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

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

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 21, *Equipment for fire protection and firefighting*.

This second edition cancels and replaces the first edition (ISO 16852:2008), which has been technically revised with the following changes:

— Clause 1: information concerning existing standard from IMO (International Maritime Organization) for maritime application added;

— 3.18: definition of dynamic flame arrester revised;

— Clause 4: abbreviation for the time t_{Ppeak} added;

— 6.5: production test procedure for flame arresters of welded construction and of cast components revised;

— 6.7: flow measurement (air) revised;

— 7.3.3.2 and 7.3.3.4: in the flame transmission test for stable and unstable detonation without restriction the deflagration tests with $L_u/D = 5$ deleted;

— 7.3.3.2: formula for the calculation of the average value p_{md} added;

— Figure 1 and Figure 3: figures for the test apparatus for deflagration tests of end-of-line flame arrester and of pre-volume flame arresters revised;

— Figure 6 and Figure 7: figures for the test apparatus for short time burning test and for endurance burning test revised;

— 7.3.4: short time burning test for inline flame arresters revised;

— 7.3.5: test pressure for the endurance burning test of inline flame arresters added;

— 7.4.5: limits for use of short time burn flame arresters added;

— 8.3: flame transmission test for liquid product detonation flame arresters revised;

- Clause 9: “Specific requirements for dynamic flame arresters (high velocity vent valves)” revised;
- Clause 11: “Test of flame arresters installed on or within gas conveying equipment” added;
- 12.1: “Instructions for use” revised;
- 12.2: “Marking” revised;
- Figure A.1: pipe lengths revised;
- Annex C: “Best practice” revised;
- Annex D: “Use of in-line stable detonation flame arresters” deleted;
- Bibliography: updated.

It also incorporates the Technical Corrigenda ISO 16852:2008/Cor 1:2008 and ISO 16852:2008/Cor 2:2009.

Introduction

Flame arresters are safety devices fitted to openings of enclosures or to pipe work and are intended to allow flow but prevent flame transmission. They have widely been used for decades in the chemical and oil industry, and a variety of national standards is available. This International Standard was prepared by an international group of experts, whose aim was to establish an international basis by harmonizing and incorporating recent national developments and standards as far as reasonable.

This International Standard addresses manufacturers (performance requirements) and test institutes (test methods), as well as customers (limits for use).

Only relatively general performance requirements are specified and these are kept to a strict minimum. Experience has shown that excessively specific requirements in this field often create unjustified restrictions and prevent innovative solutions.

The hazard identification of common applications found in industry leads to the specification of the test methods. These test methods reflect standard practical situations and, as such, form the heart of this International Standard because they also allow classification of the various types of flame arresters and then determination of the limits of use.

A considerable number of test methods and test conditions had to be taken into account for two main reasons.

a) Different types of flame arresters are covered with respect to the operating principle (static, hydraulic, liquid, dynamic) and each type clearly needs its specific test set-up and test procedure.

b) It is necessary to adapt flame arresters to the special conditions of application (gas, installation) because of the conflicting demands of high flame quenching capability and low pressure loss; this situation is completely different from the otherwise similar principle of protection by flameproof enclosure (of electrical equipment), where the importance of process gas flow through gaps is negligible; importance being placed on the flame quenching effect of the gap.

Consequently, in this International Standard, the testing and classification related to the gas groups and the installation conditions have been subdivided more than is usually the case. In particular,

— explosion group IIA is subdivided into sub-groups IIA1 and IIA,

— explosion group IIB is subdivided into sub-groups IIB1, IIB2, IIB3 and IIB, and

— the type “detonation arrester” is divided into four sub-types, which take into account specific installation situations.

The test conditions lead to the limits for use which are most important for the customer. This International Standard specifies this safety relevant information and its dissemination through the manufacturer’s written instructions for use and the marking of the flame arresters.

The limits for use are also a link to more general (operational) safety considerations and regulations, which remain the responsibility of national or corporate authorities. Annex B and Annex C offer some guidance in this field.

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

1 Scope

This International Standard specifies the requirements for flame arresters that prevent flame transmission when explosive gas-air or vapour-air mixtures are present. It establishes uniform principles for the classification, basic construction and information for use, including the marking of flame arresters, and specifies test methods to verify the safety requirements and determine safe limits of use.

This International Standard is valid for pressures ranging from 80 kPa to 160 kPa and temperatures ranging from −20 °C to + 150 °C.

NOTE 1 For flame arresters with operational conditions inside the scope, but outside atmospheric conditions, see 7.4.

NOTE 2 In designing and testing flame arresters for operation under conditions other than those specified above, this International Standard can be used as a guide. However, additional testing related specifically to the intended conditions of use is advisable. This is particularly important when high temperatures and pressures are applied. The test mixtures might need to be modified in these cases.

NOTE 3 An additional standard IMO MSC/Circ. 677 for maritime application from IMO (International Maritime Organization) exists.

This International Standard is not applicable to the following:

— external safety-related measurement and control equipment that might be required to keep the operational conditions within the established safe limits;

NOTE 4 Integrated measurement and control equipment, such as integrated temperature and flame sensors as well as parts which, for example, intentionally melt (retaining pin), burn away (weather hoods) or bend (bimetallic strips), is within the scope of this International Standard.

— 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 whose intended use is for mixtures other than gas-air or vapour-air mixtures (e.g. higher oxygen-nitrogen ratio, chlorine as oxidant, etc.);

— flame arrester test procedures for internal-combustion compression ignition engines;

— fast acting valves, extinguishing systems and other explosion isolating systems.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-1, *Explosive atmospheres — Part 1: Equipment protection by flameproof enclosures "d"*

3 Terms and definitions

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

3.1
flame arrester
device fitted to the opening of an enclosure, or to the connecting pipe work of a system of enclosures, and whose intended function is to allow flow but prevent the transmission of flame

3.2
housing
portion of a *flame arrester* (3.1) whose principal function is to provide a suitable enclosure for the *flame arrester element* (3.3) and allow mechanical connections to other systems

3.3
flame arrester element
portion of a *flame arrester* (3.1) whose principal function is to prevent flame transmission

3.4
stabilized burning
steady burning of a flame stabilized at, or close to, the *flame arrester element* (3.3)

3.5
short time burning
stabilized burning (3.4) for a specified time

3.6
endurance burning
stabilized burning (3.4) for an unlimited time

3.7
explosion
abrupt oxidation or decomposition reaction producing an increase in temperature, pressure, or both simultaneously

[SOURCE: ISO 8421-1:1987, 1.13]

3.8
deflagration
explosion (3.7) propagating at subsonic velocity

[SOURCE: ISO 8421-1:1987, 1.11]

3.9
detonation
explosion (3.7) propagating at supersonic velocity and characterized by a shock wave

[SOURCE: ISO 8421-1:1987, 1.12]

3.10
stable detonation
detonation (3.9) progressing through a confined system without significant variation of velocity and pressure characteristics

Note 1 to entry: For the atmospheric conditions, test mixtures and test procedures of this International Standard, typical velocities range between 1 600 m/s and 2 200 m/s.

3.11
unstable detonation
detonation (3.9) during the transition of a combustion process from a *deflagration* (3.8) into a stable detonation

Note 1 to entry: 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. The position of this transition zone depends, amongst other factors, on pipe diameter, pipe configuration, test gas and explosion group.

Note 2 to entry: An unstable detonation presents a higher level of hazard than a stable detonation due to higher flame speeds and pressures.

3.12 Characteristic safety data of explosive mixtures

3.12.1
maximum experimental safe gap
MESG
maximum gap between the two parts of the interior chamber which, under the test conditions specified below, prevents ignition of the external gas mixture through a 25 mm long flame path when the internal mixture is ignited, for all concentrations of the tested gas or vapour in air

Note 1 to entry: Safe gap measured in accordance with IEC 60079-20-1:2010.

3.12.2
explosion group
Ex.G
ranking of flammable gas-air mixtures with respect to the MESG

Note 1 to entry: See Table 2, columns 1 and 2.

3.13
bi-directional flame arrester
flame arrester (3.1) that prevents flame transmission from both sides

3.14
deflagration flame arrester
DEF
flame arrester (3.1) designed to prevent the transmission of a *deflagration* (3.8)

Note 1 to entry: It can be an *end-of-line flame arrester* (3.21) or an *in-line flame arrester* (3.22).

3.15
detonation flame arrester
DET
flame arrester (3.1) designed to prevent the transmission of a detonation

Note 1 to entry: It can be an *end-of-line flame arrester* (3.21) or an *in-line flame arrester* (3.22), and can be used for both *stable detonations* (3.10) and *unstable detonations* (3.11).

3.16
endurance flame arrester
flame arrester (3.1) that prevents flame transmission during and after *endurance burning* (3.6)

3.17
static flame arrester
flame arrester (3.1) designed to prevent flame transmission by quenching gaps

3.17.1
measurable type
flame arrester (3.1) where the quenching gaps of the *flame arrester element* (3.3) can be technically drawn, measured and controlled

3.17.2
non-measurable type
flame arrester (3.1) where the quenching gaps of the *flame arrester element* (3.3) cannot be technically drawn, measured or controlled

EXAMPLE Random structures such as knitted mesh, sintered materials and gravel beds.

3.18
dynamic flame arrester
high velocity vent valve
pressure relief valve designed always to have efflux velocities that prevent the flame propagation against the flow direction

Note 1 to entry: It can be deflagration proof (see 3.14) or endurance burn proof (see 3.16).

3.19
liquid product detonation flame arrester
flame arrester (3.1) in which the liquid product is used to form a liquid seal as a flame arrester medium, in order to prevent flame transmission of a detonation

Note 1 to entry: There are two types of liquid product detonation flame arrester for use in liquid product lines: liquid seals and foot valves.

3.19.1
liquid seal flame arrester
flame arrester (3.1) designed to use the liquid product to form a barrier to flame transmission

3.19.2
foot valve flame arrester
flame arrester (3.1) designed to use the liquid product combined with a non-return valve to form a barrier to flame transmission

3.20
hydraulic flame arrester
flame arrester (3.1) designed to break the flow of an explosive mixture into discrete bubbles in a water column, thus preventing flame transmission

3.21
end-of-line flame arrester
flame arrester (3.1) that is fitted with one pipe connection only

3.22
in-line flame arrester
flame arrester (3.1) that is fitted with two pipe connections, one on each side of the flame arrester

3.23
pre-volume flame arrester
VDEF
flame arrester (3.1) that, after ignition by an internal ignition source, prevents flame transmission from inside an explosion-pressure-resistant containment (e.g. a vessel or closed pipe work) to the outside, or into the connecting pipe work

Note 1 to entry: Explosion-pressure resistance is a property of vessels and equipment designed to withstand the expected explosion pressure without becoming permanently deformed.

