer (Pt)	11	Camera
5	Transducer pressure (Tp)	L_1	Length of pipe
6	Flame transducer (Ft)	L_2	Length of pipe, $L_2 \geq 1$ m, $L_2 \geq 2 \times$ DN
7	Transducer flame (Tf)		

Figure 4 — Test arrangement for functional testing for active isolation valves

c) Measuring technique

At least the following parameters shall be measured:

1) Pressure, minimum one transducer (Pt) in the enclosure and one directly in front of the explosion isolation device with a maximum distance of 100 mm from the connecting flange.

2) Flame, minimum one transducer (Ft) at the beginning of the pipe with a maximum distance of 100 mm from the connecting flange and one in front of and one direct after the explosion isolation device with a maximum distance of 100 mm from the connecting flange.

3) Closing time, i.e. the closing time of the full system shall be determined (period between moment of detection and the complete closing of the shut-off valve).

d) Execution of test

1) Explosive atmospheres

Dust: The highest K_{max} as specified by the intended use and a K_{max} with a value of 30 % of the highest K_{max}, but minimum K_{max} = 50 bar · m · s^{-1}.

Gas: The highest K_{max} as specified by the intended use and a K_{max} with a value of 30 % of the highest K_{max}, but minimum K_{max} = 50 bar · m · s^{-1}.

Hybrid mixtures: The highest K_{max} as specified by the intended use and a K_{max} with a value of 30 % of the highest K_{max}, but minimum K_{max} = 50 bar · m · s^{-1}.

2) Location of the explosive atmospheres

For gases the explosive atmosphere shall extend throughout the enclosure and the entire pipe.

This accounts also for dusts unless:

$$L < 0{,}5 \cdot (D_B / D_R)^2 \cdot L_B$$

where

L is the length of the pipe between the enclosure and the isolation device in metres (m);

D_B is the diameter of the closed enclosure in metres (m);

D_R is the diameter of the pipe between the enclosure and the isolation device in metres (m);

L_B is the length of the enclosure in metres (m).

For these geometrical conditions it is sufficient to generate an explosive atmosphere in the enclosure only. The dust cloud needs to be generated in the pipe if the ignition is effected close to the pipe entry, this in spite of agreeing to the relationship mentioned above.

During the execution of the tests it shall however be made sure that the flame will pass the valve if it is kept open.

3) Determination of the minimum and maximum installation distance

Table 3 shows all test conditions, which shall be used for verification/determination of the minimum installation distances for either pressure detection or flame detection.

The higher value found for the test conditions to be used for verification/determination of the minimum installation distance shall be used as the minimum installation distance.

Table 3 — Location of ignition source to be used for verification/determination of the minimum installation distance

Ignition source location in the enclosure	K_{max} (p_{max} or $p_{red,max}$)		30 % of K_{max} or minimum 50 bar·m·s^{-1} (p_{max} or $p_{red,max}$)	
	Pressure sensor only	Optical sensor only	Pressure sensor only	Optical sensor only
close to pipe ($Z2$)	X	–	X	–
centre ($Z1$)	X	X	X	–
opposite to pipe ($Z3$)	–	X	–	–

p_{max} for design for the maximum explosion overpressure
$p_{red,max}$ for venting or suppression

NOTE The ignition source locations $Z1$, $Z2$ and $Z3$ are all located on the axis trough the connected pipeline. $Z1$ is located at a distance of 50% of the distance between pipe entrance and opposite side of the test vessel from the pipe entrance. $Z2$ is located at a distance of 10% of the distance between pipe entrance and opposite side of the test vessel from the pipe entrance and $Z3$ is located at a distance of 90% of the distance between pipe entrance and opposite side of the test vessel from the pipe entrance.

If a combination of optical and pressure detection is applied, the minimum installation distance can be constructed as follows:

i. determination of the minimum installation distance according to Table 3 for a pressure sensor only (highest value of the four installation distances which were found for the ignition locations $Z1$ and $Z2$);

ii. determination of the minimum installation distance according to Table 3 for an optical sensor only (higher value of the installation distances which were found for the ignition locations $Z1$ and $Z3$);

iii. the smallest of these two distances is the minimum installation distance.

To get full advantage of using a combination of the two types of detectors additional tests are necessary for ignition locations in between $Z1$ and $Z2$ or $Z1$ and $Z3$ (depending on the respective values found for $Z1$, $Z2$, $Z3$ for each of the two sensor types and range of applications according to the intended use), see A.2 with Figure A.2.

The maximum installation distance shall be determined by varying the distance from the enclosure to isolation device until the pressures are equal to the resistance of the device determined under Module A. The tests shall be performed with an explosive atmosphere with K_{max} and location of ignition source far from the pipe inlet $Z3$ (90 %).

