BRITISH STANDARD

BS EN 12874:2001

Flame arresters — Performance requirements, test methods and limits for use

The European Standard EN 12874:2001 has the status of a British Standard

ICS 13.220.99; 13.230

National foreword

This British Standard is the official English language version of EN 12874:2001.

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

— aid enquirers to understand the text;

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

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

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

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Flame arresters — Performance requirements, test methods and limits for use

Arrête-flamme — Exigences de performance, méthodes d'essai et limites d'utilisation

Flammendurchschlagsicherungen — Leistungsanforderungen, Prüfverfahren und Einsatzgrenzen

This European Standard was approved by CEN on 24 November 2000.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Foreword

This European Standard 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of an identical text or by endorsement, at the latest by July 2001, and conflicting national standards shall be withdrawn at the latest by July 2001.

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 standard.

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

Introduction

This European Standard is type C as stated in ENV 1070.

1 Scope

This standard specifies the requirements for flame arresters which prevent flame transmission when flammable gas/air-mixtures or vapour/air-mixtures are present. It establishes uniform principles for the classification, basic construction and marking of flame arresters and specifies test methods to verify the safety requirements and determine safe limits of use.

This standard does not cover the following:

– External safety-related measurement and control equipment which may be required to keep the operational conditions within the established safe limits.

– Flame arresters used for explosive mixtures of vapours and gases, which tend to self-decompose (e.g. acetylene) or which are chemically unstable.

– Flame arresters used for carbon disulphide due to its special properties.

– Flame arresters used for gas or vapour mixtures containing more than the atmospheric oxygen concentration.

– Flame arrester test procedures for internal combustion, compression ignition engines. Refer to EN 1834-1 and EN 1834-2.

The safety factors incorporated into the tests specified in this standard mean that the uncertainty of measurement inherent in good quality, regularly calibrated measurement equipment is not considered to have any significant detrimental effect on the results and need not be taken into account when making the measurements necessary to verify compliance of the flame arrester with the requirements of this standard.

2 Normative references

This standard incorporates by dated or undated reference, provisions from other publications. These normative references are included at the appropriate places in the text and the publications are listed. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1267, *Valves — Test of flow resistance using water as test fluid.*

prEN 1759-3:1994, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, class designated — Part 3: Copper alloy and composite flanges.*

prEN 1759-4:1997, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, class designated — Part 4: Aluminium alloy flanges.*

EN 1834-1, *Reciprocating internal combustion engines — Safety requirements for design and construction of engines for use in potentially explosive atmospheres — Part 1: Group II engines for use in flammable gas and vapour atmospheres.*

EN 1834-2, *Reciprocating internal combustion engines — Safety requirements for design and construction of engines for use in potentially explosive atmospheres — Part 2: Group I engines for use in underground workings susceptible to firedamp and/or combustible dust.*

ENV 1070, *Safety of machinery — Terminology.*

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

EN 1092-1, *Flanges and their joints — Circular flanges for pipes, valves and fittings — Part 1: Steel flanges, PN designated.*

EN 50014, *Electrical apparatus for potentially explosive atmospheres — General requirements.*

EN 50018, *Electrical apparatus for explosive atmospheres — Flameproof enclosures "d".*

ISO 7005-1, *Metallic flanges — Part 1: Steel flanges.*

ISO 7-1, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation.*

ISO 7-2, *Pipe threads where pressure-tight joints are made on the threads — Part 2: Verification by means of limit gauges.*

3 Terms and definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this standard, the following terms and definitions apply.

3.1.1
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

3.1.2
flame arrester element
that portion of a flame arrester whose principal function is to prevent flame transmission

3.1.3
flame arrester housing
that portion of a flame arrester whose principal function is to provide a suitable enclosure for the flame arrester element, and allow mechanical connections to other systems

3.1.4
stabilized burning
steady burning of a flame stabilized at, or close to, the flame arrester element

3.1.5
short time burning
stabilized burning for a specified time

3.1.6
endurance burning
stabilized burning for an unspecified time

3.1.7
explosion
abrupt oxidation or decomposition reaction producing an increase in temperature, pressure, or in both simultaneously
[EN 1127-1:1997]

3.1.8
deflagration
explosion propagating at subsonic velocity
[EN 1127-1:1997]

3.1.9
detonation
explosion propagating at supersonic velocity and characterized by a shock wave
[EN 1127-1:1997]

3.1.10
stable detonation
detonation is stable when it progresses through a confined system without significant variation of velocity and pressure characteristics

NOTE For atmospheric conditions, test mixtures and test procedures of this standard, typical velocities range between 1 600 m/s and 2 200 m/s.

3.1.11
unstable detonation
detonation is unstable during the transition of a combustion process from a deflagration into a stable detonation. The transition occurs in a limited spatial zone where the velocity of the combustion wave is not constant and where the explosion pressure is significantly higher than in a stable detonation

NOTE The position of this transition zone depends on, among other things, the pipe diameter, pipe configuration, test gas and explosion group, and may be established by experiment in each case.

3.1.12 Characteristic safety data of explosive mixtures

3.1.12.1
ignition temperature
lowest temperature of a heated wall, as determined under specified test conditions, at which the ignition of a combustible substance in the form of gas or vapour mixture with air will occur
[EN 1127-1:1997]

NOTE IEC 60079-4 standardizes the test method.

3.1.12.2
maximum experimental safe gap
maximum gap of the joint between the two parts of the interior chamber of a test apparatus which, when the internal gas mixture is ignited and under specified conditions, prevents ignition of the external gas mixture through a 25 mm long joint, for all concentrations of the tested gas or vapour in air. The MESG is a property of the respective gas mixture
[EN 1127-1:1997]

NOTE IEC 60079-1 A standardizes the test apparatus and the test method.

3.1.13
bi-directional flame arrester
flame arrester which prevents flame transmission from both sides

3.1.14
deflagration flame arrester
flame arrester designed to prevent the transmission of a deflagration. It can be end-of-line (3.1.22) or in-line (3.1.23)

3.1.15
detonation flame arrester
flame arrester designed to prevent the transmission of a detonation. It can be end-of-line (3.1.22) or in-line (3.1.23)

3.1.16
endurance burning flame arrester
flame arrester which prevents flame transmission during and after endurance burning

3.1.17
static flame arrester
flame arrester designed to prevent flame transmission by quenching gaps

3.1.17.1
measurable type (static flame arrester)
flame arrester where the quenching gaps of the flame arrester element can be technically drawn, measured and controlled

3.1.17.2
non-measurable type (static flame arrester)
flame arrester where the quenching gaps of the flame arrester element cannot be technically drawn, measured or controlled (e.g. random structures such as knitted mesh, sintered metal and gravel beds)

3.1.18
high velocity vent valve
pressure relief valve designed to have nominal flow velocities which exceed the flame velocity of the flammable mixture thus preventing flame transmission

3.1.19
flow controlled aperture
aperture designed to be used with flow velocities which exceed the flame velocity of the flammable mixture thus preventing flame transmission

3.1.20
liquid product detonation flame arrester
flame arrester, in which the liquid product is used to form a liquid seal as a flame arrester medium to prevent flame transmission of a detonation. There are two types of liquid product detonation flame arrester for use in liquid product lines:

a) liquid seals
b) foot valves

3.1.20.1
liquid seal
flame arrester designed to use the liquid product to form a barrier to flame transmission

3.1.20.2
foot valve
flame arrester designed to use the liquid product combined with a non return valve to form a barrier to flame transmission

3.1.21
hydraulic flame arrester
flame arrester designed to break the flow of a flammable mixture into discrete bubbles in a water column, thus preventing flame transmission

3.1.22
end-of-line flame arrester
flame arrester which is fitted with one pipe connection only

3.1.23
in-line flame arrester
flame arrester which is fitted with two pipe connections one on each side of the flame arrester element

3.1.24
pre-volume flame arrester
flame arrester which prevents flame transmission from inside a vessel to the outside or into connecting pipework. It may be end-of-line (3.1.22) or in-line (3.1.23)

3.1.25
integrated temperature sensor
temperature sensor to indicate a stabilized flame and integrated into the flame arrester by the manufacturer

3.2 Symbols and abbreviations

I	=	explosion group (1,14 mm ≤ MESG)
IIA	=	explosion group (0,9 mm < MESG)
IIB	=	explosion group (0,5 ≤ MESG ≤ 0,9 mm)
IIC	=	explosion group (MESG < 0,5 mm)
A_5	=	elongation at rupture (%)
A_0	=	free area of a static flame arrester element (mm^2)
D	=	nominal pipe diameter (mm)
L_i	=	pipe length on the unprotected side (m)
L_m	=	max. length without undamped oscillations (m)
L_{ni}	=	pipe length on the protected side (m)
L_1, L_2, L...	=	pipe length in the flow test (m)
MESG	=	maximum experimental safe gap (mm)
p_T	=	pressure in the flow test of an end-of-line flame arrester (Pa)
p_t	=	pressure in the pressure test (Pa)
p_{md}	=	time average value of the detonation pressure in the time interval of 200 µs after arrival of the detonation shock wave (Pa)
p_e	=	value of deflagration pressure when the flame first arrives at a defined position close to the flame arrester (Pa)
p_{mu}	=	average value of the detonation pressure in the time interval of 200 µs from the peak pressure of an unstable detonation (Pa)
p_i	=	pressure before ignition (Pa)
p_0	=	maximum operational pressure (Pa)
Δp	=	pressure drop in the flow test of an in-line flame arrester (Pa)
R_A	=	ratio of the area of the flame arrester element to pipe cross-sectional area
R_m	=	tensile strength (N/mm^2)
T_m	=	max. operational temperature of a flow controlled aperture (°C)
T_i	=	temperature of the flame arrester before ignition (°C)
T_0	=	operational temperature of the flame arrester (°C)
v_l	=	laminar burning velocity (m/s)
v_{max}	=	max. flow velocity during the volume flow-pressure drop measurement (flow test) (m/s)
v_{min}	=	min. flow velocity during the volume flow-pressure drop measurement (flow test) (m/s)
$\mathring{V}$	=	volume flow rate (m^3/h)
$\mathring{V}_C$	=	critical volume flow rate (m^3/h)
$\mathring{V}_0$	=	min. volume flow rate for endurance burning on high velocity vent valves (m^3/h)
$\mathring{V}_E$	=	max. volume flow rate for endurance burning on high velocity vent valves (m^3/h)
$\mathring{V}_K$	=	max. volume flow rate for high velocity vent valves at the set pressure (m^3/h)
$\mathring{V}_m$	=	volume flow rate which led to max. temperature (m^3/h)
$\mathring{V}_{max}$	=	safe volume flow rate (m^3/h)
$\mathring{V}_s$	=	safe volume flow rate including a safety margin (m^3/h)
$\mathring{V}_t$	=	max. volume flow rate which led to flame transmission (m^3/h)
Z_{Rmin}	=	the minimum water seal immersion depth at rest (mm) above the outlet openings of the immersion tubes
Z_R	=	the immersion depth at rest (mm) = Z_{Rmin} + the manufacturer's recommended safety margin
Z_{0min}	=	the minimum operational water seal immersion depth (mm) when the mixture flow displaces the water from the immersion tubes - $Z_{0min} > Z_{Rmin}$
Z_0	=	the operational immersion depth (mm) = Z_{0min} + the manufacturer's recommended safety margin

4 Hazards and flame arrester classifications

4.1 Flame transmission: Deflagration, stable and unstable detonation

The ignition of an explosive mixture will initiate a deflagration. A flame arrester covering only this hazard is classified as a deflagration flame arrester.