3.24
integrated temperature sensor
temperature sensor integrated into the flame arrester, as specified by the manufacturer of the flame arrester, in order to provide a signal suitable to activate counter measures

3.25
atmospheric conditions
conditions with pressures ranging from 80 kPa to 110 kPa and temperatures ranging from −20 °C to +60 °C

4 Abbreviated terms and symbols

A_0	free area of a static flame arrester element
A_p	nominal cross sectional area of the flame arrester connection
A_t	cross sectional area on the unprotected side of the flame arrester element
A_u	effective open area of the flame arrester element on the protected side
D	pipe diameter
D_M	minimum diameter of the pipe on the protected side of a dynamic flame arrester
L_M	maximum length without undamped oscillations
L_m	pipe length upstream of the dynamic flame arrester used in flame transmission test
L_p	pipe length on the protected side
L_r	pipe length between flame arrester and restriction
L_u	pipe length on the unprotected side, maximum allowable run-up length for installation
L_1, L_2, L_3, L_4	pipe lengths in the flow test
p_{md}	time average value of the detonation pressure in the time interval of 200 µs after arrival of the detonation shock wave
p_{mu}	maximum time average value of the transient pressure of an unstable detonation over a time interval of 200 µs
p_t	pressure in the pressure test
p_T	pressure in the flow test of an end-of-line flame arrester
p_{TB}	pressure before ignition
p_0	maximum operational pressure
Δ_p	pressure drop in the flow test of an in-line flame arrester
p_E	maximum pressure for the endurance burning test of dynamic flame arresters
p_m	pressure which cause the maximum temperature at endurance burning test
R_A	ratio of the effective open area of the flame arrester element to pipe cross sectional area
R_U	ratio of the free volume of the flame arrester element to the whole volume
t_{BT}	burning time
t_{Ppeak}	time at which the peak pressure correlating to the leading shock front is achieved in the test
T_{TB}	temperature of the flame arrester before ignition
T_0	maximum operational temperature of the flame arrester
v_{max}	maximum flow velocity during the volume flow-pressure drop measurement (flow test)
v_{min}	minimum flow velocity during the volume flow-pressure drop measurement (flow test)
$\dot{V}$	volume flow rate
$\dot{V}_c$	critical volume flow rate
$\dot{V}_{CL}$	flow rate at closing point of dynamic flame arresters
$\dot{V}_0$	minimum volume flow rate for endurance burning on dynamic flame arresters
$\dot{V}_E$	maximum volume flow rate for endurance burning on dynamic flame arresters
$\dot{V}_K$	maximum volume flow rate for dynamic flame arresters at the set pressure
$\dot{V}_m$	volume flow rate leading to maximum temperature

V_M	minimum volume in the protected tank
$\dot{V}_{max}$	safe volume flow rate
$\dot{V}_s$	safe volume flow rate including a safety margin
$\dot{V}_t$	maximum volume flow *rate* leading to flame transmission
Z_{Rmin}	minimum water seal immersion depth at rest above the outlet openings of the immersion tubes
Z_R	immersion depth at rest, corresponding to Z_{Rmin} plus the manufacturer's recommended safety margin
Z_{0min}	minimum operational water seal immersion depth when the mixture flow displaces the water from the immersion tubes, where $Z_{0min} > Z_{Rmin}$
Z_0	operational immersion depth, corresponding to Z_{0min} plus the manufacturer's recommended safety margin

All pressure values are absolute pressures.

NOTE Symbols in the figures for the flame arrester are in line with ISO 14617-7.

5 Hazards and flame arrester classifications

5.1 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 sufficient pipe length is available. This pipe length may vary depending upon the initial conditions of the mixture and the pipe work configuration.

A flame arrester tested in accordance with 7.3.3.2 or 7.3.3.3 is classified as a stable detonation flame arrester and is suitable for deflagrations and stable detonations.

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

A flame arrester tested in accordance with 7.3.3.4 or 7.3.3.5 is classified as an unstable detonation flame arrester and is suitable for deflagrations, stable detonations and unstable detonations.

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

The specific hazards covered by this International Standard, the classification and the 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
a) unconfined deflagration into an enclosure or vessel	end-of-line deflagration
b) confined deflagration propagating along a pipe into connecting pipe work	in-line deflagration
c) deflagration confined by an enclosure or pipe work to the outside atmosphere or into connecting apparatus	pre-volume deflagration

Table 1 *(continued)*

Application	Flame arrester classification
d) stable detonation propagating along a pipe into connecting pipe work	in-line stable detonation
e) unstable detonation propagating along a pipe into connecting pipe work	in-line unstable detonation
f) stable detonation at the end of a pipe propagating into an enclosure or vessel	end-of-line stable detonation

5.2 Flame transmission: stabilized burning

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

— if the flow of the explosive mixture can be stopped within a specific time that is between 1 min and 30 min, flame arresters which, when tested in accordance with 7.3.4, prevent flame transmission during that period of stabilized burning are suitable for that hazard, and they are classified as safe against short time burning;

NOTE Bypassing, sufficient diluting or inerting are measures equivalent to stopping the flow.

— if the flow of the explosive mixture cannot be stopped or, for operational reasons, is not intended to be stopped within 30 min, flame arresters which, when tested in accordance with 7.3.5, prevent flame transmission for this type of stabilized burning are suitable for that hazard, and they are classified as safe against endurance burning.

6 General requirements

6.1 Measuring instruments

Appropriate metrological traceable calibrated measuring instruments shall be used for the tests.

NOTE It is advisable that the uncertainty of measurement in the tests be such that it can be shown that all the required test parameter limits are met.

6.2 Construction

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

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 a way that makes flame transmission possible.

Where stabilized burning is considered as an additional hazard, 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.

6.3 Housings

Thread gaps, which shall prevent flame transmission, shall be in accordance with the constructional requirements of IEC 60079-1.

6.4 Joints

All joints shall be constructed and sealed in such a way that

— flame cannot bypass the flame arrester element, and

— flame is prevented from propagating to the outside of the flame arrester.

6.5 Pressure test

Pressure testing of in-line and end-of-line detonation flame arresters shall be carried out at each flame arrester at a pressure of not less than 10 × p_0, and of all in-line deflagration flame arresters at not less than 1,1 × 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, where documentary evidence is provided that the weld procedure and welder qualification satisfy the requirements of the design method employed. Flame arresters with any subsequent alteration to the design, affecting its strength, shall be retested.

Cast components may be pressure tested individually prior to assembly of the complete unit.

No permanent deformation shall occur during the tests.

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

6.6 Leak test

Each flame arrester shall be leak tested with air at 1,1 × p_0, with a minimum of 150 kPa absolute for not less than 3 min. No leak shall occur.

End-of-line deflagration flame arresters need not be leak tested.

6.7 Flow measurement (air)

The pressure drop across the flame arrester shall be tested before and after flame transmission tests at a volume flow that is suitable for identifying any alteration (deformation) of the flame arrester, particularly of the flame arrester element. After flame transmission testing, the pressure drop shall not differ by more than 20 % from the value measured at the same flow rate before that testing. After short time burn test and after endurance burn test, no additional flow measurement is required.

The flow capacity of in-line flame arresters shall be recorded in accordance with A.2 in a type test.

The flow capacity of end-of-line flame arresters shall be recorded in accordance with A.3 in a type test.

The flow capacity of end-of-line flame arresters directly combined with or integrated into pressure and/or vacuum valves shall be recorded in accordance with A.3. Pressure and/or vacuum valves manufactured for different pressure settings shall be tested at the lowest and the highest set pressure and for intermediate set pressures ≤1 kPa apart.

The flow capacity of dynamic flame arresters shall be recorded in accordance with A.3 in a type test.

In addition, all dynamic flame arresters shall be tested for undamped oscillations in accordance with A.4 in a type test.

6.8 Flame transmission test

6.8.1 General

All flame arresters shall be type tested against flame transmission. There shall be no permanent visible deformation of the housing.

The tests shall be specific for the basic types of operation (as defined in 3.17, 3.18, 3.19 and 3.20) and shall be carried out in accordance with Clauses 7, 8, 9 or 10. 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, $T_{TB} \leq 150$ °C. Gas-air or vapour-air mixtures shall be as specified in 6.8.2.

Depending on their intended use, flame arresters shall be tested to the specific explosion group of the explosive gas-air or vapour-air mixture (see Table 2, columns 1 and 2).

For the purposes of this International Standard, explosion group IIC covers hydrogen and other gas-air or vapour-air mixtures with MESG less than 0,5 mm, and group IIB is divided into four sub-groups: IIB1, IIB2, IIB3 and IIB. Explosion group IIA is divided into two sub-groups: IIA1 and IIA. This International Standard covers deflagration and detonation tests for groups IIA, IIB1, IIB2, IIB3, IIB and IIC. Group IIA1 shall only be used for the testing of deflagration flame arresters.

The limiting MESG values, which define the explosion groups IIA1, IIA, IIB1, IIB2, IIB3, IIB and IIC, are shown in Table 2.

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

6.8.2 Test mixtures

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 shall be established with a concentration measuring instrument or a 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**[a] %	**Safe gap of gas-air mixture** mm
IIA1	≥1,14	Methane	≥98	8,4 ± 0,2	1,16 ± 0,02
IIA[b]	>0,90	Propane	≥95	4,2 ± 0,2	0,94 ± 0,02
IIB1[b]	≥0,85	Ethylene	≥98	5,2 ± 0,2	0,83 ± 0,02
IIB2[b]	≥0,75			5,7 ± 0,2	0,73 ± 0,02
IIB3[b]	≥0,65			6,6 ± 0,3	0,67 ± 0,02
IIB[b]	≥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

NOTE The ranking in columns 1 and 2 is not comparable with the ranking in IEC 60079–1.