A minimum of two tests (see evaluation) are required for each test condition.

Minimum and maximum installation distances obtained from tests where the enclosure has been protected by designing for the maximum explosion overpressure or by explosion venting can be applied directly for enclosures protected by explosion suppression.

4) Setting of detectors

The activation pressure shall be varied across the whole range of pressures defined in the intended use. Typically the two extreme values of the whole range are tested.

The sensitivity of optical sensors shall be varied across the whole range of sensitivities defined in the intended use. Typically the two extreme values of the whole range are tested.

5) Evaluation

The test is successful if there is no occurrence of sparks/flames behind the point of isolation device.

At least the following shall be reported regarding the intended use:

a) maximum pressure in front of the isolation device,

b) maximum of installation distance with reference to the strength of the device,

c) minimum of installation distance,

d) range of settings of detectors,

e) closing time of the system.

7.2.4.4 Extinguishing barrier

a) Aim of the functional testing

The test will assess the efficacy of the device and the minimum and maximum installation distance as well as the extinguishing distance, i.e., the needed distance behind an extinguishing barrier to ensure a proper isolation of the flame of an explosion.

This shall be determined by varying the location of the ignition source in the test enclosure and other influencing parameters e.g., enclosure volume, maximum reduced explosion pressure in the enclosure, type of detector or sensor used all according to the intended use.

When applying suppression only ignition source positions in the vicinity of the pipe inlet are important (*Z2*).

When applying explosion venting or design for the maximum explosion overpressure all ignition source positions shall be taken into account. To assure that the extinguishing barrier is working properly it shall be active (supplying sufficient suppressant to stop the explosion) during the explosion event in the enclosure also when ignition is effected far from the inlet and the extinguishing barrier is activated early during the event.

If an extinguishing barrier system is applied for an explosive atmosphere with unknown suppressability characteristics (due to chemical composition or extreme process conditions) it shall be tested (see EN 14373). If the explosibility characteristics of the explosive atmosphere are not known they shall be determined.

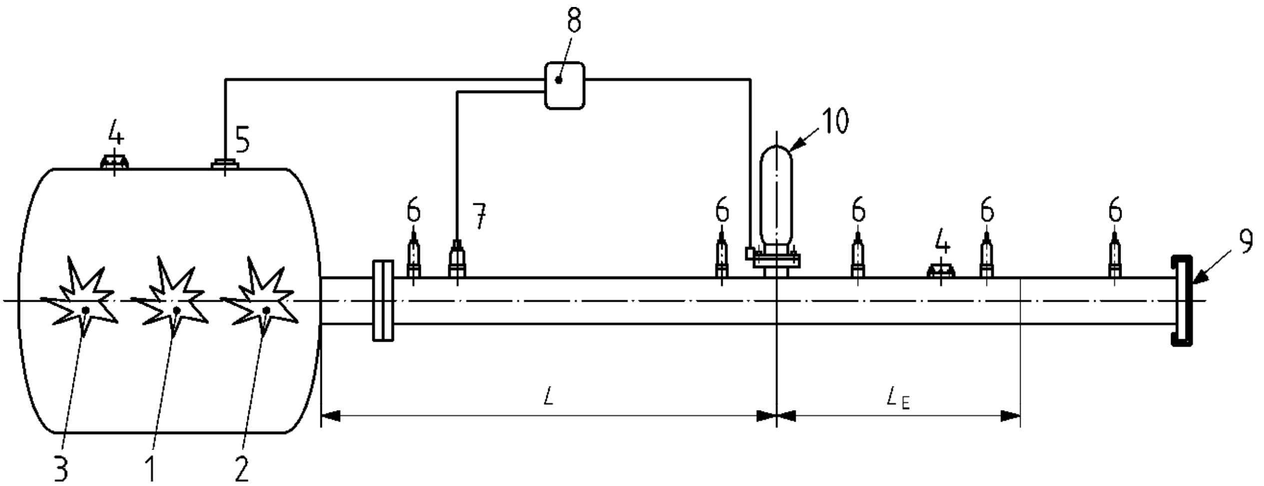
b) Test set-up

The test rig consisting of a compact enclosure (with a length (height) to diameter ratio less than 2) in combination with a pipe (see Figure 5) shall reflect the specified intended use (orientation of the isolation valve, presence of restrictions, elbows, volume of enclosure). Depending on the intended use, the enclosure is explosion proof, vented or suppressed. The generation of the explosion characteristics in the test enclosure shall reflect the explosibility characteristics required.