A deflagration when confined in a pipe may accelerate and undergo transition through an unstable to a stable detonation provided a sufficient pipe length is available.

A flame arrester tested according to 6.3.3.2 is classified as a stable detonation flame arrester and is suitable for deflagrations and stable detonations.

A flame arrester tested according to 6.3.3.3 is classified as an unstable detonation flame arrester and is suitable for deflagrations, stable detonations and unstable detonations.

Unstable detonations are a specific hazard requiring higher performance flame arresters than for stable detonations.

These hazards relate to specific installations and in each case the flame arrester successfully tested at p_i is suitable for operational pressures $p_0 \leq p_i$ and the application is limited to mixtures with an MESG equal to or greater than that tested.

The detailed hazards covered by this standard, the classification and testing required for the appropriate flame arrester are listed in Table 1.

Table 1 — Flame arrester classification for deflagration, stable and unstable detonation

Application	Flame arrester classification	Test required
(a) An unconfined deflagration into an enclosure or vessel	End-of-line deflagration	6.3.2.1
(b) A confined deflagration propagating along a pipe into connecting pipework	In-line deflagration	6.3.2.2
(c) A deflagration confined by an enclosure or pipework (length to diameter ratio < 5) to the out-side atmosphere or into connecting apparatus	Pre-volume deflagration	6.3.2.3
(d) A stable detonation propagating along a pipe into connecting pipework	In-line stable detonation	6.3.3.2
(e) An unstable detonation propagating along a pipe into connecting pipework	In-line unstable detonation	6.3.3.3
(f) A stable detonation into an enclosure or vessel	End-of-line stable detonation	7.3

4.2 Flame transmission: Stabilized burning

Stabilized burning after ignition creates additional hazards in applications where there could be a continuous flow of the flammable mixture towards the unprotected side of the flame arrester. The following situations have to be taken into account:

– The flow of the flammable mixture can be stopped[1)] within 1 min.

  Flame arresters which prevent flame transmission during that period of stabilized burning are suitable for that hazard. This type of flame arrester is classified as safe against short time burning.

– The flow of the flammable mixture cannot be stopped or for operational reasons is not intended to be stopped.

  Flame arresters which prevent flame transmission during stabilized burning are suitable for that hazard. This type of flame arrester is classified as safe against endurance burning.

5 General requirements

5.1 Construction

All parts of the flame arrester shall resist the expected mechanical, thermal and chemical loads for the intended use.

When a flame arrester element has no intrinsic stability, it shall be secured in a rigid case or housing which cannot be dismantled without destruction.

Production flame arresters shall have flame quenching capabilities no less than the tested flame arrester.

Light metal alloys shall not contain more than 6 % magnesium.

Coatings of components which may be exposed to flames during operation shall not be damaged in such a way that flame transmission is possible.

Flame arresters for short time burning shall be fitted with one or more integrated temperature sensors, taking into account the intended orientation of the flame arrester.

5.2 Housings

In-line flame arrester housing materials shall have an elongation at rupture of $A_5 \geq 12$ % and a tensile strength of $R_m \geq 350$ N/mm^2.

End-of-line flame arrester housing materials shall have an elongation at rupture of $A_5 \geq 5$ % and a tensile strength of $R_m \geq 160$ N/mm^2.

Thread gaps, which shall prevent flame transmission, shall be in accordance with EN 50018.

5.3 Joints

All joints shall be constructed and sealed in such a way that flame cannot bypass the flame arrester element and also flame is prevented from propagating to the outside of the flame arrester.

[1)] By-passing, sufficient diluting or inerting are measures equivalent to stopping the flow.

5.4 Joints to adjacent pipework

All flanges shall be in accordance with prEN 1759-3:1995, prEN 1759-4:1997 or ISO 7005-1.

All screwed connections shall be in accordance with ISO 7-1 and ISO 7-2.

Ends prepared for welding shall be in accordance with EN 1092-1.

5.5 Pressure test

Pressure testing of in-line and end-of-line detonation flame arresters shall be carried out at not less than 10 times p_0 and all in-line deflagration flame arresters at not less than 10^6 Pa for not less than 3 min. All in-line deflagration and detonation flame arresters and end-of-line detonation flame arresters of welded construction need only be type tested, but flame arresters with any subsequent alteration to the design, affecting its strength, shall be retested. No permanent deformation shall occur during the test.

End-of-line deflagration and endurance burning flame arresters need not be pressure tested.

5.6 Leak test

Flame arresters shall be leak tested with air at 1,1 times p_0, with a minimum of 150 kPa absolute for not less than 3 min. No leak shall occur.

The leak test is not required for end-of-line flame arresters of welded construction.

5.7 Flow measurement (air)

The pressure drop shall be checked for one flow rate in the middle of the flow rate/pressure drop curve (± 20 %) before and after all tests (flame transmission and endurance burning). The deviation from the manufacturer's data shall not exceed 10 % before the tests and be within 10 % of this figure after the tests.

The flow capacity of in-line flame arresters shall be recorded according to A.2.

The flow capacity of end-of-line flame arresters shall be recorded according to A.3.

The flow capacity of end-of-line flame arresters combined with or integrated into pressure and/or vacuum valves shall be recorded according to A.3. Pressure and/or vacuum valves manufactured for different pressure settings shall be tested at the lowest and the highest set pressure (vacuum) and for intermediate set pressures $\leq$ 1 kPa apart.

The flow capacity of high velocity vent valves shall be recorded according to A.3.

In addition, all high velocity vent valves shall be tested for undamped oscillations according to A.4.

5.8 Flame transmission test

5.8.1 General

All flame arresters shall be type tested against flame transmission. Housings shall not have visible deformations during the tests.

The tests shall be specific for the basic types of operation (as defined in 3.1.17, 3.1.18, 3.1.19, 3.1.20 and 3.1.21) and shall be carried out according to clauses 6, 7, 8, 9 or 10. If not otherwise stated, tests for detonation (stable and unstable), short time burning and endurance burning are optional. One flame arrester shall be used throughout all deflagration or detonation flame transmission tests. No replacement parts or modifications shall be made to the flame arrester during these tests.

Short time and endurance burning tests shall be carried out in the orientation to be used in service. Bi-directional flame arresters shall only be tested from one side if the protected and unprotected sides are identical.

All flame transmission tests shall be carried out with gas/air-mixtures at ambient temperatures. When heat tracing of the flame arrester is required, tests shall be carried out as described in the specific section but with the flame arrester only being heated to the required temperature $T_l \leq 150$ °C. Gas- or vapour/air-mixtures shall be as specified in 5.8.2.

Flame arresters shall be tested to the specific explosion group of the flammable gas/air- or vapour/air-mixture according to its intended use in accordance with EN 50014.

For the purposes of this standard group IIC covers hydrogen only and group IIB is divided into four sub-groups IIB1, IIB2, IIB3 and IIB covering deflagration and detonation tests.

The limiting MESG values which define the explosion groups IIA, IIB1, IIB2, IIB3, IIB and IIC are shown in Table 2.

A flame arrester for a particular explosion group is suitable for flammable mixtures of another group having a higher MESG.

5.8.2 Test mixtures

The following Tables 2, 3 and 4 specify the mixtures for deflagration and detonation tests, short time burning and endurance burning tests.

Gas/air-mixtures for testing may be established with a concentration measuring instrument or an MESG test apparatus.

Table 2 — Specification of gas/air-mixtures for deflagration and detonation tests

Range of Application (Marking)		**Requirements for test mixture**			
Explosion group	MESG of mixture mm	Gas type	Gas purity by volume %	Gas in air by volume %	Safe gap of gas/air mixture mm
IIA	> 0,90	Propane	≥ 95	4,2 ± 0,2	0,94 ± 0,02
IIB1[a)]	≥ 0,85	Ethylene	≥ 98	5,0 ± 0,1	0,83 ± 0,02
IIB2	≥ 0,75			5,5 ± 0,1	0,73 ± 0,02
IIB3	≥ 0,65			6,5 ± 0,5	0,67 ± 0,02
IIB[a)]	≥ 0,50	Hydrogen	≥ 99	45,0 ± 0,5	0,48 ± 0,02
IIC	< 0,50	Hydrogen	≥ 99	28,5 ± 2,0	0,31 ± 0,02
[a)] With small pipe diameters it may be difficult to generate stable detonations. Tests may be carried out using a gas/air-mixture of a lower safe gap.					

Table 3 — Specification of gas/air-mixtures for short time burning tests

Range of Application (Marking)	**Requirements for test mixture**		
Explosion group	Gas type	Gas purity by volume %	Gas in air by volume %
IIA	Propane	≥ 95	4,2 ± 0,2
IIB1	Ethylene	≥ 98	6,5 ± 0,5
IIB2			
IIB3			
IIB			
IIC	Hydrogen	≥ 99	28,5 ± 2,0

Table 4 — Specification of gas or vapour/air-mixtures for endurance burning test

Range of Application (Marking)[b)]	Requirements for test mixture		
Explosion group	Gas or liquid	Purity by volume %	Gas, vapour in air by volume[a)] %
IIA	Hexane	≥ 70	2,1 ± 0,1
IIB1	Ethylene	≥ 98	6,5 ± 0,5
IIB2			
IIB3			
IIB			
IIC	Hydrogen	≥ 99	28,5 ± 2,0

a) Testing of high velocity vent valves may require a variation in mixture composition.

b) For static flame arresters the range of applications is limited to hydrocarbons only (see 6.3.5).

6 Specific requirements for static flame arresters

6.1 Construction

Static flame arresters shall consist of a flame arrester element and a housing. Flame arrester elements with quenching gaps shall be manufactured within clearly defined tolerances. Evidence shall be available that the manufacture is controlled within tolerances to ensure reproducibility.

Materials for the flame arrester element shall be suitable for use up to 1 000 °C.

6.2 Design series

Static flame arresters of similar design, except endurance burning and pre-volume flame arresters, may be grouped in a design series. The design series shall comply with the following:

i) One drawing shall cover all nominal sizes in a design series and all parts shall be listed and dimensioned.

ii) The flame arrester elements shall have identical features of construction such as the quenching gaps and have the same thickness measured in the direction of the flame path.

Additional requirements for in-line flame arresters:

iii) A design series is limited to four consecutive nominal sizes according to the list of flange connections as follows.