[a] When the test gas mixture is measured by the safe gap of the gas-air mixture, the mixture shall be in the lower half of the specified gap range. If the test gas mixture is measured by the percentage of gas in air by volume, then for IIA1, IIA, IIB3 and IIC, the mixture shall be within the specified percentage volume range. For IIB1 and IIB2, the mixture shall be in the upper half side of the specified percentage volume range. For IIB, the mixture shall be on the lower half side of the specified percentage volume range. All the stated limit deviations relate to the uncertainty of the measuring equipment.

[b] With small 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 and burning tests of dynamic flame arresters

Range of application (marking) Explosion group	Requirements for test mixture		
	Gas type	Gas purity by volume %	Gas in air by volume[a] %
IIA1	Methane	≥98	9,5 ± 0,2
IIA	Propane	≥95	4,2 ± 0,2
IIB1	Ethylene	≥98	6,6 ± 0,3
IIB2			
IIB3			
IIB			
IIC	Hydrogen	≥99	28,5 ± 2,0

[a] Testing of dynamic flame arresters may require a variation in mixture composition.

Table 4 — Specification of gas-air or vapour-air mixtures for endurance burning tests of static flame arresters

Range of application (marking) Explosion group[a]	Requirements for test mixture		
	Gas or liquid	Purity by volume %	Gas vapour in air by volume %
IIA1	Methane	≥98	9,5 ± 0,2
IIA	Hexane	≥70	2,1 ± 0,1
IIB1	Ethylene	≥98	6,6 ± 0,3
IIB2			
IIB3			
IIB			
IIC	Hydrogen	≥99	28,5 ± 2,0

[a] The range of applications is limited to pure hydrocarbons (compounds containing only carbon and hydrogen).

6.9 Summary of tests to be conducted

The tests to be conducted are given in Table 5.

Table 5 — Summary of tests to be conducted

Type of flame arrester		Flame transmission test	Burning test (when required)	Flow test
End-of-line deflagration flame arrester	short time burn proof	7.3.2.1	7.3.4	A.3
	endurance burn proof		7.3.5	
In-line deflagration flame arrester	short time burn proof	7.3.2.2	7.3.4	A.2
	endurance burn proof		7.3.5	
Pre-volume flame arrester	—	7.3.2.3	—	A.2 or A.3
Stable detonation flame arrester without restriction	short time burn proof	7.3.3.2	7.3.4	A.2
	endurance burn proof		7.3.5	
Stable detonation flame arrester with restriction	short time burn proof	7.3.3.3	7.3.4	A.2
	endurance burn proof		7.3.5	
Unstable detonation flame arrester without restriction	short time burn proof	7.3.3.4	7.3.4	A.2
	endurance burn proof		7.3.5	

Table 5 *(continued)*

Type of flame arrester		Flame transmission test	Burning test (when required)	Flow test
Unstable detonation flame arrester with restriction	short time burn proof	7.3.3.5	7.3.4	A.2
	endurance burn proof		7.3.5	
Liquid product detonation flame arrester	—	8.3	—	—
Dynamic flame arrester	deflagration proof	9.2.1, 9.2.2 and 9.2.3	—	A.3.2 and A.4
(high velocity vent valve)	endurance burn proof		9.2.4	
Hydraulic flame arrester	—	10.2.3, 10.2.4	10.2.2	—

7 Specific requirements for static flame arresters

7.1 Construction

Static flame arresters shall consist of a flame arrester element and a housing.

For flame arrester elements with quenching gaps, the dimensions and tolerances shall be indicated (for example, gap length and width of gap).

For crimped ribbon flame arrester elements used for the test, the gaps shall not fall below the upper tolerance limits over 90 % of the entire surface. For production reasons, the gap dimensions may be less than the lower tolerance limits in the inner and outer areas of the flame arrester element. The total affected area shall not exceed 10 % of the total surface area.

NOTE The intention of this test is to include the worst case.

Evidence shall be available that manufacture is controlled within tolerances to ensure reproducibility.

Materials for flame arresters shall be suitable for the intended use (e.g. temperature range, chemical properties of the gases and vapours).

7.2 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:

a) one drawing shall cover all nominal sizes in a design series and all parts shall be listed and dimensioned;

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

Additional requirements for in-line flame arresters are the following:

— a design series is limited to a maximum of four consecutive nominal sizes according to Table 6, even if the intermediate sizes are not included in the design series;

— for every nominal size in a design series (maximum four), the ratio, R_A, as calculated in Formula (1), shall not deviate by more than ±10 % from the ratio of the largest nominal size of the four members:

$$R_A = \frac{A_u}{A_p} \qquad (1)$$

Concentric and eccentric shaped housings form different design series.

Table 6 — Design series

	Nominal size of connection mm															
Design series	10 to 15	20 to 25	32 to 40	50	60 to 65	75 to 80	100	125	150	200	250	300	350	400	450 to 500	600 to 750	800 to 1000

7.3 Flame transmission test

7.3.1 General

For non-measurable types of flame arresters, evidence shall be available to prove that the production flame arrester elements are equivalent in design, manufacture and construction to the test sample. The test pressure shall be at least 10 % higher than the maximum operational pressure, p_0, of the flame arrester.

Flame arresters with pressure and/or vacuum valve(s) integrated on the protected side shall have the valve secured in the fully open position, or the pressure and/or vacuum valve pallets shall be taken out during the test.

Flame arresters with pressure and/or vacuum valve(s) integrated on the unprotected side shall have the valve pallets installed and blocked open to provide a gap of (2,5 ± 0,5) mm during each test.

Flame arresters directly combined with separate pressure and/or vacuum valves used as end-of-line venting systems shall be tested in the same way as end-of-line flame arresters with integrated pressure and/or vacuum valves.

NOTE These end-of-line venting systems could be classified as follows:

a) as end-of-line deflagration arresters, in accordance with 7.3.2.1;

b) as end-of-line deflagration arresters, in accordance with 7.3.2.1, and with a short time burning test, in accordance with 7.3.4;

c) as end-of-line deflagration arresters, in accordance with 7.3.2.1, and with an endurance burning test, in accordance with 7.3.5.

The protected and unprotected side of a flame arrester may be modified to allow connection to smaller pipe sizes without further testing. The connection on the protected side shall not be smaller than the connection on the unprotected side.

The temperatures (mixture, pipe, flame arrester) during testing shall be given in the test report.

7.3.2 Deflagration test

7.3.2.1 End-of-line flame arrester

The test apparatus is as shown in Figure 1. Distances shall be measured from the top of the complete flame arrester.

For end-of-line flame arresters with non-measurable elements, it might be necessary to pressurize the plastic bag (see 7.4.1). In this case, the mixture outlet (item 6 in Figure 1) needs to be fitted with a shut-off valve.

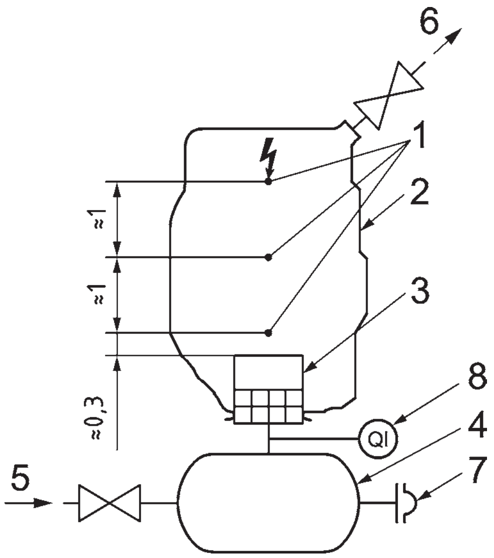
Assemble the flame arrester with all ancillary equipment, including weather cowls or other covers, and enclose it in a plastic bag.

Fill the apparatus, fully inflating the bag with a mixture as specified in 6.8.2. Disconnect the mixture supply and ignite. The ignition source shall be a spark plug or a chemical igniter (maximum energy 1 kJ).

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.

Dimensions in metres



Key

1 ignition sources

2 plastic bag (Ø ≥ 1,2 m; length ≥2,5 m; foil thickness ≥0,05 mm)

3 end-of-line flame arrester

4 explosion-pressure-resistant containment (vessel or closed pipe work)

5 mixture inlet with shut-off valve

6 mixture outlet with shut-off valve

7 bursting diaphragm

8 flame detector for indication

Figure 1 — Test apparatus for end-of-line flame arrester for deflagration test

7.3.2.2 In-line flame arrester

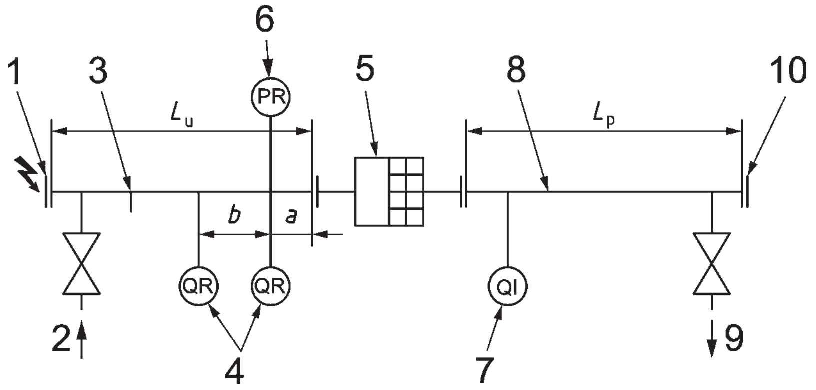
The test apparatus is shown in Figure 2. The ignition source shall be a spark plug fitted in the centre of the blind flange.

The pipe diameter, *D*, shall have the same size as the flame arrester connection. The pipe length, L_u, shall be not less than 10 × *D* and not greater than 50 × *D* for hydrocarbon-air mixtures (IIA1, IIA, IIB1, IIB2 and IIB3) and not greater than 30 × *D* for hydrogen-air mixtures (IIB and IIC). The pipe length, L_p, shall be 50 × *D* for hydrocarbon-air mixtures (IIA1, IIA, IIB1, IIB2 and IIB3) and 30 × *D* for hydrogen-air mixtures (IIB and IIC).

NOTE 1 It is advisable that the pipe length, L_u, be given by the manufacturer. In case of successful testing, L_u will be the maximum allowable run-up length for practical installations (see 7.4.2).

NOTE 2 It is possible in larger pipe sizes to approach the transition from a deflagration to a detonation when testing at raised p_{TB} and L_u = 50 × *D*. If a deflagration to detonation transition is indicated, then testing with lower L_u is appropriate.