The following recommendations are given in respect of detector location for triggering the isolation device:

1) For pressure the detector or sensor (Tp) is located on the interconnected enclosure, and not on the pipeline;

2) For flame the detector or sensor (Tf) is located on the interconnected duct within 2 diameters of the duct entry.



Key

1	Location of ignition source, *Z1*, 50 %	8	Control and indication equipment/ indication equipment (CIE/IE)
2	Location of ignition source, *Z2*, 10 %	9	Foil cover
3	Location of ignition source, *Z3*, 90 %	10	isolation device
4	Pressure transducer (Pt)	L	Length of pipe between the enclosure and the isolation device
5	Transducer pressure (Tp)	L_E	Extinguishing distance
6	Flame transducer (Ft)		
7	Transducer flame (Tf)		

Figure 5 — Test arrangement for functional testing for extinguishing barriers

c) Measuring techniques

The following parameters shall be measured:

1) Pressure, minimum one transducer (Pt) in the enclosure and one behind the extinguishing barrier;

2) Flame, minimum one transducer (Ft) at the beginning of the pipe with a maximum distance of 100 mm from the connecting flange and one in front of and at least two after the extinguishing barrier (the latter to measure the extinguishing distance, position of transducers to be varied).

d) Execution of tests

1) Explosive atmospheres

Dust: The highest K_{max} as specified by the intended use and a K_{max} with a value of 30 % of the highest K_{max}, but minimum K_{max} = 50 bar · m · s^{-1}.

Gas: The highest K_{max} as specified by the intended use and a K_{max} with a value of 30 % of the highest K_{max}, but minimum K_{max} = 50 bar · m · s^{-1}.

Hybrid mixtures: The highest K_{max} as specified by the intended use and a K_{max} with a value of 30 % of the highest K_{max}, but minimum K_{max} = 50 bar · m · s^{-1}.

2) Location of the explosive atmospheres

The explosive atmosphere shall extend from the closed enclosure into the entire pipe.

3) Determination of the minimum and maximum installation distance

Table 4 shows all test conditions, which shall be used for verification/determination of the minimum installation distance using a flame detector only. For applications where a pressure sensor is used only Table 3 shall be used for determination of the minimum installation distance. For a combination of flame and pressure detection the test conditions described in 7.2.4.3 d) shall be used.

The higher value found for the test conditions to be used for verification/determination of the minimum installation distance shall be used as the minimum installation distance.

Table 4 — Location of ignition source to be used for verification/determination of the minimum installation distance using flame detection only

Ignition source location in the enclosure	K_{max} (p_{max} or $p_{red,max}$)		30 % of K_{max} or minimum 50 bar·m·s^{-1} (p_{max} or $p_{red,max}$)	
	Venting/Design for max. expl. overpressure	Suppression	Venting/ Design for max. expl. overpressure	Suppression
close to pipe (*Z2*)	–	X	–	X
centre (*Z1*)	X	X	X	–
opposite to pipe (*Z3*)	X	–	X	–

p_{max} for design for the maximum explosion overpressure
$p_{red,max}$ for venting or suppression

NOTE The ignition source locations *Z1*, *Z2* and *Z3* are all located on the axis trough the connected pipeline. *Z1* is located at a distance of 50 % of the distance between pipe entrance and opposite side of the test vessel from the pipe entrance. *Z2* is located at a distance of 10 % of the distance between pipe entrance and opposite side of the test vessel from the pipe entrance and *Z3* is located at a distance of 90 % of the distance between pipe entrance and opposite side of the test vessel from the pipe entrance.

A minimum of two tests (see evaluation) are required for each test condition.

The maximum installation distance shall be determined by varying the distance from the enclosure to extinguishing barrier and the amount of suppressant until the system fails. The maximum installation distance will be dependent on the amount of suppressant. The tests shall be performed with an explosive atmosphere with K_{max} and location of ignition source far from the pipe inlet $Z3$ (90 %).

4) Setting of detectors

The sensitivity of optical sensors shall be varied across the whole range of sensitivities defined in the intended use. Typically the two extreme values of the whole range are tested.

When using a pressure sensor the activation pressure shall be varied across the whole range of pressures defined in the intended use. Typically the two extreme values of the whole range are tested.

5) Evaluation

The test is successful if there is no occurrence of sparks/flames behind the point of isolation device.

At least the following shall be reported regarding the intended use:

a) pressure in front of and behind the isolation device;

b) applicability of suppressant;

c) minimum sectional density of suppressant (kg/m²);

d) maximum installation distance (depending on the pressure resistance);

e) minimum installation distance;

f) minimum extinguishing distance behind the extinguishing barrier (depending on the flame velocity);

g) activation time of sensor;

h) activation time of CIE;

i) range of settings of detectors;

j) time of deployment of extinguishing barrier.