Table 5 — Flange connection (mm)

10/15	20/25	32/40	50	60/65	75/80	100	125	150	200	250	300	350	400

iv) For every nominal size in a design series (maximum four) the ratio R_A shall not deviate by more than ± 10 % from the ratio of the largest nominal size of the four members:

$$R_A = \frac{A_U}{A_P}$$

where:

A_U is the effective area of the flame arrester element on the protected side; and

A_P is the nominal cross-sectional area of the connecting pipe.

6.3 Flame transmission test

6.3.1 General

Production flame arrester elements of the non-measurable type shall be manufactured 50 % thicker than the element tested to ensure that they have flame quenching capabilities no less than the flame arrester element tested. The thickness of the flame arrester element is defined as being the distance between the protected and unprotected surface of the flame arrester element.

Production flame arrester elements shall be made to the same design specification as the flame arrester element tested.

All static flame arresters with integral pressure and/or vacuum valve(s) shall have the valve secured in the fully open position during the tests.

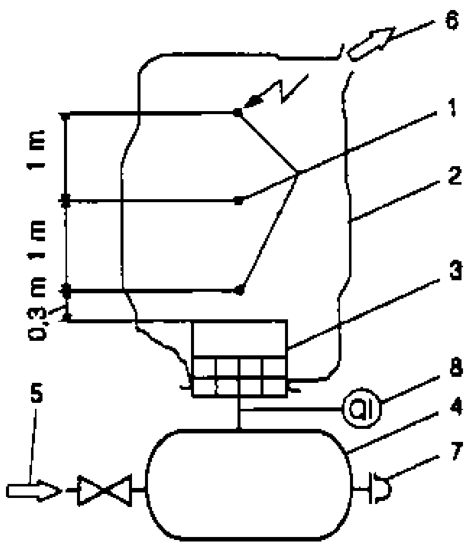
Flame arresters of the original design but with connections smaller than the original ones are acceptable without further testing.

6.3.2 Deflagration test

6.3.2.1 End-of-line flame arrester

The test apparatus is shown in Figure 1.

Assemble the flame arrester with all ancillary equipment including weather cowls or other covers and enclose it in a plastic bag.



Key
1 Ignition source
2 Plastic bag: diameter ≥ 1,2 m, length ≥ 2,5 m, foil thickness ≥ 0,05 mm
3 End-of-line flame arrester
4 Explosion proof container
5 Mixture inlet with shut-off valve
6 Mixture outlet
7 Bursting diaphragm
8 Flame detector

Figure 1

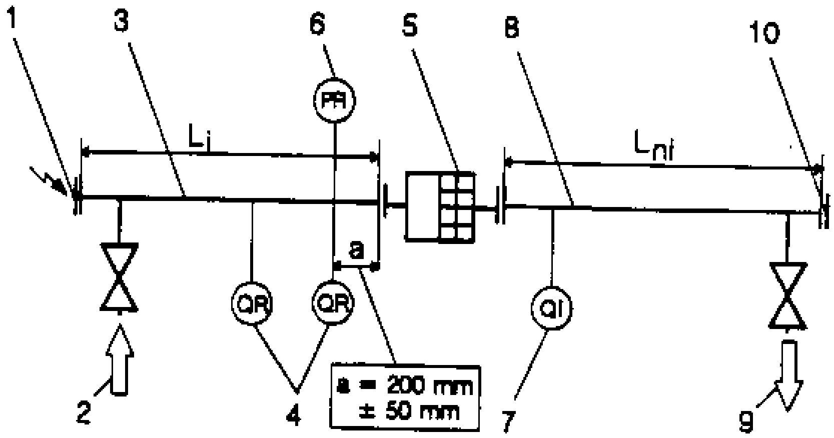
The ignition source shall be a spark plug, electrical fusehead or a small chemical igniter.

Fill the apparatus fully inflating the bag with a mixture as specified in 5.8.2. Disconnect the mixture supply and ignite. Carry out two tests for each ignition point so that a total of six tests will result. Flame transmission shall be indicated by the flame detector on the protected side. No flame transmission shall occur in any of the tests.

If the largest and smallest nominal sizes of a design series are satisfactorily tested, intermediate sizes may be considered acceptable without testing.

6.3.2.2 In-line flame arrester

The test apparatus is shown in Figure 2 with blind flanges at both ends. The ignition source shall be a spark plug fitted in the centre of the blind flange.



Key

1 Blind flange with ignition source
2 Mixture inlet
3 Unprotected pipe (length L_i, diameter D)
4 Flame detectors
5 In-line deflagration flame arrester
6 Pressure transducer
7 Flame detector
8 Protected pipe (length L_{ni}, diameter D)
9 Mixture outlet
10 Blind flange or pipe end

Figure 2

The nominal pipe diameter D shall have the same size as the flame arrester connection. The pipe length L_i shall be not less than 10 × D and not greater than 50 × D for hydrocarbon-air mixtures (IIA, IIB1, IIB2, IIB3) and not greater than 30 × D for hydrogen-air mixtures (IIB and IIC). The pipe length L_{ni} shall be 50 × D for hydrocarbon-air mixtures (IIA, IIB1, IIB2, IIB3) and 30 × D for hydrogen-air mixtures (IIB and IIC).

The flame velocity shall be measured by two flame detectors fitted to the pipe on the unprotected side. One flame detector shall not be more than 200 mm from the flame arrester connection and the distance between the two shall be at least three times the pipe diameter but not less than 100 mm.

The pressure shall be measured by a pressure transducer (limiting frequency ≥ 100 kHz) fitted to the pipe on the unprotected side 200 mm ± 50 mm from the flame arrester connection.

Fill the apparatus with a test mixture as specified in 5.8.2 and pressurize to p_i when $p_i \geq p_0$ (p_0 is the maximum operational pressure requested by the manufacturer or user). In six consecutive tests no flame transmission shall occur. A flame transmission is indicated by the flame detector on the protected side.

The flame velocities, maximum explosion pressures and pipe length (L_i) in each test shall be given in the test report. If the largest and smallest nominal size of a design series are satisfactorily tested, the two intermediate nominal sizes according to 6.2 may be considered acceptable without testing. Each size larger than 400 mm shall be tested.

6.3.2.3 Pre-volume flame arrester

The test apparatus is shown in Figure 3.

Pre-volume flame arresters shall be tested using the original or simulated enclosure and contents and any pipework between the enclosure and the flame arrester.

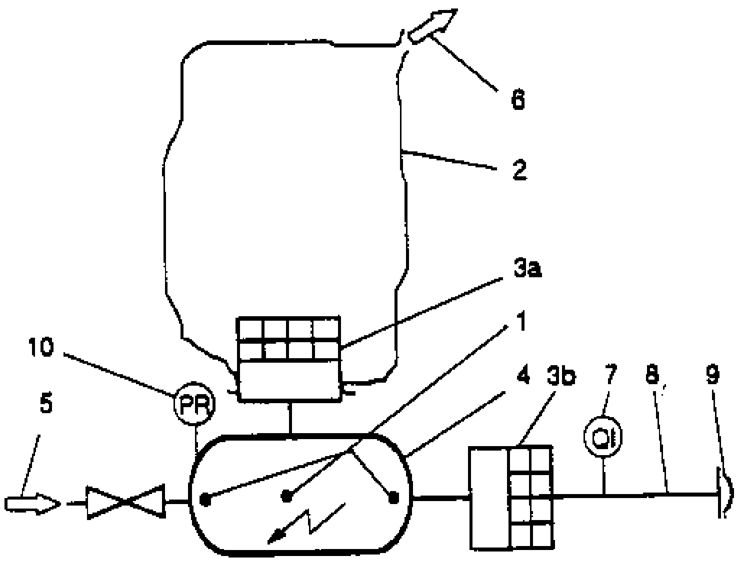
Pre-volume applications using end-of-line types shall be enclosed in a plastic bag as shown in Figure 3.

Pre-volume applications using in-line types shall be connected to the actual pipework or equipment on the protected side or to pipework simulating the actual length, diameter and volume.

Flame transmission shall be indicated by the following:

a) End-of-line types by the ignition of the mixture in the plastic bag (2), a flame detector is optional.

b) In-line types by the flame detector (7).



Key

1 Ignition source
2 Plastic bag: diameter ≥ 1,2 m, length ≥ 2,5 m, foil thickness ≥ 0,05 mm
3a End-of-line flame arrester
3b In-line flame arrester
4 Equipment or simulated equipment containing the explosion
5 Mixture inlet with shut-off valve
6 Mixture outlet
7 Flame detector
8 Original or simulated pipework
9 Bursting diaphragm
10 Pressure transducer

Figure 3

If the enclosure has more than one outlet, all flame arresters shall be used and tested simultaneously.

Fill the enclosure and the plastic bag or pipe with a mixture as specified in 5.8.2. Disconnect the mixture supply and ignite separately at three positions inside the enclosure, one as close as possible to the flame arrester, one at the most likely position of an ignition source and one as far away from the flame arrester as possible.

Carry out two tests for each position resulting in a total of six tests. No flame transmission shall occur in any of the tests.

All types and sizes shall be tested.

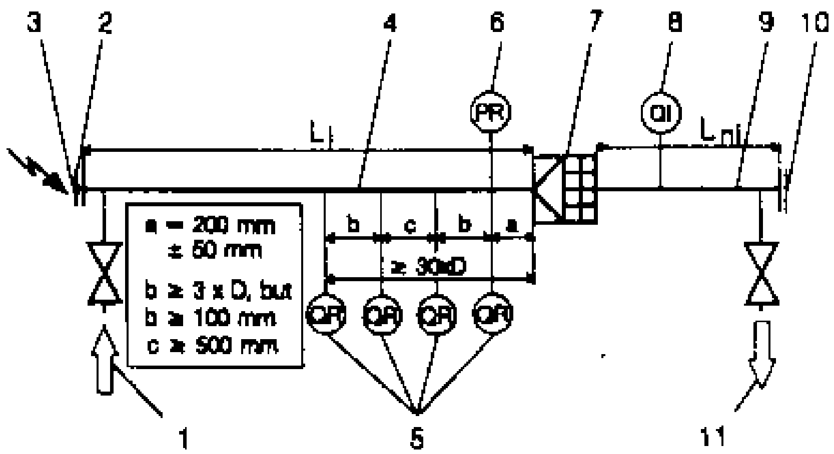
6.3.3 Detonation test

6.3.3.1 General

If the largest and smallest nominal size of a design series are satisfactorily tested for detonations, the two intermediate nominal sizes according to 6.2, may be considered acceptable without testing. Each nominal size larger than 400 mm shall be tested.

6.3.3.2 Stable detonation

The test apparatus is shown in Figure 4.



Key

1 Mixture inlet
2 Explosion proof container or pipe end
3 Ignition source
4 Unprotected pipe (length L_i, diameter D)
5 Flame detectors for flame velocity measurement
6 Pressure transducer
7 Detonation flame arrester
8 Flame detector
9 Protected pipe (length L_{ni}, diameter D)
10 Pipe end
11 Mixture outlet

Figure 4

The nominal pipe diameter D shall have the same size as the flame arrester connection.