The flame velocity shall be measured by two flame detectors fitted to the pipe on the unprotected side, in accordance with Figure 2. The distance *b* between the two flame detectors shall be in accordance with Figure 2. The pressure shall be recorded by a pressure recording system (limiting frequency ≥100 kHz) fitted to the pipe on the unprotected side, at a distance *a* in accordance with Figure 2.



Key

1 blind flange with ignition source

2 mixture inlet

3 unprotected pipe (length, L_u; diameter, D)

4 flame detectors for recording

5 in-line deflagration flame arrester

6 pressure transducer for recording

7 flame detector for indication

8 protected pipe (length, L_p; diameter, D)

9 mixture outlet

10 blind flange or other closure

$a \leq 2 \times D$ (±10 %, max. ± 50 mm), but $a \leq 250$ mm

$5 \times D \geq b \geq 3 \times D$

Figure 2 — Test apparatus for in-line flame arrester for deflagration test

Fill the apparatus with a test mixture as specified in 6.8.2 and pressurize to p_{TB} when $p_{TB} \geq p_0$ (where 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_u) 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 in accordance with 7.2 may be considered acceptable without testing. Each size larger than 1 000 mm shall be tested.

7.3.2.3 Pre-volume flame arrester

The test apparatus is shown in Figure 3.

For pre-volume flame arresters with non-measurable elements, it might be necessary to pressurize the plastic bag (end-of-line application, see 7.4.1). In this case, the mixture outlet (item 6 in Figure 3) needs to be fitted with a shut-off valve.

Pre-volume flame arresters shall be tested using the original configuration or equivalent full-scale model configuration.

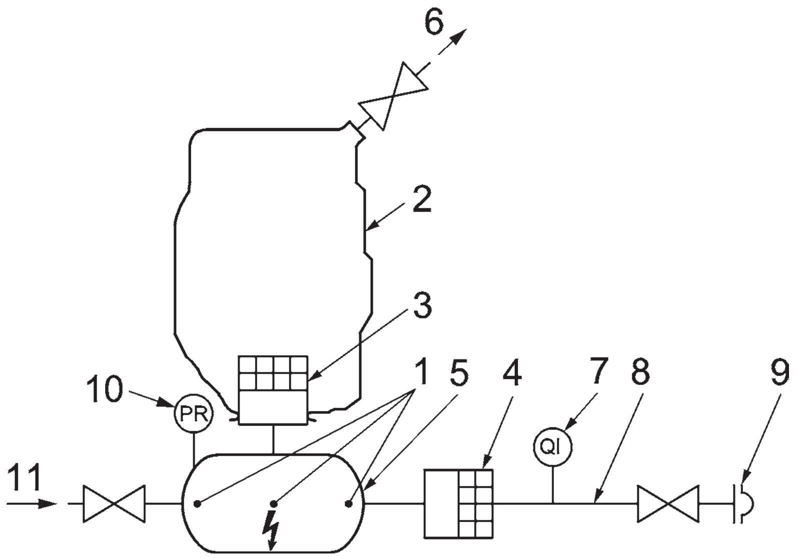
Pre-volume applications using end-of-line types shall be enclosed in a plastic bag, as shown in Figure 3.

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

Flame transmission shall be indicated by the following:

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

b) for in-line types, by the flame detector (7).



Key

1 ignition sources

2 plastic bag (Ø ≥ 1,2 m; length ≥2,5 m; foil thickness ≥0,05 mm)

3 end-of-line flame arrester

4 in-line flame arrester

5 explosion-pressure-resistant containment (vessel or closed pipe work)

6 mixture outlet with shut-off valve

7 flame detector for indication

8 original or simulated pipe work with mixture outlet and shut-off valve

9 bursting diaphragm

10 pressure transducer for recording

11 mixture inlet with shut-off valve

Figure 3 — Test apparatus for pre-volume flame arrester for deflagration test

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 6.8.2. 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.

7.3.3 Detonation test

7.3.3.1 General

If the largest and smallest nominal sizes of a design series are satisfactorily tested for detonations, the two intermediate nominal sizes in accordance with 7.2 may be considered acceptable without testing. Each nominal size larger than 1 000 mm shall be tested.

Detonation flame arresters tested for unstable detonations with restriction (see 7.3.3.5) are classified as Type 1.

Detonation flame arresters tested for unstable detonations without restriction (see 7.3.3.4) are classified as Type 2.

Detonation flame arresters tested for stable detonations with restriction (see 7.3.3.3) are classified as Type 3.

Detonation flame arresters tested for stable detonations without restriction (see 7.3.3.2) are classified as Type 4.

Type 1 detonation flame arresters are also suitable for use as Type 2, Type 3 and Type 4 without additional testing.

Type 2 detonation flame arresters are also suitable for use as Type 4 without additional testing.

Type 3 detonation flame arresters are also suitable for use as Type 4 without additional testing.

7.3.3.2 Stable detonation without restriction

The test apparatus is shown in Figure 4.

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

The pipe on the unprotected side shall have a length, L_u, sufficient to develop a stable detonation and shall have a blind flange or an explosion-pressure-resistant containment (vessel or closed pipe work) 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_p, of 10 × D, but not less than 3 m. The blind flange or other closure 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 in accordance with Figure 4.

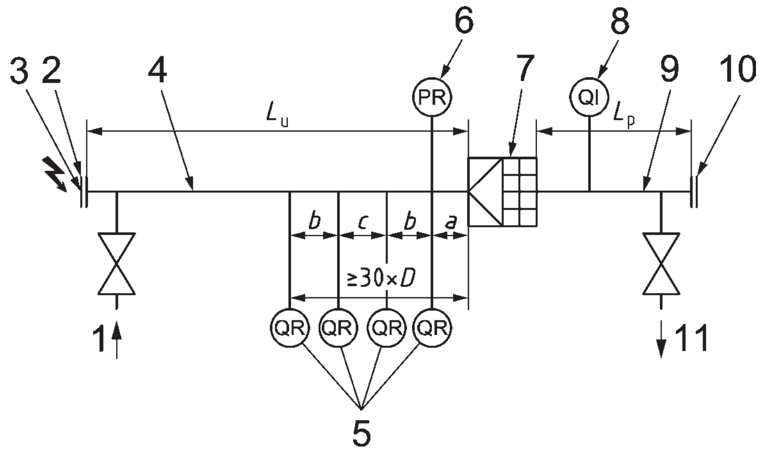
One flame detector shall be fitted to the pipe on the protected side to indicate flame transmission.

The apparatus shall be filled with a test mixture as specified in 6.8.2, and at a pressure of, p_{TB}, when $p_{TB} \geq p_0$. Under these conditions, five 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 shall be ≥1 600 m/s for hydrocarbon-air mixtures (IIA, IIB1, IIB2 and IIB3) and ≥1 900 m/s for hydrogen-air mixtures (IIB and IIC).

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



Key

1 mixture inlet

2 explosion-pressure-resistant containment (vessel or closed pipe work) or blind flange

3 ignition source

4 unprotected pipe (length, L_u; diameter, D)

5 flame detectors for recording of the flame velocity measurement

6 pressure transducer for recording

7 detonation flame arrester

8 flame detector for indication

9 protected pipe (length, L_p; diameter, D)

10 blind flange or other closure

11 mixture outlet

a = (200 ± 50) mm

$b \geq 3 \times D$, but $b \geq 100$ mm

$c \geq 500$ mm

Figure 4 — Test apparatus for detonation flame arrester for detonation without restriction

Until the arrival of a stable detonation shock wave, the pressure (see item 6 in Figure 4) shall remain constant at p_{TB}. 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 average value p_{md} shall be calculated according to Formula (2):

$$p_{md} = \frac{\int_{t_{Ppeak}}^{t_{Ppeak+200\ \mu s}} p(t)dt}{200\ \mu s} \quad (2)$$

The ratio p_{md}/p_{TB}, with regard to mixture and pipe size, shall correspond to the values given in Table 7 with a maximum deviation of ±20 %.

NOTE When p_{md}/p_{TB} exceeds the quoted values of Table 7 by more than 20 % and flame transmission occurs, the detonation might still be overdriven and it is advisable that a longer pipe or turbulence promoting equipment be used.

Table 7 — Ratio p_{md}/p_{TB}

Explosion group	Ratio p_{md}/p_{TB} for pipe diameter, D mm			
	$D \leq 80$[a]	$80 < D \leq 150$	$150 < D < 1\,000$	$D \geq 1\,000$
IIA	10	12	14	16
IIB1	9	11	13	14
IIB2	9	11	13	15
IIB3	10	12	14	16
IIB	8	10	10	12
IIC	8	8	8	8

[a] If for 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, deflagration tests shall be carried out where the basic test set-up shall be in accordance with Figure 4, with $L_p = 50 \times D$, as follows:

a) five deflagration tests with

— $L_u/D = 50$ for IIA, IIB1, IIB2 and IIB3, or

— $L_u/D = 30$ for IIB and IIC.

The ignition source for these deflagration tests shall be a spark plug fitted in the centre of the blind flange. For these deflagration tests, flame velocity measurement is not required.

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

A stable detonation flame arrester (Type 4) shall prevent flame transmission in any of these stable detonation and deflagration tests.

7.3.3.3 Stable detonation with restriction

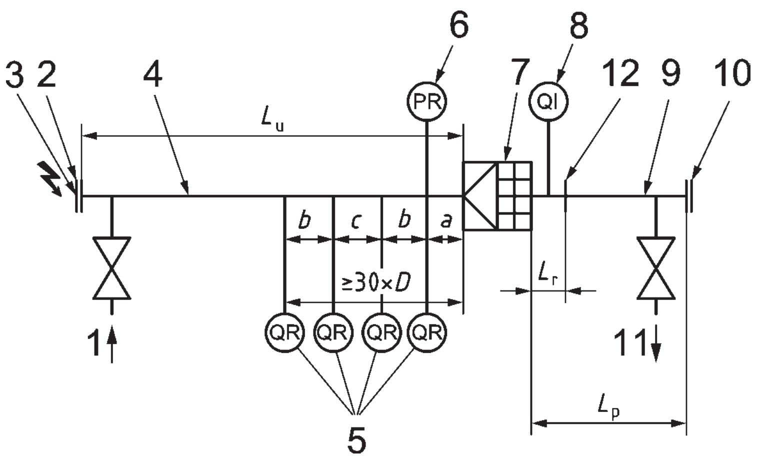
The test apparatus is shown in Figure 5.