7.2.4.5 Rotary valve (dust or hybrid mixtures)

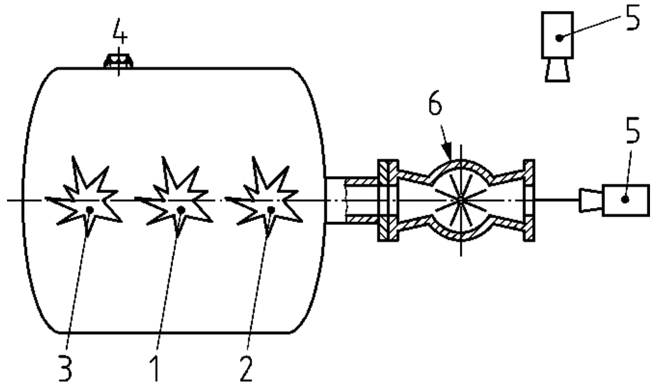
a) Aim of the functional testing

The range of the efficacy of the rotary valve shall be determined by varying the location of the ignition source in the test enclosure and other influencing parameters e.g., ignitability of the explosive atmosphere (MIE, MIT), pressure in the enclosure all according to the intended use.

b) Test set-up

The test rig (see Figure 6) shall reflect the specified intended use (presence of restrictions, length and geometry of connecting pipe, etc.) A compact enclosure (with a length (height) to diameter ratio less than 2) shall be used as a test vessel. Depending on the intended use, the test vessel is explosion resistant for the maximum explosion overpressure, vented or suppressed. The rotary valve shall be operated in the desired conveying direction. The cross section of the connection of the rotary valve shall not be reduced.

NOTE The functionality of stopping the rotary valve and associated alarm should be tested separately and is not considered to be part of this European Standard.



Key

1 Location of ignition source, *Z1*, 50%
2 Location of ignition source, *Z2*, 10%
3 Location of ignition source, *Z3*, 90%
4 Pressure transducer (Pt)
5 Camera
6 Rotary valve

Figure 6 — Test arrangement for functional testing for rotary valves

c) Measuring technique

The following parameters shall be measured:

1) Pressure, at least one transducer (Pt) in the enclosure,

2) 2 suitable cameras shall be used for spark/flame detection.

d) Execution of tests

1) Explosive atmospheres

An explosive atmosphere with minimum ignition energy and minimum ignition temperature according to the intended use shall be used. The mixture in the test vessel has to be created and ignited according to the definition in EN 14034-series.

2) Location of the ignition source

The flame has to arrive at the rotary valve. Varying the dust concentration from values slightly above the lower explosion limit up to a concentration value above the "optimal concentration" for maximum explosion overpressure and maximum pressure rise ignition shall be effected at first in the centre *Z1* of the test vessel. At the "optimal concentration" the ignition point *Z2* shall be used, close to the rotary valve. Also at ignition point *Z3* (longest possible distance from the rotary valve) tests shall be carried out at the "optimal concentration". At this ignition point also the ignition time delay will be varied from the value given in EN 14034-series up to 1,5 s. By increasing the initial pressure of the explosive mixture in the test vessel the explosion overpressure shall be increased up to the necessary maximum explosion test pressure of the rotary valve. The tests shall be carried out with the rotor not being in operation and with a rotor at maximum rotational speed for the intended use. The conveying direction shall be chosen in accordance with the intended use.

3) Evaluation

The test is successful if there is no occurrence of sparks/flames behind the rotary valve. The following shall be reported regarding the intended use:

i) explosion resistance of the isolation device,

ii) minimum gap length,

iii) maximum gap width.

NOTE The functionality of stopping the rotary valve and associated alarm should be tested separately and is not considered to be part of this European Standard.

7.2.4.6 Explosive proof interlocked double valve arrangement

The functional safety of the control system, which secures that at least one process valve is closed, shall be demonstrated. See e.g. EN 61508-series and EN ISO 13849-1.

NOTE The functionality of stopping the explosion proof interlocked double valve arrangement in combination with the alarm in case of an explosion should be tested separately. This is not a part of this European Standard (see EN ISO 13850).