The pipe on the unprotected side shall have a length L_i sufficient to develop a stable detonation and shall have a pipe end or an explosion proof container fitted with an ignition source. The pipe may also contain a flame accelerator to reduce the pipe length for stable detonation conditions.

The pipe on the protected side shall have a length L_{ni} of 10 × D, and not less than 3 m. The pipe end shall resist the shock pressures during testing.

For measuring flame velocities and detonation pressures, four flame detectors and a pressure transducer (limiting frequency ≥ 100 kHz) shall be fitted to the pipe on the unprotected side. The position of the flame detectors and the pressure transducer shall be according to Figure 4.

One flame detector shall be fitted to the pipe on the protected side to indicate flame transmission.

The apparatus shall be filled with a test mixture as specified in 5.8.2 and at a pressure of p_i when $p_i \geq p_o$. Under these conditions three tests shall be carried out.

In each test the flame velocities from the two pairs of flame detectors (see Figure 4) shall be constant, i.e. the difference between the two flame velocities shall not exceed 10 % of the lower value.

The velocities may be greater but not less than 1 600 m/s for hydrocarbon-air mixtures (IIA, IIB1, IIB2, IIB3) and 1 900 m/s for hydrogen-air mixtures (IIB and IIC).

The pressure time record shall indicate a stable detonation shock wave.

Until the arrival of a stable detonation shock wave the pressure (pressure transducer, (6), Figure 4) shall remain constant at p_i. If not, a longer pipe or turbulence promoting equipment may be used.

The average value p_{md} of the detonation pressure shall be calculated from the area integral below the pressure-time trace, starting at the maximum pressure peak and covering a time interval of 200 µs. The ratio p_{md}/p_i, with regard to mixture and pipe size, shall correspond to the values given in Table 6 with a maximum deviation of ± 20 %.

NOTE 1 When p_{md}/p_i exceeds the quoted values of Table 6 by more than 20 % and flame transmission occurs the detonation might still be overdriven and a longer pipe or turbulence promoting equipment should be used.

Table 6 — The ratio p_{md}/p_i

Explosion group	Ratio p_{md}/p_i Nominal Pipe diameter mm			
	D ≤ 80[a)]	80 < D ≤ 150	150 < D < 400	D ≥ 400
IIA	10	12	14	16
IIB1	10	12	14	16
IIB2	10	12	14	16
IIB3	10	12	14	16
IIB	8	10	10	12
IIC	8	8	8	8

[a)] If for nominal pipe diameters ≤ 80 mm the quoted pressure ratio is not achieved, tests shall be carried out using a gas/air-mixture of a lower safe gap to qualify the arrester as a detonation flame arrester.

In addition, three deflagration tests shall be carried out according to 6.3.2.2. The pipe length L_{ni} shall be 50 × D for hydrocarbon-air mixtures (IIA, IIB1, IIB2, IIB3) and 30 × D for hydrogen-air mixtures (IIB and IIC). The ignition source may also be mounted to the wall of the unprotected side pipe.

The pipe length L_i or the distance between the ignition source and the flame arrester shall be developed so that the deflagration pressure p_e, at the time when the flame front arrives at the pressure transducer, is in the following range:

$2 \times p_i \leq p_e \leq 0{,}8 \times p_{md}$, where p_{md} is taken from Table 6 with regard to the actual p_i.

NOTE 2 As a starting point, a pipe length L_i slightly longer than L_{ni} is recommended.

The initial pressure, deflagration and stable detonation pressure, the values of p_{md}/p_i and also flame velocities recorded during all tests shall be reported.

A stable detonation flame arrester shall prevent flame transmission in any of the stable detonation and deflagration tests.

6.3.3.3 Unstable detonation

The nominal pipe diameter D shall have the same size as the flame arrester connection. The pipe on the unprotected side shall have a length L_i sufficient to develop an unstable detonation and shall have a pipe end or an explosion proof container fitted with an ignition source. The ignition source may be mounted to the wall of the unprotected pipe. The pipe may also contain a flame accelerator to reduce the pipe length for unstable detonation conditions.

The pipe length and configuration on the unprotected side and the location of the ignition source shall, after ignition, produce an unstable detonation at the detonation flame arrester.

The pipe on the protected side shall have a length L_{ni} of $10 \times D$, and not less than 3 m. The pipe end shall resist the shock pressures during testing.

Four flame detectors and a pressure transducer shall be fitted to the pipe on the unprotected side to record flame velocities and pressures respectively. One flame detector shall not be more than 200 mm from the flame arrester connection. One flame detector shall be fitted to the pipe on the protected side to indicate flame transmission.

For the purposes of this standard a characteristic of an unstable detonation is the transient pressure peak with or without a leading shock wave, showing in a time interval of 200 µs, the mean value p_{mu} of the detonation pressure of not less than $2{,}5 \times p_{md}$ for pipe diameters < 100 mm and $3 \times p_{md}$ for pipe diameters ≥ 100 mm. Values of p_{md} shall be taken from Table 6 with regard to p_i.

NOTE 1 The unprotected side pipe length and configuration for these tests can be found by varying the distance between the ignition source and the flame arrester until the recorded flame velocities reach a maximum (above those of stable detonations). The distribution of more than four flame detectors along the pipe will make it easier to find the transition point. Direct initiation, e.g. by solid detonators, or long accelerator sections should be avoided.

The apparatus shall be filled with a test mixture as specified in 5.8.2 at a pressure p_i when $p_I \geq p_0$.

Under these conditions five tests shall be carried out.

In addition, three deflagration tests shall be carried out according to 6.3.2.2. The pipe length L_{ni} shall be $50 \times D$ for hydrocarbon-air mixtures (IIA, IIB1, IIB2, IIB3) and $30 \times D$ for hydrogen-air mixtures (IIB and IIC). The ignition source may also be mounted to the wall of the unprotected side.

The pipe length L_i or the distance between the ignition source and the flame arrester shall be developed so that the deflagration pressure p_e, at the time when the flame front arrives at the pressure transducer, is in the following range:

$2 \times p_i \leq p_e \leq 0{,}8 \times p_{md}$, where p_{md} is taken from Table 6 with regard to the actual p_i.

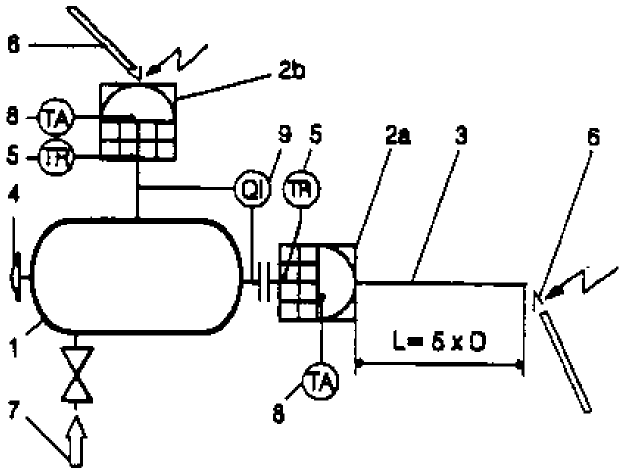
NOTE 2 As a starting point, a pipe length L_i slightly longer than L_{ni} is recommended.

The initial pressure, deflagration and unstable detonation pressures and also flame velocities shall be reported.

An unstable detonation flame arrester shall prevent flame transmission in any deflagration and unstable detonation tests.

6.3.4 Short time burning test

The test apparatus is shown in Figure 5 for an in-line and end-of-line flame arrester.



Key

1 Explosion proof container
2a In-line flame arrester
2b End-of-line flame arrester
3 Outlet pipe
4 Bursting diaphragm
5 Temperature sensor for tests only
6 Pilot flame or spark igniter
7 Mixture inlet
8 Integrated temperature sensor
9 Flame detector

Figure 5

A flow-meter shall control the mixture flow rates.

The flame arrester shall be fitted with a test temperature sensor for the test only. It shall be fitted close to the surface of the flame arrester element on the protected side close to the centre of the cross-sectional area of the flow. The temperature reading from the integrated temperature sensor(s) shall be recorded.

The tests shall be carried out using a test mixture as specified in 5.8.2. The flow rates used shall be obtained by calculating the open area A_0 of the surface of the flame arrester element on the unprotected side from the size and number of apertures per unit area. Assuming a uniform velocity of 75 % of the laminar burning velocity v_l of the mixture across this area, calculate a critical flow rate $\overset{\circ}{V}_c$, see equation (1).

$$\overset{\circ}{V}_c = 0{,}75 \times A_0 \times v_l \qquad (1)$$

(v_l = 0,5 m/s for IIA and IIB; v_l = 3 m/s for IIC)

For non-measurable flame arrester elements the critical flow rate $\overset{\circ}{V}_c$ may be obtained by using the same principle. The free area A_0 of the flame arrester element surface can be estimated as:

$$A_0 = R_U \times A_t$$

where:

R_U is the ratio of the free volume of the flame arrester element to the whole volume, and

A_t is the cross-sectional area on the unprotected side of the flame arrester element, in mm^2.

Short time burning tests shall be carried out with a continuously operated pilot flame or spark. Ignite the mixture until the flame has stabilized on the surface of the flame arrester element. Record the time response of the temperature sensor as well as all integrated temperature sensors after flame stabilization up to a total of 1 min; then stop the flow. No flame transmission shall occur during the tests or when the flow is stopped.

Carry out this test procedure with flow rates $\mathring{V}_{\mathrm{c}}$, $0{,}5 \times \mathring{V}_{\mathrm{c}}$ and $1{,}5 \times \mathring{V}_{\mathrm{c}}$. If $\mathring{V}_{\mathrm{c}}$ results in the highest 1 min temperature reading of the three tests, then $\mathring{V}_{\mathrm{m}} = \mathring{V}_{\mathrm{c}}$. If not carry out two further tests with flow rates 50 % and 150 % of the flow rate, which gave the highest reading in the first three tests. $\mathring{V}_{\mathrm{m}}$ will be the flow rate, which resulted in the highest temperature reading in all five tests. When determining the flow rate $\mathring{V}_{\mathrm{m}}$, flame arrester elements may be replaced between the tests. If the flame arrester elements have been replaced, a final test shall be carried out with the flow rate $\mathring{V}_{\mathrm{m}}$ using the original flame arrester element, without modification, which has been used for the deflagration and/or detonation test.

In any of the tests at least one of the integrated temperature sensors (8) shall record a temperature rise not less than 60 K after a burning time of not more than 30 s.

If no temperature rise occurs, relocate the position of the test temperature sensor (5), taking into account the position of the stabilized flame. Alternatively, fit the temperature sensor directly to the unprotected side of the flame arrester element in a position near to the stabilized flame.