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

The pipe on the unprotected side shall have a length, L_u, sufficient to develop a stable detonation and shall have a blind flange or an explosion-pressure-resistant containment (vessel or closed pipe work) fitted with an ignition source. The pipe may also contain a flame accelerator to reduce the pipe length for stable detonation conditions.

A restriction shall be fitted at $L_r/D = 4$. The pipe on the protected side shall have a length, L_p, of $14 \times D$ but not less than 3 m after the restriction. The restriction shall consist of a blind flange with a central bore. The central bore shall have 2,5 % of the cross sectional area of the pipe. The closed pipe end and the restriction 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 in accordance with Figure 5.



Key

1 mixture inlet

2 explosion-pressure-resistant containment (vessel or closed pipe work) or blind flange

3 ignition source

4 unprotected pipe (length, L_u; diameter, D)

5 flame detectors for recording the flame velocity

6 pressure transducer for recording

7 detonation flame arrester

8 flame detector for indication

9 protected pipe (length, L_p; diameter, D)

10 blind flange or other closure

11 mixture outlet

12 restriction ($L_r = 4 \times D$)

a = (200 ± 50) mm

$b \geq 3 \times D$, but $b \geq 100$ mm

$c \geq 500$ mm

Figure 5 — Test apparatus for detonation flame arrester for detonation with restriction

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 6.8.2, and at a pressure of p_{TB} when $p_{TB} \geq p_0$. Under these conditions, five tests shall be carried out.

In each test, the flame velocities from the two pairs of flame detectors (see Figure 5) shall be constant, i.e. the difference between the two flame velocities shall not exceed 10 % of the lower value.

The velocities shall be ≥1 600 m/s for hydrocarbon-air mixtures (IIA, IIB1, IIB2 and 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 (see item 6 in Figure 5) shall remain constant at p_{TB}. 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_{TB}, with regard to mixture and pipe size shall correspond to the values given in Table 7, with a maximum deviation of ±20 %.

NOTE When p_{md}/p_{TB} exceeds the quoted values of Table 7 by more than 20 % and flame transmission occurs, the detonation might still be overdriven and it is advisable that a longer pipe or turbulence promoting equipment be used.

In addition, deflagration tests shall be carried out, where the basic test set-up shall be in accordance with Figure 5, with $L_r = 4 \times D$ and $L_p = 54 \times D$, as follows:

a) five deflagration tests with $L_u/D = 5$, and

b) five deflagration tests with

— $L_u/D = 50$ for IIA, IIB1, IIB2 and IIB3, or

— $L_u/D = 30$ for IIB and IIC.

The ignition source for these deflagration tests shall be a spark plug fitted in the centre of the blind flange. For these deflagration tests, flame velocity measurement is not required.

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

A stable detonation flame arrester (Type 3) shall prevent flame transmission in any of these stable detonation and deflagration tests.

7.3.3.4 Unstable detonation without restriction

The test apparatus is shown in Figure 4.

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

The pipe on the unprotected side shall have a length, L_u, sufficient to develop an unstable detonation and shall have a blind flange or an explosion-pressure-resistant containment (vessel or closed pipe work) 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_p, of $10 \times D$, and not less than 3 m. The blind flange or other closure 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 International Standard, a characteristic of an unstable detonation is p_{mu} 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 7 with regard to p_{TB}.

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 6.8.2, at a pressure, p_{TB}, when $p_{TB} \geq p_0$.

Under these conditions, five tests shall be carried out.

In addition, deflagration tests shall be carried out, where the basic test set-up shall be in accordance with Figure 4, with $L_p = 50 \times D$, as follows:

Five deflagration tests with

— $L_u/D = 50$ for IIA, IIB1, IIB2 and IIB3, or

— $L_u/D = 30$ for IIB and IIC.

The ignition source for these deflagration tests shall be a spark plug fitted in the centre of the blind flange. For these deflagration tests, flame velocity measurement is not required.

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

An unstable detonation flame arrester (Type 2) shall prevent flame transmission in any of these deflagration and unstable detonation tests.

7.3.3.5 Unstable detonation with restriction

The test apparatus is shown in Figure 5.

The pipe on the protected side shall have a length, L_p, of $54 \times D$. A restriction shall be fitted at $L_r/D = 4$. The restriction shall consist of a blind flange with a central bore. The central bore shall have 2,5 % of the cross sectional area of the pipe. The closed pipe end and the restriction shall resist the shock pressures during testing.

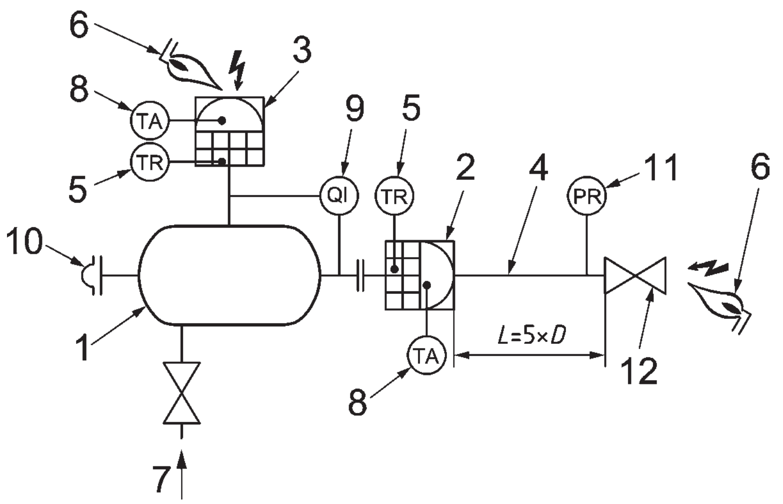
The test procedure for unstable detonation testing as well as the characteristic of an unstable detonation shall be in accordance with 7.3.3.4.

In addition, additional deflagration tests shall be carried out completely in accordance with 7.3.3.3.

An unstable detonation flame arrester (Type 1) shall prevent flame transmission in any of these deflagration and unstable detonation tests.

7.3.4 Short time burning test

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



Key

1 explosion-pressure-resistant containment (vessel or closed pipe work)
2 in-line flame arrester
3 end-of-line flame arrester
4 outlet pipe
5 temperature sensor for recording for tests only
6 pilot flame
7 mixture inlet
8 integrated temperature sensor for alarm
9 flame detector for indication
10 bursting diaphragm
11 pressure transducer for recording (only necessary for t_{BT} > 1 min)
12 valve (only necessary for t_{BT} > 1 min)

Figure 6 — Test apparatus for short time burning test

The test of inline flame arresters shall be carried out with the test pressure equal or greater than the intended maximum operation pressure. The test of inline flame arresters with t_{BT} = 1 min may be carried out under atmospheric conditions.

A flow meter shall be used to measure the mixture flow rates. The flame arrester shall be fitted with a temperature sensor for the test only. This sensor shall be mounted 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 tests shall be carried out using a test mixture as specified in Table 3. First, the critical flow rate, $\dot{V}_c$, shall be calculated from the open area, A_0, of the surface of the flame arrester element on the unprotected side and from the size and number of apertures per unit area. Assuming a uniform velocity of 75 % of a burning velocity, v_l, of the mixture across this area, calculate a critical flow rate, $\dot{V}_c$, according to Formula (3):

$$\dot{V}_c = 0{,}75 \times A_0 \times v_l \quad (3)$$

where

v_l = 0,5 m/s for IIA1 and IIA;

v_l = 0,8 m/s for IIB1, IIB2, IIB3 and IIB;

v_l = 3 m/s for IIC.

For non-measurable flame arrester elements, the critical flow rate, $\dot{V}_c$, may be obtained by using the same principle. The free area, A_0, of the flame arrester element surface can be estimated according to Formula (4):

$$A_0 = R_U \times A_t \tag{4}$$

The 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. After flame stabilization, continue burning for the burning time, t_{BT}, specified by the manufacturer (1 min ≤ t_{BT} ≤ 30 min). Record the temperature indicated by the test temperature sensor after that time and 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 $\dot{V}_c$, $0{,}5\dot{V}_c$ and $1{,}5\dot{V}_c$. In each of these tests, the flame arrester shall be at ambient temperature at the beginning. If $\dot{V}_c$ results in the highest temperature reading of the three tests, then $\dot{V}_m = \dot{V}_c$. 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. $\dot{V}_m$ will be the flow rate that results in the highest temperature reading in all five tests. When determining the flow rate $\dot{V}_m$, 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 $\dot{V}_m$, using the original flame arrester element, without modification, that was used for the deflagration and/or detonation test.

In any of the tests, the integrated temperature sensor(s) (8) shall produce a signal that may be used to activate counter measures within a burning time of 50 % of the manufacturer's specified burning time, t_{BT}, where $\frac{t_{BT}}{2} \leq 15$ min.

When using an integrated temperature measuring system, it shall record a temperature rise not less than 60 K after a burning time of not more than $\frac{t_{BT}}{2}$.

A flame transmission is indicated by the flame detector (9). No flame transmission shall occur during the tests or when the flow is stopped. The burn time without flash back shall be recorded as the burning time, t_{BT}, expressed in minutes.

If the largest and smallest nominal sizes of a design series are satisfactorily tested, the intermediate nominal sizes may be considered acceptable without testing, but these flame arresters shall be marked with the shortest burning time, t_{BT}, found in the experimental tests.

Each size of in-line flame arresters greater than 1 000 mm shall be tested.

7.3.5 Endurance burning test

The test apparatus is shown in Figure 7 for an in-line and end-of-line flame arrester.

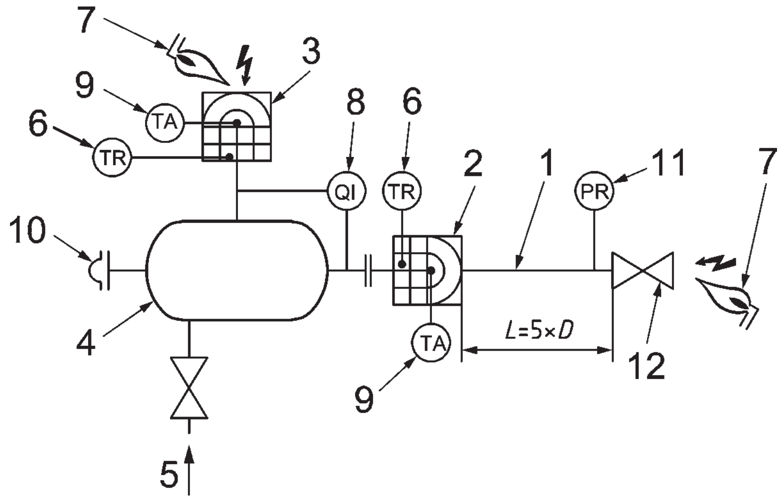
Testing of inline flame arresters shall be carried out with the test pressure equal to or greater than the intended maximum operation pressure

A flow meter shall be used to measure the mixture flow rate. The flame arrester shall be fitted with two temperature sensors for the test only.