7.3 Testing Report

The test report shall include the following information:

a) Product characteristics:

1) nature of the sample,
2) sample pre-treatment,
3) characteristics data for particle size distribution and moisture content,
4) type of explosive atmosphere and all relevant safety properties (e.g., p_{max}, K_{max}, MIT, MIE, MESG);

b) Characteristics of the test rig:

1) dimensional sketch of the test rig,
2) enclosure and pipe volume, aspect ratio, surface area,
3) dust-dispersion system for producing homogeneous or inhomogeneous explosive atmosphere clouds,
4) explosion parameters of the explosive atmosphere (sample) in the test enclosures,
5) used ignition delay time (turbulence index);

c) Characteristics of the explosion isolation system:

1) type of explosion detector,
2) type of explosion sensor,
3) location of the sensor, detector,
4) trigger point of the explosion isolation device,
5) location of the explosion isolation device,
6) dispersion agent pressure if any,
7) suppressant charge in each of HRD-Suppressor if any,
8) CIE;

d) Results:

1) data of test,
2) static activation pressure of the sensor, detector,
3) minimum and maximum installation distance,
4) pressure in front of and if necessary behind the explosion isolation device,
5) comparison of the results with nomographs or with a mathematical model if applicable;

e) Additional information:

The report shall include all pertinent observations and information, which may not be fully described above.

8 Information for use

All explosion isolation systems shall be at least accompanied by instructions that include:

a) description of the intended use of the explosion isolation system:

— all details of operational requirements;

b) information marked on the product:

1) requirements for installation,
2) general arrangement plan of the isolation system,
3) requirements for commissioning,
4) requirements for maintenance;

Periodic inspection checks shall be made to ensure that the explosion isolation capability does not deteriorate and would continue to react as originally designed in the event of an explosion.

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

After an explosion has occurred, 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 isolation precautions are suitable for the equipments intended use.

For further information see also EN 13463-1.

9 Marking

9.1 Marking of the explosion isolation system

The serial number shall refer to the current operating manuals.

The complete system shall have a central marking which is placed on a clearly visible spot. This marking shall include as a minimum the following:

a) Name and address of the supplier;
b) EC-type examination certificate number of the explosion isolation system;
c) serial number of the explosion isolation system.

An example is shown below:

Logo of supplier Explosion Isolation System
Marking isolation system: notified body (NB), notified body identification number, number of certificate, specific conditions EXAMPLE **NB 4444 1234X**
Name and address of manufacturer serial number of the explosion isolation system

9.2 Marking of components of an explosion isolation system

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

For each component the marking shall include as a minimum:

a) the serial number of the explosion isolation system;

b) the serial number of the component and type;

and in addition the following:

c) Detector/Sensor:

   1) operating temperature rating;

d) HRD-Suppressor:

   1) operating temperature rating,

   2) contents of the HRD-Suppressors (type of powder, type of gas, working pressure, and setting);

e) Explosion isolation valve (passive/active):

   1) operating temperature rating,

   2) explosion pressure resistance of the valve;

f) Rotary valve:

   1) operating temperature rating,

   2) explosion pressure resistance of the rotary valve;

g) Explosion proof interlocked double valve arrangement:

   1) operating temperature rating,

   2) explosion pressure resistance of the explosion proof process valves;

h) CIE:

   1) operating temperature rating.

For further information see EN 13463-1.

Annex A
(informative)

Verification of design methods

A.1 General

Design methods for explosion isolation devices are used by the manufacturer/supplier of isolation devices/ systems for determining the installation distances and, in addition for extinguishing barriers, the amount of suppressant to be applied as well as the extinguishing distance. Because of the nature of the explosion isolation devices, design methods are only used for applying the following devices: passive isolation valves, active isolation valves and extinguishing barriers.

There are two main classes of design methods:

a) methods heavily relying on experimental data, (nomograph-type);

b) mathematical methods describing the explosion processes in detail.

Both methods need to take various aspects into account depending on the isolation device, the geometry to be protected and the explosive atmosphere involved (see Table A.1).

Table A.1 — Important criteria, which can influence the design/installation distance of an isolation device

Type of isolation device	Type of detection*	Volume of enclosure	Length to diameter ratio of enclosure	Pipe diameter	Obstruction/bends in pipe	$p_{max}/p_{red, max}$	K_{max}/S_u	Average flame velocity	Suppressebility	MIT	MIE
passive valves	–	x	x	x	x	x	x	x	–	–	–
active valves	F	x	x	x	x	x	x	x	–	–	–
	P	x	x	x	x	x	x	x	–	–	–
	F/P	x	x	x	x	x	x	x	–	–	–
rotary valves	P	x	x	–	–	x	x	–	–	x	x
extinguishing barriers	F	x	x	x	x	x	x	x	x	x	–
	P	x	x	x	x	x	x	x	x	x	–
	F/P	x	x	x	x	x	x	x	x	x	–
*) F Optical sensor located on the pipe P Pressure sensor located on the enclosure											

The following recommendations are given in respect of detector or sensor location:

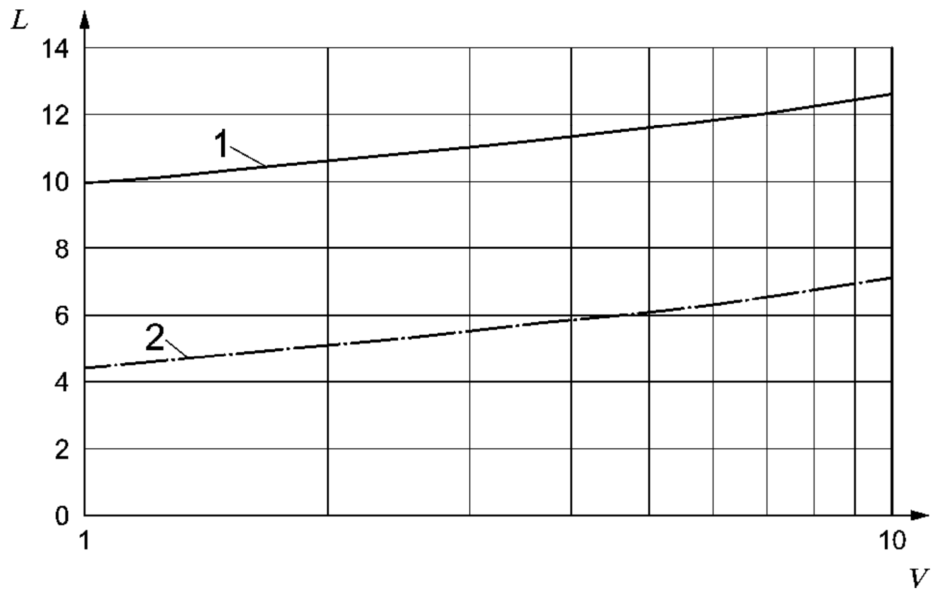
1) For pressure P detection, the detector or sensor is located on the interconnected enclosure, and not on pipeline;

2) For flame F detection, the detector or sensor is located on the interconnected duct within 2 diameters of the duct entry.

A.2 Design on the basis of an interpretation of test results

These types of design method (nomograph-type) consist of relatively simple methods being an interpretation of experimental data and are generally only applicable for a single type of isolation system/device (see example in Figure A.1). The methods normally predict minimum and maximum installation distances. For extinguishing barriers the amount of suppressant and the extinguishing distance needed, depending on the local flame speed, is predicted as well.

For extrapolation these methods may not be reliable depending on the degree of implementation of physics into these methods. The methods would often inherently take several properties of the isolation system into account such as delays within the detector and the CIE and closing time of the valve or time for a cloud of extinguishing powder to be deployed. Also the type of detection system: a single optical or pressure detector or a combination of the two, will have a strong influence.



(p_{max} ≤ 10 bar; K_{max} ≤ 200 m · bar · s^{-1}; Diameter of pipe 300 mm; L/D of enclosures < 2; no forward air velocity)

Key

1	Maximum installation distance (L_{max})	2	Minimum installation distance (L_{min})
L	Length of pipe	V	Enclosure volume [m^3]

Figure A.1 — Example of interpolating the minimum and maximum distance of an active explosion valve for enclosure volumes between 1 m³ to 10 m³, triggering device: pressure detection on the enclosure (p_a = 0,1 bar)

A combination of other components would therefore often necessitate new experiments to be able to develop a reliable interpolation technique. It should be assured that the design method considers accident scenarios such as explosive atmosphere reactivity and ignition source location.

The method should be validated by performing predictions for tests with the relevant explosion isolation systems/devices. The result of these predictions should then be compared to the results of these tests performed afterwards. The extent of the test programme to validate the design method depends on the number of parameters the method predicts, as well as the range of these parameters and the number of components (e.g., type of detection: single optical or pressure detector or a combination of the two).

The tests should be carried out at both ends of the range and at least one in between. The explosive atmosphere reactivity should be chosen equal (K_{max}, p_{max}) to the explosive atmosphere reactivity for which the method is valid. The validation process should verify that the minimum and maximum installation distances (see Figure A.1) are predicted in a conservative way ensuring a safe design. The deviation of the experimental points from the trend of the models should not exceed the experimental errors. The calibration constants should be chosen such that the predictions are on the safe side. The same accounts for the amount of suppressant and extinguishing distance needed when designing extinguishing barriers. The extent of the validation programme should be decided upon on a case-by-case basis but a minimum of three different tests should be performed for each parameter the method can predict and for each set of isolation system components the method can handle.