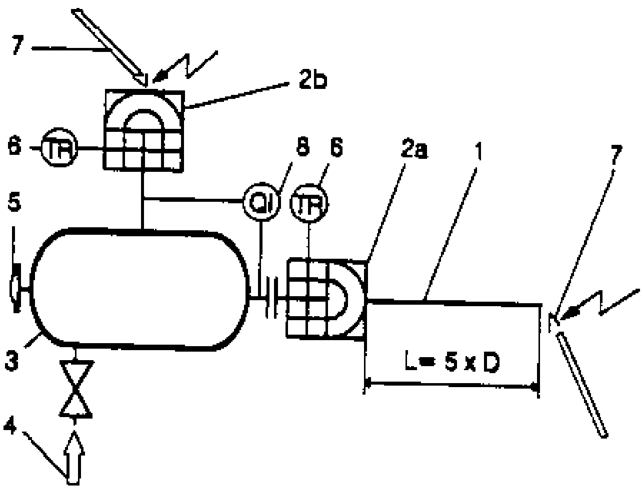
A flame transmission is indicated by the flame detector (9). No flame transmission shall occur in any of the tests.

If the largest and smallest nominal size of a design series are satisfactorily tested, the intermediate nominal sizes may be considered acceptable without testing.

Each size larger than 400 mm shall be tested.

6.3.5 Endurance burning test

The test apparatus is shown in Figure 6 for an in-line and end-of-line flame arrester.



Key

1 Outlet pipe
2a In-line flame arrester
2b End-of-line flame arrester
3 Explosion proof container
4 Mixture inlet
5 Bursting diaphragm
6 Temperature sensor for tests only
7 Pilot flame or spark igniter
8 Flame detector

Figure 6

The tests shall be carried out using a mixture as specified in 5.8.2.

Applications for chemicals other than pure hydrocarbons (e.g. alcohols, ketones, etc.) refer to 12.1 d).

Determine the volume flow rate $\mathring{V}_m$ according to 6.3.4. No integrated temperature sensors are required. The following test shall be carried out by using the original flame arrester element without modification which had been used for deflagration or detonation tests. Maintain the mixture composition and the flow rate $\mathring{V}_m$ (± 5 %) until a stable temperature is established. The highest temperature may be considered to have been reached when the average rate of temperature rise does not exceed 10 K in 10 min. The flow of the mixture shall be stopped when a stable temperature is established but not before 2 h of burning.

The flame detector (8) shall indicate any flame transmission. No flame transmission shall occur during the test, or when the flow is stopped.

All types and nominal sizes shall be tested.

6.4 Limits for use

6.4.1 General

Operational temperature T_0 and operational (absolute) pressure P_0 shall be limited as follows:

– Testing at atmospheric conditions.

  – -20 °C ≤ T_0 ≤ 60 °C when testing is at ambient temperature (T_i ≤ 60 °C).

  – $0{,}8 \times 10^5$ Pa ≤ p_0 ≤ $1{,}1 \times 10^5$ Pa when testing is at ambient pressure ($p_l \sim 10^5$ Pa absolute).

– Testing at elevated temperature and pressure.

  – $T_0 \leq T_i$ but T_0 not higher than the ignition temperature of the gas/air-mixture to be used, when testing is at elevated temperature T_i of the flame arrester (60 °C < T_i ≤ 150 °C).

  – $p_0 \leq p_l$ ($p_l \leq 1{,}6 \times 10^5$ Pa absolute).

The use shall be limited to gas/air-mixtures with an MESG equal to or greater than that tested. For endurance burning and for chemicals other than hydrocarbons (e.g. alcohols, ketones etc.) refer to 12.1 d).

6.4.2 In-line deflagration flame arrester

The use of in-line deflagration flame arresters tested according to 6.3.2.2 shall be limited to the following conditions:

1) At least 10 % of the cross-sectional area of the pipe shall be open at the ignition source.

2) The ratio of pipe length (between the potential ignition source and the flame arrester) and pipe diameter shall not exceed the tested ratio L_i/D.

3) Pipe branches and valves on the unprotected side shall be installed as close as possible to the in-line deflagration flame arrester.

4) The pipe diameter on the unprotected side shall be no larger than the flame arrester connection. The pipe diameter on the protected side shall be no less than the pipe diameter on the unprotected side.

6.4.3 Pre-volume flame arrester

The use of pre-volume flame arresters shall be limited to enclosures, contents and pipework on the unprotected side as used or simulated in the test.

6.4.4 Detonation flame arrester

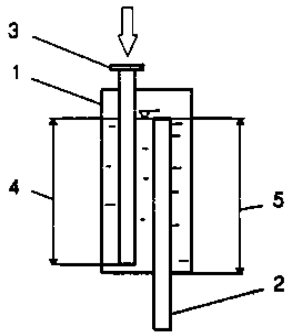
Detonation flame arresters may be used for open and closed pipework on the unprotected side.

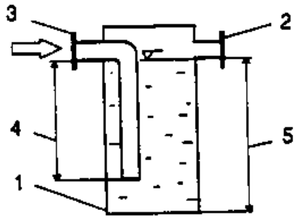
A flame arrester which is successfully tested for unstable detonations and deflagrations at p_i is suitable for stable detonations for operational pressure $p_0 \leq p_i$ in the same or smaller nominal pipe size when the application is limited to mixtures with an MESG equal to or greater than that tested.

7 Specific requirements for liquid product detonation flame arresters

7.1 Liquid seals

A flame arrester consisting of a liquid seal formed by the liquid product may be an end-of-line [see Figure 7a)] or an in-line flame arrester [see Figure 7b)].





Key

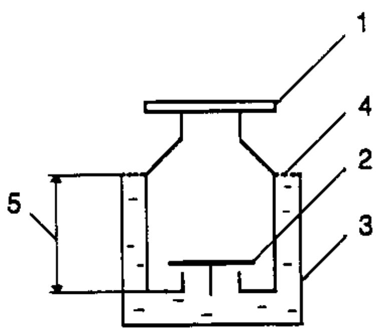
1 Housing
2 Overflow pipe/outlet pipe
3 Immersion pipe
4 Immersion depth
5 Filling height

Figure 7 a) **Figure 7 b)**

The housings for liquid seals suitable for emptying operations shall incorporate a safety device which prevents loss of the sealing liquid.

7.2 Foot valves

An end-of-line flame arrester incorporating a non-return valve (foot valve) in an immersion cup, providing an immersion depth of not less than that specified by the manufacturer. A screen or perforated plate shall protect the valve seal from solid particles.



Key

1 Valve housing
2 Valve disk
3 Immersion cup
4 Perforated plate or screen
5 Immersion depth

Figure 8

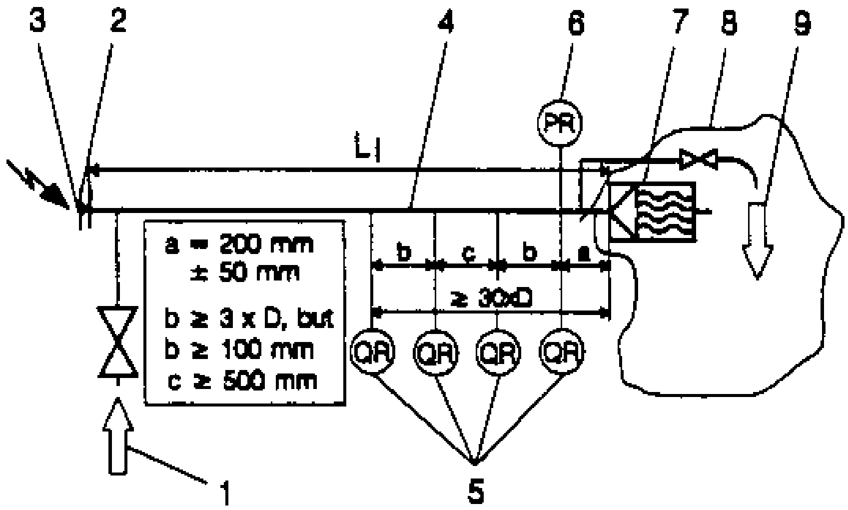
7.3 Flame transmission test

The test apparatus is shown in Figure 9.

Liquid product detonation flame arresters shall be tested under atmospheric conditions for detonations only. The flame arrester shall be filled either with the liquid to be used in operation or, alternatively with gasoline having a boiling range from 125 °C to 140 °C. These liquids may also be used in tests for group IIB mixtures. The filling height shall be recorded, see Figure 7 or 8.

In-line and end-of-line flame arrester shall be tested according to 6.3.3.2 and if necessary to 6.3.3.3.

The flame arrester test shall be carried out in the orientation required in service.



Key

1 Mixture inlet
2 Explosion proof container
3 Ignition source
4 Unprotected pipe (length L_i, diameter D) with by-pass
5 Flame detectors for flame velocity measurement
6 Pressure transducer
7 Liquid product detonation flame arrester
8 Plastic bag: diameter ≥ 1,2 m, length ≥ 2,5 m, foil thickness ≥ 0,05 mm
9 Mixture outlet (by-pass)

Figure 9

7.4 Limits for use

If a liquid product detonation flame arrester is satisfactorily tested for detonations it may be considered acceptable for deflagrations without further testing. The operation shall be limited to atmospheric conditions.

Liquid product detonation flame arresters suitable for emptying operations shall have the flow rate restricted so that the pressure drop does not exceed the static pressure given by the immersion depth (see 7.1). For filling operations there are no limitations.

8 Specific requirements for high velocity vent valves

8.1 Flame transmission test

High velocity vent valves shall be tested for endurance burning and deflagration. All types and sizes shall be tested.

The opening and closing pressure of the valve shall be specified. High velocity vent valves with an adjustable opening and closing pressure shall be tested at the lowest closing pressure used in service.

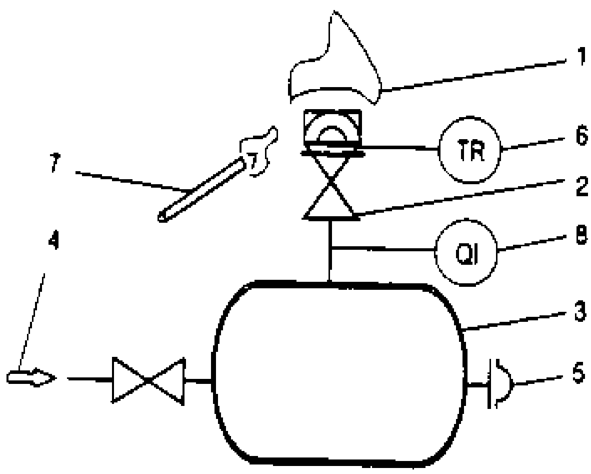
NOTE Adjustable: the setting can be changed but without making any changes to the form and shape of the valve housing and the physical appearance of any component, (e.g. by changing the magnet power, spring compression, etc.). The spring wire diameter need not be taken into consideration.