One temperature sensor (6) shall be mounted on the protected side. The location of this temperature sensor shall be left to the discretion of the test laboratory.

Another temperature sensor (9) shall be fitted to the unprotected side to detect the stabilized flame (start of burning load).

The tests shall be carried out using a mixture as specified in Table 4.



Key

1 outlet pipe
2 in-line flame arrester
3 end-of-line flame arrester
4 explosion-pressure-resistant containment (vessel or closed pipe work)
5 mixture inlet
6 temperature sensor for recording for tests only
7 pilot flame or spark igniter
8 flame detector for indication
9 test temperature sensor for alarm to detect stabilized flame
10 bursting diaphragm
11 pressure transducer for recording
12 valve

Figure 7 — Test apparatus for endurance burning test

First, the critical flow rate, $\dot{V}_c$, shall be calculated from the open area, A_0, of the surface of the flame arrester element on the unprotected side and from the size and number of apertures per unit area. Assuming a uniform velocity of 75 % of a burning velocity, v_l, of the mixture across this area, calculate a critical flow rate, $\dot{V}_c$, according to Formula (3) in 7.3.4.

For non-measurable flame arrester elements, the critical flow rate, $\dot{V}_c$, may be obtained by using the same principle. The free area, A_0, of the flame arrester element surface can be estimated according to Formula (4) in 7.3.4.

The 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.

Carry out the following preliminary testing for critical flow rates.

After flame stabilization, continue burning until the protected side temperature sensor indicates a temperature rise of 20 K and then stop the flow. Record the time from stabilization of the flame to the 20 K temperature increase.

Carry out this test procedure with flow rates $\dot{V}_c$, $0{,}5\dot{V}_c$ and $1{,}5\dot{V}_c$. In each of these tests, the flame arrester shall be at ambient temperature at the start.

If $\dot{V}_c$ results in the shortest time to 20 K temperature increase, then $\dot{V}_m = \dot{V}_c$. If not, carry out two further tests with flow rates 50 % and 150 % of the flow rate which gave the shortest time in the first three tests. $\dot{V}_m$ will be the flow rate that results in the shortest time in all five tests. When determining the flow rate $\dot{V}_m$, flame arrester elements may be replaced between the tests.

The endurance burn test shall be carried out with the flow rate $\dot{V}_m$, using the original flame arrester element, without modification, that was used for the deflagration and/or detonation test. Maintain the mixture composition and the flow rate $\dot{V}_m$ (±5 %) until a stable temperature is established at the temperature sensor on the protected side. The temperature on the protected side shall be stable within ±5 K over 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 tests or when the flow is stopped.

All types and nominal sizes shall be tested.

Modifications that do not change the flame arrester element and are part of the housing to which the flame arrester element is fitted do not require retesting, e.g. flame arresters with integrated pressure and/or vacuum valves.

7.4 Limits for use

7.4.1 General

The general limits for use are as indicated below.

a) The operational temperature, T_0, shall be limited as follows:

— $-20\ °C \le T_0 \le 60\ °C$ when testing is at atmospheric conditions ($T_{TB} \le 60\ °C$);

— $T_0 \le T_{TB}$ where $T_{TB} \le 150\ °C$ (see 6.8.1, paragraph 4).

b) The operational pressure p_0 shall be limited as follows:

1) for flame arresters with measurable element:

— end-of-line flame arresters with or without pressure and/or vacuum valve on the protected side:

$(0{,}8 \times 10^5\ Pa) \le p_0 \le (1{,}1 \times 10^5\ Pa)$ when testing is at atmospheric pressure (p_{TB} approximately 10^5 Pa);

— in-line flame arresters:

$p_0 \le p_{TB}$ where $p_{TB} \le 1{,}6 \times 10^5$ Pa;

2) for flame arresters with non-measurable element:

$p_0 \le 0{,}9 \times p_{TB}$ where $p_{TB} \le 1{,}6 \times 10^5$ Pa.

Use shall be limited to gas-air mixtures with an MESG equal to or greater than that tested.

7.4.2 In-line flame arrester

7.4.2.1 General

For an in-line flame arrester, the pipe diameter on the protected side shall be no less than the pipe diameter on the unprotected side.

For an in-line flame arrester, the pipe diameter on the unprotected side shall be no greater than the flame arrester connection.

7.4.2.2 In-line deflagration flame arrester

The use of in-line deflagration flame arresters tested in accordance with 7.3.2.2 shall be limited to the following conditions:

a) the ratio of pipe length (between the potential ignition source and the flame arrester) and pipe diameter shall not exceed the tested ratio, L_u/D;

b) at least 10 % of the cross sectional area of the pipe shall be open at the ignition source;

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

7.4.3 Pre-volume flame arrester

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

7.4.4 Detonation flame arrester

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

Detonation flame arresters tested at p_{TB} are suitable for operational pressures $p_0 \le p_{TB}$ in the same or smaller pipe size when the application is limited to mixtures with an MESG equal to or greater than that tested.

NOTE An unstable detonation presents a higher level of hazard than a stable detonation (see 3.11).

Unstable detonation flame arresters (Type 1 and Type 2) are designed and tested for stopping deflagrations and stable and unstable detonations.

Stable detonation flame arresters (Type 3 and Type 4) are designed and tested for stopping deflagrations and stable detonations.

7.4.5 Short time burn flame arresters

If there are operating conditions which can lead to a stabilized burning at the flame arrester element, additional safety measures are required. Depending on the operating conditions, the devices shall be equipped with temperature sensors on one or two sides which initiate measures for the elimination of the stabilized burning (for example, emergency functions like switching-off the system, inerting or similar) and this within the half of the time for which the device is short-time burn proof ($0{,}5 \times t_{BT}$).

When t_{BT} is exceeded during a short-time burning situation, then the flame arresting safety cannot be assured.

When operating with only one temperature sensor, the installation side (identification on side to be protected) has to be respected.

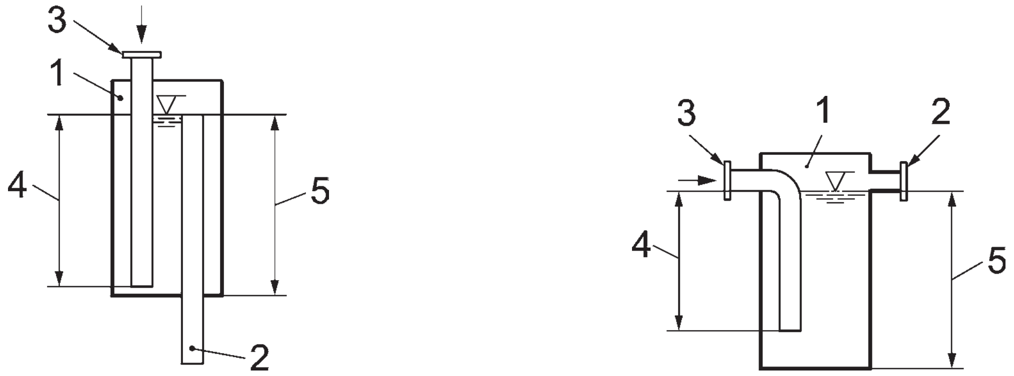
Temperature sensors shall meet the flame arrester manufacturer's specification, they shall be installed in the flame arrester according to the flame arrester manufacturer´s instructions. Temperature sensors shall be integrated into the control system so that safety measures to stop the stabilized burning are initiated. Prior to putting the devices with safety system into operation, the switching temperature shall be adjusted so that the admissible time period for the activating of the emergency measures will be observed.

8 Specific requirements for liquid product detonation flame arresters

8.1 Liquid seals

A flame arrester consisting of a liquid seal formed by the liquid product may be an end-of-line flame arrester [see Figure 8 a)] or an in-line flame arrester [see Figure 8 b)].

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



a) End-of-line flame arrester

b) In-line flame arrester

Key

1 housing

2 overflow pipe/outlet pipe

3 immersion pipe

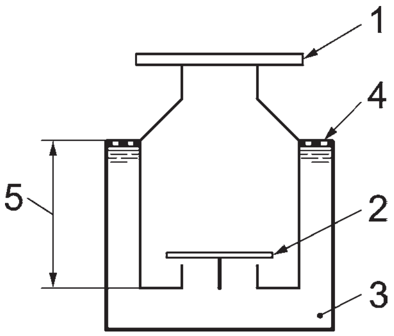
4 immersion depth

5 filling height

Figure 8 — Liquid product detonation flame arrester

8.2 Foot valves

There shall be 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 seat from solid particles (see Figure 9).



Key

1 valve housing
2 valve disc
3 immersion cup
4 perforated plate or screen
5 immersion depth

Figure 9 — End-of-line flame arrester incorporating a non-return valve (foot valve)

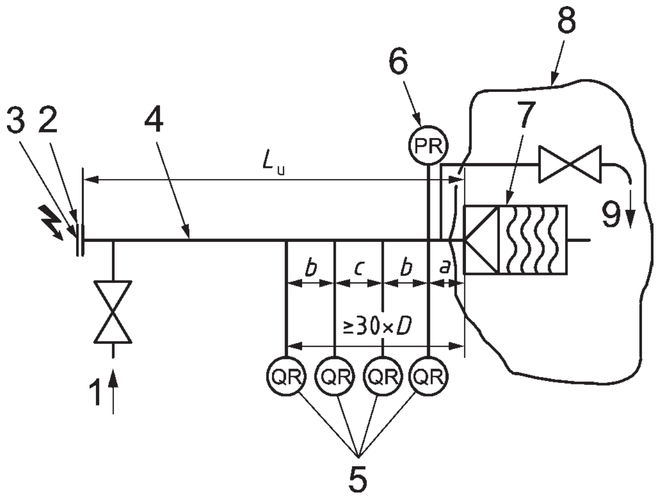
8.3 Flame transmission test

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 100 °C to 140 °C. These liquids may also be used in tests for group IIB mixtures. The filling height shall be recorded (see Figures 8 and 9).