A.3 Mathematical model

Alternatively mathematical models may be used for the design of isolation systems. There are two types of mathematical models:

a) phenomenological models and

b) computational fluid dynamics (CFD)-based prediction tools.

Phenomenological models rely on experimental data as well but performed in the absence of isolation systems/devices. The experimental data cover a large number of enclosure volumes, pipe diameters and explosive atmosphere types and reactivity. The data in combination with simple theoretical models allow for sound extrapolation of flame propagation in ducts to larger ignition enclosure volumes, higher explosive atmosphere reactivity, etc.

Phenomenological methods heavily rely on measured delay times of detectors and CIE's, closing times of isolation valves, deployment times of extinguishing barriers, etc. The model also contains a model for prediction of the amount of suppressant needed in extinguishing barriers depending on the local flame speed also supported by experimental data.

Based on these times, predictions can be made for minimum and maximum installation distances of isolation systems/devices, the number of HRD-Suppressors used for extinguishing barriers, etc. To this end several scenarios (variation of explosive atmosphere reactivity and ignition location) should be considered.

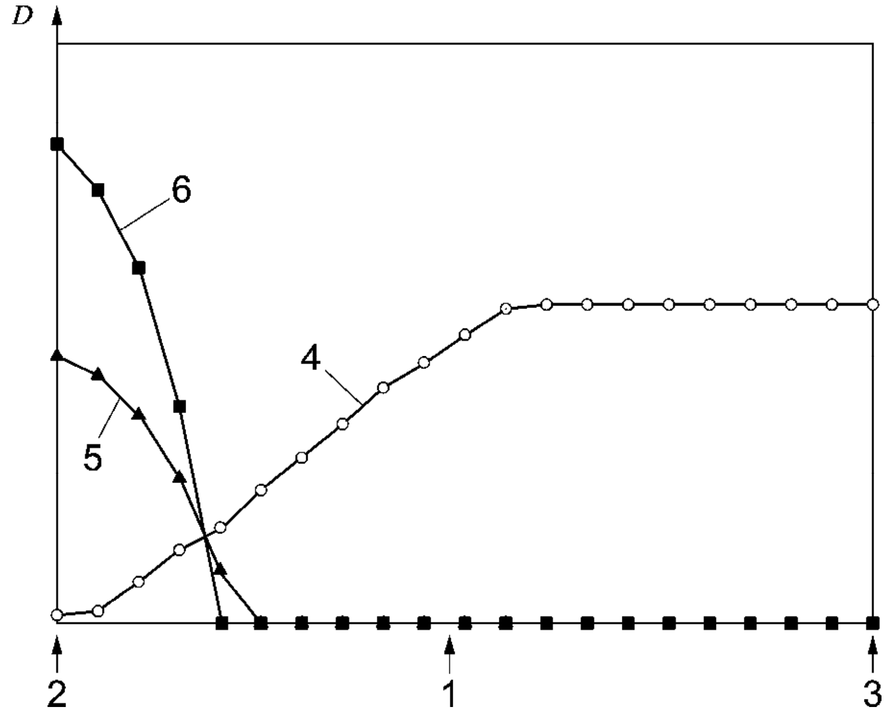
Figure A.2 shows an example of the output of a phenomenological design method. The Figure shows the predicted position of the isolation device in the duct (installation distance D measured from the duct mouth) as a function of the ignition source position in the vessel connected to the duct. The isolation device is part of an isolation system consisting of a detector (flame or pressure), a CIE and the device itself. The position of the isolation device is predicted for two types of detection (flame detector or pressure detector) and for two explosive atmosphere reactivities (using pressure detection).

Curve 2 shows the calculated minimum installation distance in the duct measured from the duct mouth as a function of ignition location using pressure detection. Inspection of the Figure shows that, for this configuration, locating the isolation device close to the duct mouth is sufficient provided that ignition occurs towards the centre of the vessel or even further away. The pressure rise due to the explosion in the vessel at these ignition locations reaches the activation pressure of the isolation system sufficiently early to assure that the isolation device is fully deployed before the flame reaches the mouth of the duct. At a distance from the mouth of the duct smaller than 0,25 times the diameter of the vessel the isolation device is not deployed before the flame reaches the mouth of the duct and as a result the isolation device must be installed further down into the duct. This distance increases when the ignition occurs closer to the mouth of the duct.

Curve 3 shows a similar development but for a mixture with a lower reactivity. The curve shows that even when igniting closer to the mouth of the duct the isolation device can still be positioned at the mouth of the duct since the explosion needs more time to reach the duct due to the lower reactivity. Moving even closer, however, the moment of detection starts playing a role. Due to the low reactivity the pressure rise is slow, allowing the flame to propagate deeper into the duct before being detected by the pressure detector. As a result the isolation device needs to be positioned further down into the duct for lower reactivity explosive atmosphere.