8.2 Endurance burning test

The test apparatus is shown in Figure 10. The pipe length between the explosion proof container and valve shall not exceed L_m. A temperature test sensor shall be attached to the high velocity vent valve as close as possible to the stabilized flame. Ignition shall be maintained by a permanent pilot flame positioned as close as possible to the mixture outlet. Using a gas/air mixture as specified in 5.8.2 the pressure in the container shall be increased to force the high velocity vent valve open and then maintained at 10 % higher than the established closing pressure. The corresponding flow rate $\mathring{V}_0$ shall be recorded. If no stabilized burning is possible under these conditions, the mixture shall be gradually enriched until the flame is stabilized. Without changing that mixture composition the flow shall be increased in increments of 20 % of $\mathring{V}_0$ and after each increment the flow shall be maintained until the temperature rise is less than 10° K/min.

When the temperature starts to decrease, the corresponding flow $\mathring{V}_E$ is the maximum flow to be used in this test. The flow shall then be reduced in increments of 10 % of $\mathring{V}_0$ and after each step shall be maintained until the temperature change is less than 10° K/min. Flow rates for which the corresponding temperature has been recorded need not be repeated and tests need not be made at flow rates below $\mathring{V}_0$. Upon completion, the flow rate yielding the highest temperature shall be recorded as $\mathring{V}_m$ and the burning at that rate shall be continued until the change of temperature indicated by the test temperature sensor does not exceed 10° K in 10 min.

For enriched mixtures, the concentration of fuel shall be gradually reduced as far as possible towards the initial value (see Table 4) keeping the flame stabilized. The flow shall be stopped and no flame transmission shall occur.



Key

1 Flame
2 High velocity vent valve
3 Explosion proof container
4 Mixture inlet
5 Bursting diaphragm
6 Temperature sensor for tests only
7 Pilot flame or spark igniter
8 Flame detector

Figure 10

8.3 Deflagration test

These tests shall be carried out according to 6.3.2.1 immediately after the endurance burning test.

8.4 Additional burning test

The test apparatus is shown in Figure 10. The pipe length between the container and valve shall not exceed L_m. A test temperature sensor shall be attached to the high velocity vent valve as close as possible to the stabilized flame. Ignition shall be maintained by a pilot flame positioned as close as possible to the mixture outlet. Using a gas/air-mixture as specified in 5.8.2, five tests at small flow rates shall be carried out with each test for a period of not less than 10 min.

The flow rate shall be calculated as follows.

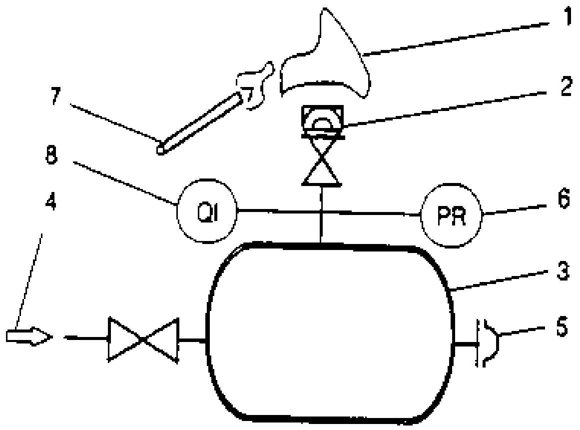
Using the flow measurement according to 5.7, the max. volume flow rate corresponding to the set pressure shall be recorded as $\mathring{V}_K$. If at the set pressure no volume flow rate is measurable, $\mathring{V}_K$ shall be set to 1 000 m^3/h. The first test shall be carried out at a volume flow rate which is 1 % of $\mathring{V}_K$ and the following tests shall be carried out at 2 %, 3 %, 4 % and 5 % of $\mathring{V}_K$.

No flame transmission shall occur during the test.

8.5 Flame transmission test by opening and closing

The test apparatus is shown in Figure 11. The high velocity vent valve shall be subjected to 50 open/closed cycles, using a gas-/air-mixture as specified in 5.8.2, Table 3, and the period from open to closed shall not be less than 3 s. During the 50 cycles the mixture shall be ignited by a pilot flame close to the outlet.

No flame transmission shall occur during the test.



Key

1 Flame
2 High velocity vent valve
3 Explosion proof container
4 Mixture inlet
5 Bursting diaphragm
6 Pressure sensor
7 Pilot flame or spark igniter
8 Flame detector

Figure 11

8.6 Limits for use

The use of a high velocity vent valve shall be limited to ambient temperatures. The pipe length on the protected side shall not exceed L_m determined in A.4.

9 Specific requirements for flow controlled apertures

9.1 Equipment

Flow controlled apertures shall be manufactured with an integrated temperature sensor at the outlet in contact with the inner surface.

9.2 Flame transmission test

The test apparatus is shown in Figure 6.

The flow controlled aperture outlet shall be heated to and maintained at the intended maximum operational temperature T_m by means of an external heater and/or by a stabilized flame. Having stabilized the temperature T_m, a gas/air-mixture according to 5.8.2 at ambient temperature shall be introduced into the flow controlled aperture with a flow rate which, after ignition, enables stabilized burning to take place. Keeping the gas concentration constant, the flow rate shall be decreased until flame transmission occurs. The test shall be repeated three times and the largest volume flow rate which led to flame transmission shall be recorded as $\overset{\circ}{V}_t$. The flow rate $\overset{\circ}{V}_s$, for safe operation, shall be calculated according to equation (2).

$$\overset{\circ}{V}_s = 1{,}5 \times \overset{\circ}{V}_t \qquad (2)$$

9.3 Limits for use

The use of a flow controlled aperture shall be limited to conditions where a minimum volume flow rate of $\overset{\circ}{V}_s$ is guaranteed as long as the gas/air-mixture is in the flammable concentration range. Temperature and pressure of the flammable mixture shall be ambient.

The maximum temperature indicated by the integrated temperature sensor shall not exceed T_m.

10 Specific requirements for hydraulic flame arresters

10.1 Equipment

Hydraulic flame arresters are in-line flame arresters and consist of a mixture inlet (3), a container (1) with a water seal (12), one or more immersion pipe(s) (2) and a mixture outlet (16). An example is shown schematically in Figure 12. The design and construction shall ensure that the immersion depth is always constant within ± 5 mm.

Hydraulic flame arresters shall include the following features:

a) a level indicator with an optical display (4) for the immersion depth at rest (Z_R) and the operational immersion depth (Z_0);

b) automatic equipment (5) to maintain the water level above the minimum operational immersion depth (Z_{0min});

c) a temperature sensor (8) for the water seal;

d) an integrated temperature sensor (7) above the water seal (12) to indicate a stabilized flame.

10.2 Flame transmission test

10.2.1 General

Hydraulic flame arresters shall be tested for short time burning, deflagration and stable detonation in succession. Before ignition, mixtures shall be at ambient conditions on the unprotected side. Each test shall be carried out with the minimum immersion depth at rest (Z_{Rmin}) and with the minimum operational immersion depth (Z_{0min}) given by the manufacturer. The flow rate of the mixture shall be recorded with a sensor (9) at the inlet, and flame transmission shall be detected with a flame detector (18) in the inlet pipe.

10.2.2 Short time burning test

The test apparatus is shown in Figure 12 with the mixture outlet pipe (6) removed if necessary.

The ignition source (14) shall be positioned 100 mm ± 20 mm above the water seal (12). The test shall be carried out for not less than 5 min with a water seal temperature of ≥ 10 °C at which time the temperature shall remain ≤ 30 °C.

The safe volume flow rate $\overset{\circ}{V}_{max}$ shall be determined for the minimum immersion depth at rest (Z_{Rmin}) and the minimum operational immersion depth (Z_{0min}) at which no flame transmission occurs. Four tests shall be carried out with $\overset{\circ}{V}_{max}$. No flame transmission shall occur in any of the tests.

10.2.3 Deflagration test

The test apparatus is shown in Figure 12 with the mixture outlet pipe (6) in place and equipped with two flame detectors (18) in a straight part of the pipe close to the mixture outlet (16) (see also Figure 2 in 6.3.2.2).

The maximum diameter D of the mixture outlet pipe (6) shall be used for all tests for which the hydraulic flame arrester is acceptable. The ignition source (13) shall be positioned at the open end of the mixture outlet pipe (6).

Tests shall be carried out by using a test mixture as specified in 5.8.2.

The deflagration test shall be carried out at the minimum immersion depth at rest (Z_{Rmin}) and minimum operational immersion depth (Z_{0min}) with the mixture flow rate at $\overset{\circ}{V}_{max}$ as determined in 10.2.2. The test shall be carried out with the following lengths of mixture outlet pipe (6):

$L_i = 50 \times D$
$L_i = 100 \times D$

Carry out three tests on each length.

If flame transmission takes place, the flow shall be reduced to a level where no flame transmission occurs. This reduced flow shall then be recorded as $\overset{\circ}{V}_{max}$.

10.2.4 Detonation test

The test apparatus is shown in Figure 12 with the mixture outlet pipe (6) in place and equipped with four flame detectors (15) in the straight part of the pipe close to the outlet (16) (see also Figure 4 in 6.3.3.2). All tests shall be carried out with the mixture outlet pipe (6) with the maximum diameter D for which the hydraulic flame arrester shall be used.

The mixture outlet pipe (6) shall have a blind flange equipped with an ignition source (13). The mixture outlet pipe (6) shall have sufficient length to develop a stable detonation (see 6.3.3.2 for further details).

Tests shall be carried out by using a test mixture as specified in 5.8.2.

Carry out three detonation tests with the mixture at rest and with the minimum immersion depth at rest (Z_{Rmin}) and with the minimum operational immersion depth (Z_{0min}), for which the hydraulic flame arrester is acceptable.

No flame transmission shall occur in any of the tests.

10.3 Limits for use

The use of a hydraulic flame arrester shall be limited to the following conditions:

1) The flow rate does not exceed the safe value $\overset{\circ}{V}_s = 0{,}9 \times \overset{\circ}{V}_{max}$;

2) The operational immersion depth is kept above the tested minimum value Z_{0min};

3) The mixture on the unprotected side is at ambient temperature and pressure.

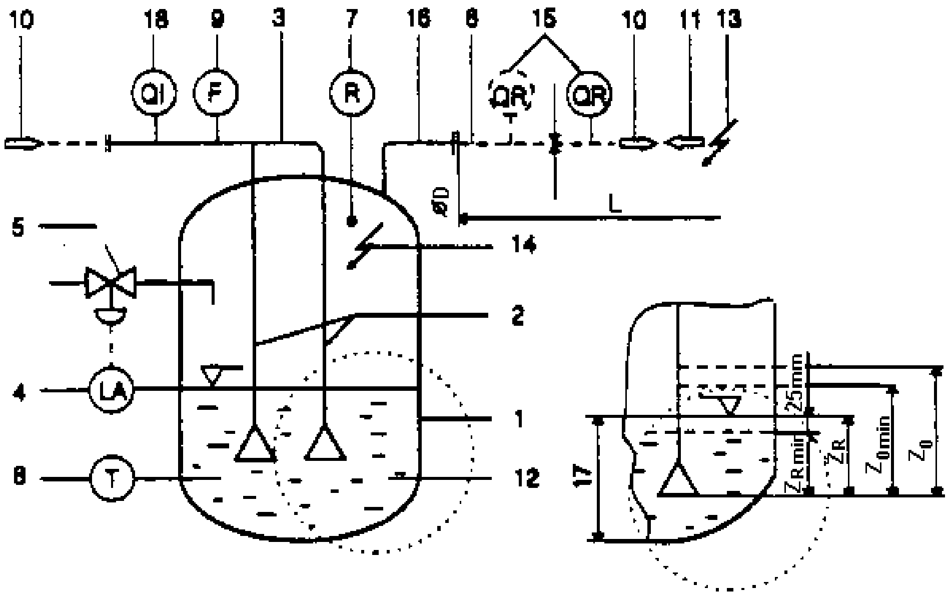
Failure of any of the above equipment as 10.1 a) to d) inclusive, shall operate an alarm and stop the gas flow.