In-line and end-of-line flame arresters shall be tested in accordance with the test procedure given in 7.3.3.2 and, if necessary, in accordance with 7.3.3.4, but using the test apparatus shown in Figure 10. On the basis of the operational conditions for these flame arresters, only three stable detonation tests shall be carried out.

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

The foot valve shall be opened for the test to present a gap at least equal to or greater than the opening in the screen or perforated plate used to protect the valve seat from solid particles.



Key

1 mixture inlet

2 explosion-pressure-resistant containment (vessel or closed pipe work)

3 ignition source

4 unprotected pipe (length, L_u; diameter, D) with bypass

5 flame detectors for recording the flame velocity measurement

6 pressure transducer for recording

7 liquid product detonation flame arrester

8 plastic bag (Ø ≥ 1,2 m; length ≥2,5 m; foil thickness ≥0,05 mm)

9 mixture outlet (bypass)

a = (200 ± 50) mm

$b \geq 3 \times D$, but $b \geq 100$ mm

$c \geq 500$ mm

Figure 10 — Test apparatus for liquid product detonation flame arresters

8.4 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 pressure for the product-air mixture shall be limited to the test pressure.

NOTE The operation pressure for the liquid flow is not limited by flame arresting requirements.

Liquid product detonation flame arresters suitable for emptying operations shall have the flow rate restricted so that the pressure drop of the safety device that prevents loss of sealing liquid does not exceed the static pressure given by the immersion depth (see 8.1). For filling operations, there are no such limitations.

9 Specific requirements for dynamic flame arresters (high velocity vent valves)

9.1 General

Dynamic flame arresters shall be tested for flame transmission (see 9.2). All types and sizes shall be tested. Testing shall be carried out at the lowest setting and closing pressure intended for approval.

NOTE The minimum efflux velocity is typically 30 m/s.

The set pressure, closing pressure and flow rate at closing point, $\dot{V}_{CL}$, of the dynamic flame arrester shall be specified.

Dynamic flame arresters with more than one nozzle shall have each nozzle tested for flame transmission. During the flame transmission tests, the dynamic flame arrester shall be combined as one flame arrester.

Other openings (e.g. drain plug) should be tested in accordance with their operation principle.

The tests shall be carried out with the same test sample without adjustments and without replacement of components.

For endurance burn proof dynamic flame arresters, the test order has to start with endurance burning according to 9.2.4.

For the tests described in 9.2, the completion of the undamped oscillation test in accordance with A.4 is required to provide L_M, D_M, and V_M.

9.2 Flame transmission tests

9.2.1 Low flow flame transmission test

The test apparatus is shown in Figure 11. The pipe length and the pipe diameter between the explosion-pressure-resistant containment and the dynamic flame arrester shall be L_M and D_M and the volume of the explosion-pressure-resistant containment shall be V_M (given in A.4). A smaller volume than V_M may be used providing that it does not increase the risk of flame transmission.

NOTE If the valve displays undamped oscillation (hammering) according to A.4, it is an indication that the volume used is too small.

A temperature sensor for testing shall be attached to the dynamic flame arrester as close as possible to the stabilized flame (e.g. at the valve seat). Ignition shall be maintained by a permanent pilot flame. The pilot flame shall be positioned as close as possible to the mixture outlet to atmosphere, but far enough away from the mixture outlet to avoid heating, or influencing the correct operation of, the dynamic flame arrester. The pilot flame shall burn propane and provide a stabilized pilot flame.

A gas-air mixture as specified in Table 3 shall be fed into the explosion-pressure-resistant containment. The flow rate into the explosion-pressure-resistant containment shall be increased in four steps. The step width depends on the dynamic flame arrester characteristic, as follows:

— for a dynamic flame arrester with $\dot{V}_{CL} > 0$, the step width shall be $0{,}2 \times \dot{V}_{CL}$ with a starting point of $0{,}2 \times \dot{V}_{CL}$;

— for a dynamic flame arrester with $\dot{V}_{CL} = 0$, the step width shall be 20 % of the flow rate of the fully open dynamic flame arrester. The starting point shall be 10 % of the flow rate of the fully open dynamic flame arrester.

The duration of each test step shall be chosen depending on the dynamic flame arrester action, as specified below.

a) If at some point during the sequence of tests the dynamic flame arrester remains in the open position while steadily relieving, the test shall be stopped (e.g. by a shut-off valve), thereby forcing the dynamic flame arrester to close.

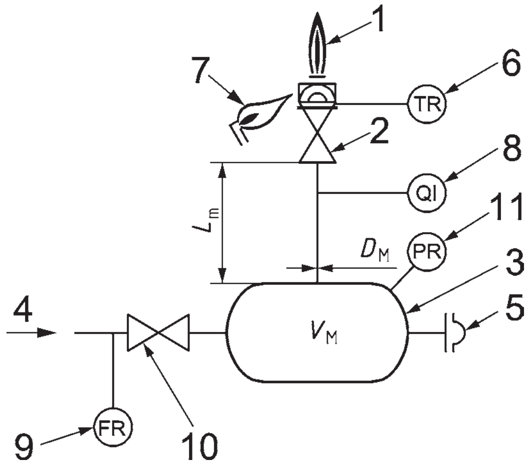
b) If the dynamic flame arrester varies periodically between the closed and open position associated with a varying pressure in the containment, the test duration shall be a minimum of 5 min or 50 open/closed cycles and shall furthermore cover a minimum of five closing actions before the next flow rate step is adjusted.

If the flow rate readings vary due to the opening and closing cycles [see case b) above], the appropriate averaged flow rate shall be used.

This procedure shall be carried out with the dynamic flame arrester in the upright position. The tests shall be repeated with the dynamic flame arrester inclined (10 ± 1)° to the vertical orientation, unless the use is limited to fixed vertical applications without changing of inclination during operation.

NOTE Testing in the inclined position is intended to simulate motion of the dynamic flame arrester, e.g. on marine vessels.

No flame transmission shall occur during these tests.



Key

1 flame
2 dynamic flame arrester
3 explosion-pressure-resistant containment
4 mixture inlet
5 bursting diaphragm
6 temperature sensor for recording (for tests only)
7 pilot flame
8 flame detector for indication
9 flow meter for recording
10 shut-off valve
11 pressure sensor for recording
D_M diameter of the pipe on the protected side determined in accordance with A.4
L_m pipe length upstream of the dynamic flame arrester determined in accordance with A.4
V_M volume of the explosion-pressure-resistant containment

Figure 11 — Test apparatus for determining the non-hammering conditions for dynamic flame arresters

9.2.2 Flame transmission test by opening and closing

The test apparatus is shown in Figure 11. The pipe length and the pipe diameter between the explosion-pressure-resistant containment and the dynamic flame arrester shall be L_M and D_M and the volume of the explosion-pressure-resistant containment shall be V_M (given in A.4). A smaller volume than V_M may be used providing that it does not increase the risk of flame transmission.

NOTE If the valve displays undamped oscillation (hammering) according to A.4, it is an indication that the volume used is too small.

A temperature sensor for testing shall be attached to the dynamic flame arrester as close as possible to the stabilized flame (e.g. at the valve seat). Ignition shall be maintained by a permanent pilot flame. The pilot flame shall be positioned as close as possible to the mixture outlet to atmosphere, but far enough away from the mixture outlet to avoid heating, or influencing the correct operation of, the dynamic flame arrester. The pilot flame shall burn propane and provide a stabilized pilot flame.

The dynamic flame arrester shall be subjected to 50 open/closed cycles, using a gas-/air-mixture as specified in Table 3. During the 50 cycles the mixture shall be ignited by a pilot flame close to the outlet. This test can be disregarded if 50 open/closed cycles have been observed during the low flow flame transmission tests.

This procedure shall be carried out with the dynamic flame arrester in the upright position. The tests shall be repeated with the dynamic flame arrester inclined (10 ± 1)° to the vertical orientation, unless the use is limited to fixed vertical applications without changing of inclination during operation.

NOTE Testing in the inclined position is intended to simulate motion of the dynamic flame arrester, e.g. on marine vessels.

No flame transmission shall occur during the test.

9.2.3 Deflagration test

Deflagration tests shall be carried out according to 7.3.2.1.

9.2.4 Endurance burning test

The test apparatus is shown in Figure 11. The pipe length, L_m, between the explosion-pressure-resistant containment and the dynamic flame arrester shall not exceed L_M. A temperature sensor for testing shall be attached to the dynamic flame arrester as close as possible to the stabilized flame (e.g. at the valve seat). Ignition shall be maintained by a permanent pilot flame. The pilot flame shall be positioned as close as possible to the mixture outlet to atmosphere, but far enough away from the mixture outlet to avoid heating or influencing the correct operation of, the dynamic flame arrester. The pilot flame shall burn propane and provide a stabilized pilot flame.

Using a gas-air mixture as specified in Table 3, the pressure in the explosion-pressure-resistant containment shall be increased to force the dynamic flame arrester open and then shall be maintained at 10 % above the established closing pressure. The corresponding flow rate, $\dot{V}_0$, 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 $\dot{V}_0$, and after each increment, the flow shall be maintained until the temperature rise is less than 10 K/min, but for a minimum of 5 min.

When the temperature starts to decrease, the flow rate $\dot{V}_E$ is the maximum flow rate that shall be used in this test. The flow rate shall then be reduced in increments of 10 % of $\dot{V}_E$ and after each step shall be maintained until the temperature change is less than 10 K/min, but for a minimum of 5 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 $\dot{V}_0$. Upon completion, the flow rate yielding the highest temperature shall be recorded as $\dot{V}_m$ and the burning at that rate shall be continued until the change of temperature indicated by the test temperature sensor does not exceed ±5 K in 10 min.

For enriched mixtures, the concentration shall be gradually reduced as far as possible towards the initial value (see Table 3) keeping the flame stabilized. The flow shall be stopped and no flame transmission shall occur.

9.3 Limits for use

The use of a dynamic flame arrester shall be limited to ambient temperatures. The diameter of the connection of the dynamic flame arrester shall be at least D_M, while the minimum gaseous volume (ullage space) available at any time in the protected tank shall not be less than V_M. The equivalent pipe length on the protected side shall for pipe connection D_M not exceed L_M, as determined in A.4 and as successfully tested in 9.2.1.