Curve 1 shows the optical flame detection case. Since the flame will be detected essentially at the instant it enters the duct (there is a general requirement to install the detector within a couple of diameters from the duct mouth), ignition near the duct mouth is the easy scenario. The flame is detected immediately activating the isolation device The worst case is now ignition remote from the duct mouth, as shown in Figure A.2. The reason for this is that there is then a longer time available for the explosion pressure to develop and, consequently, turbulence is generated at the duct mouth. When the flame arrives at the flame detector position it accelerates into the duct leaving less time for the isolation device to respond. Hence it must be installed further into the duct at a longer distance. This effect increases with increasing distance of the ignition source from the duct mouth into the vessel.

Since in reality neither the ignition source position nor the reactivity of the explosive atmosphere is known beforehand, the worst case installation distance needs to be chosen. When both flame detection and pressure detection are used the minimum installation distance is determined by the cross point of the curves.



(V, p_{max}, p_a and pipe diameter are kept constant)

Key

1, 2, 3	*Z1, Z2, Z3* Location of ignition source	6	curve 3, Pressure detection, $K_{reduced}$
4	curve 1, Flame detection	*D*	Installation distance
5	curve 2, Pressure detection, K_{max},		

Figure A.2 — Effect of ignition location, detection system and *K*-value on minimum installation distance

Alternatively dedicated CFD-based tools can be used. These dedicated CFD-tools describe explosion processes in detail. They allow for describing the effects of geometrical details, explosive atmosphere reactivity and ignition source location. The tools predict the position of the flame in the geometry at any moment in time as well as the pressure development at any location in the geometry.

As for the phenomenological models a combination of detailed knowledge of the isolation system components: delay in detector and CIE, deployment time of a cloud of suppressant and closing time of an isolation valve, and predicted flame behaviour for various scenarios, the minimum installation distance can be calculated. The pressure resistance of the device allows in combination with the pressures predicted by the model to predict the maximum installation distance.

Also mathematical models should be validated by performing predictions for tests to be performed afterwards. It should be demonstrated that the installation distances are well reproduced by the model. The minimum installation distance calculated by the model should be equal to or larger than the measured value. The maximum installation distance calculated by the model should be equal to or smaller than the measured value. In addition to that the calculated pressure value in front of the isolation device should be equal to the measured one by ± 20 %. The extent of the validation process should reflect the number of parameters the model can predict as well as the number of isolation devices/systems the mathematical model can handle.

Each dependent parameter used in the mathematical model should be tested to validate applicability. Dependent factors should be tested at the extremes of their range. The extent of the validation programme should be determined by the notified body but a minimum of three different tests should be performed for each parameter the method can predict for each set of isolation system components the method can handle. In total a minimum of 100 tests should be performed in at least 4 different test volumes.

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 1993.

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 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

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

Clause(s)/sub-clause(s) of this EN	Essential Requirements (ERs) of Directive 94/9/EC	Qualifying remarks/Notes
whole document	1.0.1 Principles of integrated explosion safety	
6	1.0.2 Design consideration	
8	1.0.3 Special checking and maintenance conditions	
9	1.0.5 Marking	
8	1.0. 6 a) Instructions	
6.2, 7	1.1.2 Limits of operating	
whole document	1.2.1 Technological knowledge of explosion protection for safe	
7.2.3	1.2.9 Flameproof enclosure systems	
5.4	1.5.1 Independent function of safety devices of measurement and control. Fail safe principles for electric circuits. Safety related switches independent of software and command	
5.3, 5.4	1.5.2 Safety device failure	
5.3, 5.4	1.5.3 Emergency stop controls	
5.4	1.5.4 Control and display units	
5.4	1.6.2 Emergency shutdown system	
5.4	1.6.3 Hazards arising from power failure	

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

Clause(s)/sub-clause(s) of this EN	Essential Requirements (ERs) of Directive 94/9/EC		Remarks
5.4	1.6.4	Hazards arising from connections	
whole document	3.0	General requirements	
7.2.1, 7.2.3	3.1.2	Withstanding shock wave effects of explosions	
7.2.1	3.1.3	Accessories to withstand maximum pressure of explosions	
Whole document	3.1.4	Planning protective systems to take account of pressures on pipework, etc.	
6.2.2	3.1.5	Pressure relief systems	
6.2.3	3.1.6	Explosion suppression systems	
whole document	3.1.7	Explosion decoupling systems	
whole document	3.1.8	Protective systems integrated into a circuit with an alarm	

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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