If any temperature 10.1 c) and/or d) exceeds or falls below the specified limits, or the minimum operational immersion depth Z_{0min} falls below the specified level, or the volume flow exceeds $\mathring{V}_s$, the flow shall be stopped within 30 s.

If for operational reasons the mixture flow cannot be stopped it shall be inerted.

The immersion depth at rest Z_R and the operational immersion depth Z_0 shall not be less than the manufacturer's recommended safety margin and higher than the minimum water seal immersion depth at rest Z_{Rmin} and the minimum operational water seal immersion depth Z_{0min} at which the maximum volume flow $\mathring{V}_{max}$ has been established.

The operational immersion depth Z_0 shall be maintained by automatic control of the water supply (5) to ensure that the minimum operational immersion depth Z_{0min} is not reached.



Key

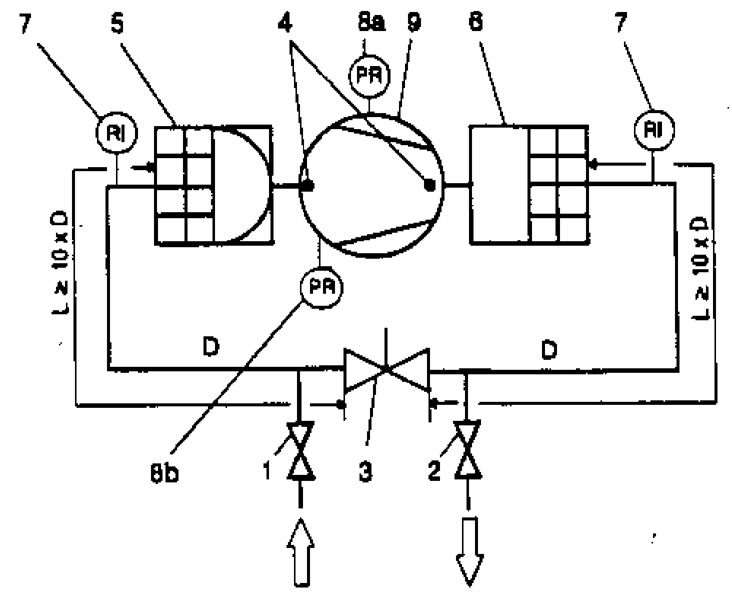
1 Container for the hydraulic flame arrester medium
2 Gas or vapour mixture immersion pipe(s)
3 Gas or vapour mixture inlet
4 Water seal (12) level indicator with an optical display
5 Automatic water seal level control
6 Mixture outlet pipe (length L, diameter D)
7 Temperature sensor to indicate a stabilized flame above the water seal (12)
8 Water seal temperature sensor
9 Mixture volume flow sensor
10 Direction of mixture flow
11 Direction of flame propagation
12 Water seal
13 Ignition source for flame transmission tests
14 Ignition source for stabilized burning tests
15 Flame detector for flame velocity measurement
16 Mixture outlet
17 Filling height
18 Flame detector to indicate flame transmission

Figure 12

11 Specific requirements for testing flame arresters in equipment

11.1 Flame transmission test in compressors, including blowers, fans and vacuum pumps

The test apparatus is shown in Figure 13.



Key

1 Mixture inlet
2 Mixture outlet
3 Throttling valve
4 Ignition positions
5 Inlet flame arrester
6 Outlet flame arrester
7 Flame detector
8a Pressure transducer (operational pressure)
8b Pressure transducer (explosion pressure)
9 Equipment to be tested

Figure 13

The nominal pipe diameter *D* shall not be larger than the diameter of the flame arrester connection. The tests shall be carried out under running conditions with a gas/air-mixture as specified in 5.8.2. The apparatus shall be filled with the gas/air-mixture at the maximum operational pressure.

The flame arrester on the inlet side shall be tested for short time burning according to 6.3.4.

The equipment shall be operated at maximum speed allowing the mixture to circulate by opening the throttling valve. Then disconnect the mixture supply and ignite.

The ignition source shall be positioned as near as possible to the moving parts in the inlet and outlet system. For each position (inlet and outlet), tests shall be carried out adjusting the throttling valve to fully open (two tests), approximately half open (two tests) and fully closed or at maximum operational pressure (four tests).

No flame transmission shall occur in the inlet or exhaust sections in any of the eight tests.

12 Information for use

12.1 Accompanying documents

The manufacturer shall provide the following minimum written instructions:

a) The information marked on the flame arrester.

b) Information concerning the classification of the flame arrester as outlined in clause 4.

c) All details of the operational requirements including the specific limits according to 6.4, 7.4, 8.5, 9.3 and 10.3 as appropriate. The maximum operational temperature and pressure shall be given.

d) Static flame arresters classified as safe for endurance burning shall include a warning that safe use is limited to hydrocarbons and extension to other chemicals may require specific tests.

e) Short time burning flame arresters, hydraulic flame arresters and flow controlled apertures shall include a warning that additional external safety equipment is required.

f) A full description of installation and maintenance procedures. Maintenance shall include cleaning instructions and the procedure to be followed after deflagration, detonation or stabilized burning conditions have taken place.

12.2 Marking

The flame arrester shall be marked with the following information:

a) Name and address of the manufacturer.

b) Designation of series or type.

c) Serial number.

d) Year of construction [if not incorporated in c)].

e) Certificate number.

f) EN-number.

g) Explosion (sub-)group.

h) Set pressure and/or set vacuum for flame arresters with integrated pressure and/or vacuum valve or for high velocity vent valves.

i) Protected side (directional types only).

j) Maximum flow rate (hydraulic flame arresters) or minimum flow rate (flow controlled apertures).

The flame arrester element shall be marked with the above or as a minimum with the following information:

k) Name of manufacturer or trade mark.

l) Manufacturer's type or code.

m) Year of construction [if not incorporated in l)].

n) Protected side (directional flame arresters only).

Compliance with this standard [item e) and f)] shall not be stated unless all appropriate requirements of the standard are met.

Manufacturers and users shall ensure that any marking is legible and labels and attachment devices are durable and resistant to environment corrosion under operating conditions.

Annex A
(normative)

Flow measurement

A.1 General

The test procedure shall be generally in accordance with EN 1267 taking into consideration the specific requirements of different designs of flame arrester.

The pipes as well as the connections between the pipes and the flame arrester shall be smooth and without obstructions causing additional turbulence.

The nominal size D of the test pipes (L_1, L_2, L_3 and L_4) shall be the same size as the flame arrester or high velocity vent valve connection.

All pressure measuring points shall be arranged normal to the pipe axis and shall not influence the flow.

The test medium shall be air at ambient conditions.

Ambient pressure and temperature shall be recorded to convert flow rate to normal conditions.

A mass flow-meter may be used to obtain a flow rate/pressure drop curve with a minimum of 10 suitably spaced readings from stationary flow conditions.

All measuring instruments shall be calibrated.

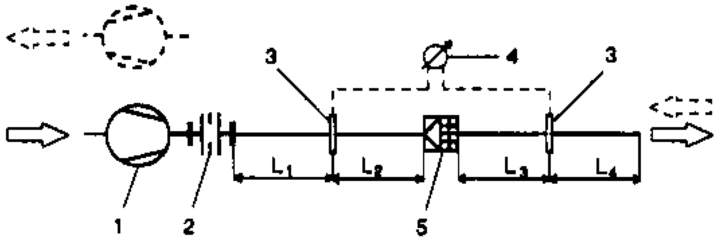
Separate flame arresters and pressure and/or vacuum valves which are combined and used together shall be flow tested together as a single unit.

A.2 In-line flame arresters

The test apparatus is shown in Figure A.1. The test pipes shall have the following lengths:

L_1 and $L_4 \geq 10 \times D$; L_2 and $L_3 = 2 \times D$

The flow rate shall be increased in suitable steps up to the maximum requested by the manufacturer or user. The pressure drop for each step shall be recorded [Figure A.1, (4)].



Key

1 Blower or fan
2 Flow-meter
3 Pressure measurement points
4 Differential pressure measurement
5 In-line flame arrester
$L_{(1\text{-}4)}$ Length of apparatus pipes

Figure A.1 — Test apparatus for flow testing in-line flame arresters

A.3 End-of-line flame arresters

The test apparatus is shown in Figure A.2. The diameter of the tank (3) shall be sufficient to allow a mean flow velocity of less than 0,5 m/s in the tank. All tank pressure data (p_T) shall be recorded under these conditions.

The test pipe L_1 shall have a length $\leq 10 \times D$. If reduction pipes are used they shall not cause additional turbulence or restriction to flow.

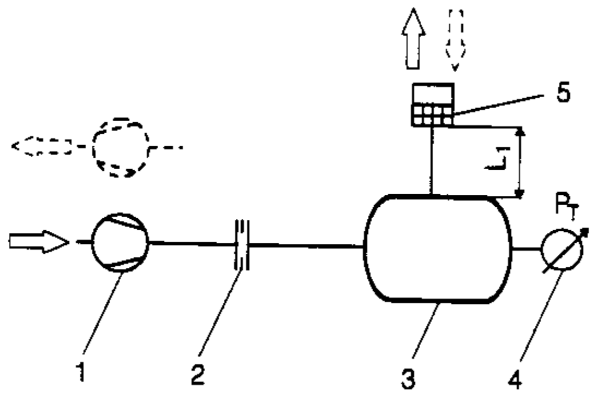
The flow rate shall be increased in suitable steps up to the maximum requested by the manufacturer. The pressure drop p_T for each step shall be recorded [Figure A.1, (4)].

End-of-line flame arresters with integrated pressure and/or vacuum valves (Figure A.2) shall have the flow rate/pressure drop curve start at the set pressure (opening pressure) and be increased in suitable steps up to the maximum flow rate requested by the manufacturer.

Vacuum valves shall have the direction of flow reversed.

The pressure or vacuum side of the blower may be used for in-line flame arresters.

The flow measurements for high velocity vent valves shall be made with the lowest and highest opening setting available for the particular model without a change of setting constituting a modification as defined in note 8.1. The flow rate/pressure drop curve shall start at the set pressure (opening pressure) and the flow rate shall be increased in suitable steps up to the maximum requested by the manufacturer.



Key

1 Blower or fan
2 Flow-meter
3 Tank
4 Pressure measurement
5 End-of-line flame arrester
L_1 Length of connecting pipe

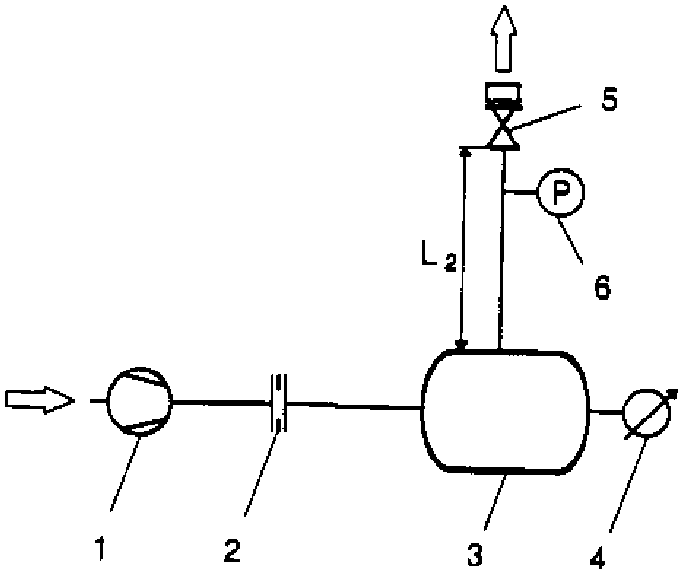
Figure A.2 — Test apparatus for flow testing end-of line flame arresters with or without integrated pressure and/or vacuum valve

A.4 Undamped oscillation tests (high velocity vent valves)

High velocity vent valves (5) shall be tested for undamped oscillations. The test apparatus is shown in Figure A.3.

This test shall be carried out with the lowest and highest opening setting available for the particular model without a change of setting constituting a modification as defined in the note in 8.1.

The length of pipe L_2 shall be requested by the manufacturer. The tests shall be carried out for 5 min each at 10 equally spaced flow rates starting at 10 % above the set pressure up to the flow rate where the valve is fully open. If the pressure sensor (6) indicates undamped oscillations the pipe length (L_2) shall be shortened until the oscillations cease. That length shall be recorded as L_m. Bends may be neglected.



Key

1 Blower or fan
2 Flow-meter
3 Tank
4 Pressure measurement
5 High velocity vent valve
6 Pressure sensor
L_2 Length of vent pipe

Figure A.3 — Test apparatus for flow testing high velocity vent valves

Annex B
(normative)

Graphic symbols for flame arresters

Table B.1

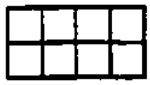
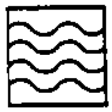
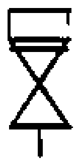
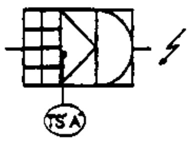
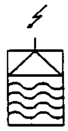
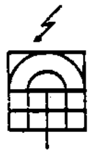
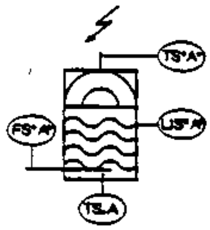
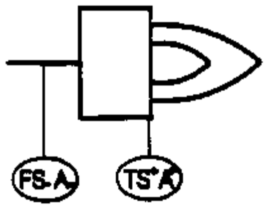
1	General	Symbol
1.1	Static flame arrester	
1.2	Liquid flame arrester	
1.3	Unprotected side deflagration	
1.4	Unprotected side stable detonation (including deflagration)	
1.5	Unprotected side unstable detonation (including deflagration and stable detonation)	
1.6	Unprotected side short time burning (including deflagration)	
1.7	Unprotected side endurance burning (including deflagration)	
1.8	High velocity vent valve (including deflagration)	

Table B.1 *(continued)*

2.	Examples	Symbol[a)]
2.1	In-line detonation flame arrester (preventing flame transmission, stable detonation and short time burning)	
2.2	End-of-line liquid product flame arrester (preventing flame transmission, stable detonation)	
2.3	End-of-line endurance burning flame arrester	
2.4	Hydraulic flame arrester (preventing flame transmission, deflagration and endurance burning)	
2.5	High velocity vent valve (preventing flame transmission, deflagration and endurance burning)	
2.6	Flow controlled aperture	
[a)] Ignition symbols indicate the direction of the approaching flame front and are not part of the symbol.		

Annex C
(informative)

Guidelines for specifying flame arresters

To help manufacturers and users decide which flame arrester is the most suitable for their application, the following should be considered:

1.	Service:	Provide a brief description of the intended use for the flame arrester.
2.	Analysis of gases or vapours:	Provide full details of flammable and non-flammable components; which will allow the correct flame arrester design, explosion group and choice of materials to be made.
3.	Molecular weight or density of gas or vapour:	This will allow an equivalent air flow rate to be calculated for pressure drop determination.
4.	Flow rate:	This should be in volumetric terms, or sufficient information provided to allow a volumetric flow rate to be calculated. For storage tank applications the inbreathing and outbreathing requirements should be given, or sufficient information on the tank type, pressure resistance shape, dimensions, fill and empty rates provided to enable these parameters to be calculated.
5.	Temperature ranges:	For both design and operating conditions, the maximum and minimum temperatures will allow the correct element and mechanical design of the flame arrester housing to be made.
6.	Pressure ranges:	For both design and operating conditions, the maximum and minimum pressures will allow the correct flame arrester element and mechanical design of the flame arrester housing to be made. The maximum pressure at which a flammable mixture can ignite in the process should be highlighted if this is different to the normal operating pressure. For storage tank applications the pressure and vacuum requirements should be given.
7.	Allowable pressure drop:	This will enable the correct flame arrester configuration to be provided and is determined from the volumetric flow rate.
8.	Type:	Specify in-line, end-of-line, pre-volume, short time or endurance burning safe and stable/unstable detonation as required. For in-line types details of the piping between the flame arrester and possible source of ignition should be supplied in the form of a dimensioned sketch or isometric drawing.
9.	Orientation:	State the intended orientation of the flame arrester.
10.	Pipe size:	The nominal size of the connecting pipework should be stated.
11.	Connection type:	Provide details of the flanged or screwed connections.
12.	Housing material:	State the preferred material of construction; this may be checked by the manufacturer from an evaluation of the mixture composition and operating conditions.
13.	Element material:	State the preferred material of construction; this may be checked by the manufacturer from an evaluation of the mixture composition and operating conditions.
14.	Construction:	Care should be taken when using materials such as aluminium or plastics which can cause incentive sparking or electrostatic charging.
15.	Documentation:	State documentation requirements.

Annex D
(informative)

Best practice

Manufacturers and users should be aware of the following:

1) Flame velocities and pressures of flammable mixtures can be enhanced by upstream turbulence which can be caused by bends, valves or any change of section in the pipe. Pipelines should be as straight as possible without obstructions. High velocity vent valves are also sensitive to turbulence which may cause “hammering” or undamped oscillations.

2) Metal parts insulated by gasket material should be earthed where necessary.

3) Flame arresters should not be positioned near hot equipment unless certified for the elevated temperature as heat transfer to the flame arrester will reduce its performance and may cause it to fail.

4) Continuous monitoring of pressure drop is advised if the process is known to contain particulates or substances which may block the element and over-pressurize the system.

5) Shut-off devices should be fully open during normal operation.

6) The suitability of a flame arrester should be checked if the process conditions or the pipework configuration has been changed.

7) Separate flow testing of flame arresters and pressure and/or vacuum valves used as combined but separate devices is not covered by this standard.

8) The use of MESG as an unequivocal measure of flame arrester effectiveness has not been validated for a wide range of gas mixtures. MESG is also a function of p_0. If there is any doubt as to the properties of any specific gas or combination of gases, further specialist advice should be looked for.

Annex ZA
(informative)

Clauses of the European Standard addressing essential requirements or other provisions of EU Directives

This European Standard has been drawn up in the framework of a mandate, which was given to CEN by the EC. It supports the Essential Safety Requirements (ESR) of the EU Directive:

Directive 94/9/EC of the European Parliament and the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres.

WARNING: Other requirements and other EU Directives may be applicable to the products falling within the scope of this standard.

The following clauses of this standard support the ESR of the above mentioned Directive.

Compliance with this standard provides one means of conforming to the specific essential requirements of the Directive concerned and associated EFTA regulations.

Table ZA.1

ESR		Reference in Standard
1.0	General requirements	Clause 5
1.0.1	Principles of integrated explosion safety	Clause 4, 5.1, clause 1 and clause 4
1.0.2		5.1, clause 1
1.0.3	Special checking and maintenance conditions	—
1.0.4	Surrounding area conditions	5.1, clause 1
1.0.5	Marking	12.2
1.0.6	Instructions	12.1
1.1	Selection of materials	5.1, clause 4; 5.2, clause 1, clause 2
1.1.1		5.1, clause 4, Annex C, 14
1.1.3		5.1, clause 1; 6.1, clause 2
1.2	Design and construction	—
1.2.1		5.1, 6.1, 7.1, 9.1, 10.1
1.2.2		Clause 11
1.2.3	Enclosed structures and prevention of leaks	5.6
1.2.8	Overloading of equipment	3.1.25, 9.1, 10.1
1.2.9		5.2, 5.3, 6.3.2.3, 11
1.3.1		5.1, clause 4

Table ZA.1 *(continued)*

1.3.2	Hazards arising from static electricity	Annex C, 14
1.3.3	Hazards arising from stray electric and leakage currents	—
1.4.1		5.1, clause 1
1.4.2		5.1, clause 1
1.5.5	Requirements in respect of devices with a measuring function for explosion protection	6.3.4, 9.2, 9.3, 10.1, 10.3
1.5.7		6.3.4, 9.2, 9.3, 10.1, 10.3
1.6.4	Hazards arising from connections	5.3, 5.4
3	Supplementary requirements in respect of protective systems	Cause 5
3.0	General requirements	—
3.0.1		Clauses 5, 6, 7, 8, 9, 10
3.0.2		Clauses 5, 6, 7, 8, 9, 10
3.1.1	Characteristics of materials	5.2, 6.1, clause 2
3.1.2		5.5
3.1.3		5.5
3.1.7	Explosion decoupling systems	Clauses 5, 6, 7, 8, 9, 10, 11
3.1.8		3.1.25, 6.4, 9.1, 9.3, 10.1, 10.3, 12.1

Bibliography

IEC 60079-1A, *Electrical apparatus for explosive gas atmospheres — Part 1: Construction and test of flameproof enclosures of electrical apparatus. First supplement: Appendix D: Method of test for ascertainment of maximum experimental safe gap.*

IEC 60079-4, *Electrical apparatus for explosive gas atmospheres — Part 4 : Method of test for ignition temperature.*

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