NOTE Equivalent pipe length is the length of straight pipe that would cause the same pressure drop under equivalent flow condition as the configuration including restrictions, e.g. bends, reducers. Calculation methods are given in e.g. Perry's chemical engineer's handbook. [11]

10 Specific requirements for hydraulic flame arresters

10.1 Equipment

Hydraulic flame arresters are in-line flame arresters. An example is shown schematically in Figure 12. They 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). 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}) which corresponds with the minimum operational immersion depth (Z_{0min}) specified 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 as shown in Figure 12, with the mixture outlet pipe (6) removed if necessary.

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

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

10.2.3 Deflagration test

The test apparatus is as 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).

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 6.8.2.

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

— $L_u = 50 \times D$;

— $L_u = 100 \times D$.

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 $\dot{V}_{max}$.

10.2.4 Detonation test

The test apparatus is as 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). 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 7.3.3.2 for further details).

Tests shall be carried out by using a test mixture as specified in 6.8.2.

Carry out three detonation tests with the mixture at rest and with the minimum immersion depth at rest (Z_{Rmin}), 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:

a) the flow rate does not exceed the safe value, $\dot{V}_s = 0{,}9 \times \dot{V}_{max}$;

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

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

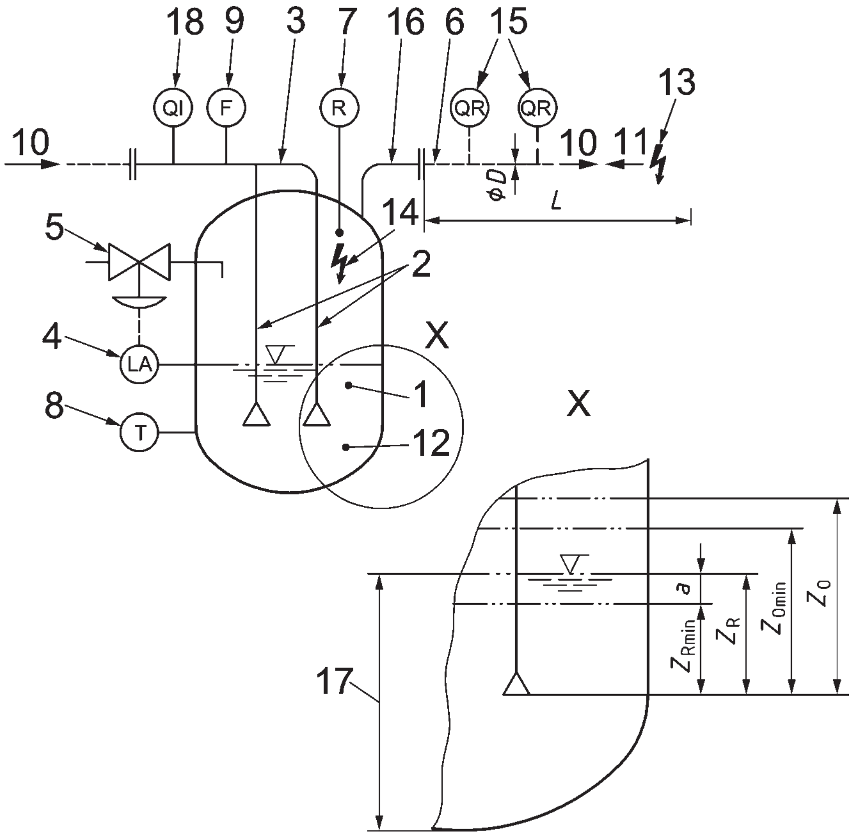
Failure of any of the features listed under points a) to d) in 10.1 shall operate an alarm and stop the gas flow.

If any temperature recorded in accordance with points c) and/or d) in 10.1 exceeds or falls below the specified limits, or if the minimum operational immersion depth Z_{0min} falls below the specified level, or if the volume flow exceeds $\dot{V}_s$, 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 greater 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, $\dot{V}_{max}$, has been established.

The operational immersion depth, Z_0, shall be maintained by automatic control of the water supply [see item (5) in Figure 12] 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 level indicator with an optical display
5 automatic water seal level control
6 mixture outlet pipe (length, L; diameter, D)
7 temperature sensor for alarm to indicate a stabilized flame above the water seal
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 recording flame velocity
16 mixture outlet
17 filling height
18 flame detector to indicate flame transmission
a = (25 ± 3) mm

Figure 12 — Test apparatus for hydraulic flame arrester

11 Test of flame arresters installed on or within gas conveying equipment

11.1 General

The gas conveying equipment described below is intended for the transport of mixtures of air and combustible gases, vapours or mists. These mixtures to be transported are situated in the working chamber inside the gas conveying equipment. These gas conveying equipment have pipe connections on the suction/inlet side and pressure/outlet side.

Flame arresters for the protection of the pipework connected to the gas conveying equipment, which are integrated or mounted on the inlet and outlet side of the gas conveying equipment shall be tested, together with the gas conveying equipment, for safety against flame transmission through the flame arrester in the case of explosions in the gas conveying equipment inside.

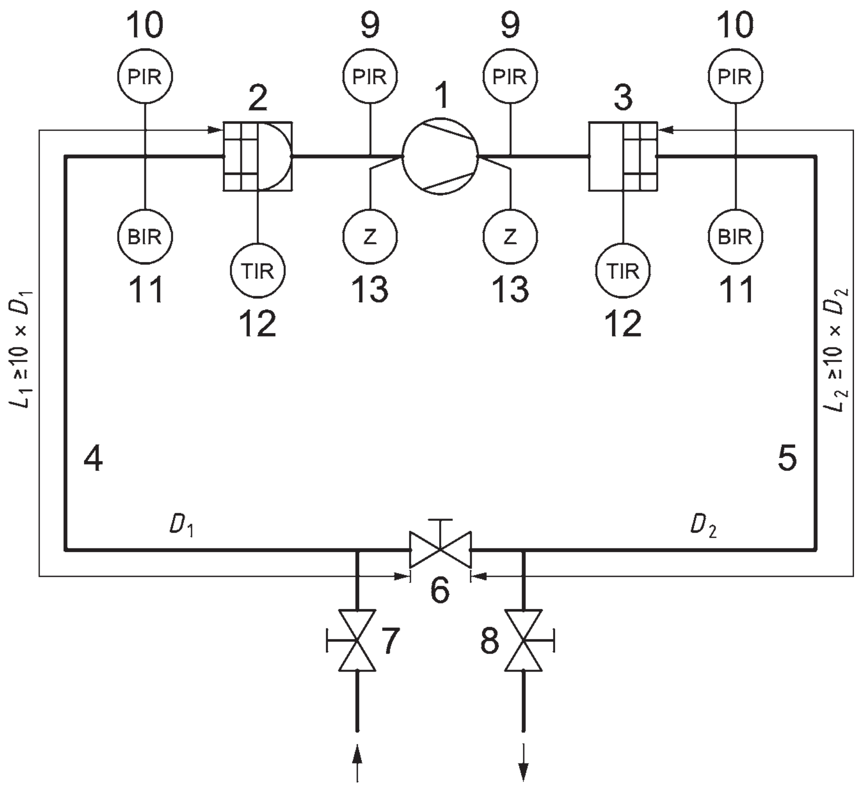
The results of the tests with ambient temperatures ≤60 °C at the flame arresters apply to temperatures from −20 °C up to +60 °C at the flame arrester elements. If, during operation of the gas conveying equipment, temperatures of more than 60 °C arise at the flame arrester element, additional tests shall be carried out with the correspondingly warmed flame arresters.

No flame transmission through the flame arrester into the connecting pipes shall occur at the flame arresters in any of the tests to be carried out.

11.2 Flame transmission test

11.2.1 General

The instructions for the tests of the gas conveying equipment are specified depending on the respective rated inlet pressure according to 11.2.2 and 11.2.3. The test apparatus is shown in Figure 13.



Key

1 gas conveying equipment
2 flame arrester inlet side, size of flange connection Ø1
3 flame arrester outlet side, size of flange connection Ø2
4 test pipe flame arrester inlet side – throttle valve (Ø: D_1, length: L_1), $D_1 \leq$ Ø1
5 test pipe flame arrester outlet side – throttle valve (Ø: D_2, length: L_2), $D_2 \leq$ Ø2
6 throttle valve
7 mixture inlet
8 mixture outlet
9 pressure sensor (static); in addition as an option: pressure sensor (dynamic), flame detector and temperature sensor
10 pressure sensor (dynamic)
11 flame detector
12 temperature sensor on the flame arrester surface facing the test pipe
13 alternative ignition points close to the moved parts of the equipment

Figure 13 — Test apparatus for the flame transmission test of flame arresters installed on or within gas conveying equipment

The diameter of the test pipe parts (D_1, D_2) installed between the flame arresters and the throttle valves shall not be larger than the size of flange connection of the respective flame arrester. Reductions or enlargements of the diameters of the test pipe parts may be carried out only after a length of 10 × D_1 downstream of the flame arrester on the inlet side and 10 × D_2 downstream of the flame arrester on the outlet side.

The nominal size of the throttle valve shall be the same or smaller than the diameter of the pipe (D_1 or D_2). Mixture inlets and outlets in the test pipe shall be arranged to be close to the throttle valve.

The ignition source shall be placed as near as possible to the mechanically moved parts of the equipment on the inlet side or on the outlet side.

The tests shall be carried out with a gas/air-test mixture as specified in Table 2.

The test apparatus with a closed throttle valve shall be purged with the test mixture until the mixture concentration at the outlet corresponds to the specifications of Table 2, and then isolated from the gas filling system.

11.2.2 Test procedure for gas conveying equipment with inlet pressure >600 hPa

After sufficiently purging the test apparatus with the test mixture, the specified parameters in Table 8:

— operating state of the equipment,

— position of the throttle valve, and

— test mixture pressure in the test apparatus

shall be adjusted for the respective test.

12 tests shall be carried out with working equipment (see Table 8). The mixture temperature and the equipment shall be warmed up that the temperature profile up to a steady-state temperature (60 °C or the maximum allowed temperature given by the manufacture at the inlet as a general rule). The maximum gas temperature shall be measured at the mixture outlet.

Six tests shall be carried out with switched-off equipment (see Table 8). The equipment and the test mixture shall be at ambient temperature when the test mixture is ignited.

Table 8 — Number of the individual tests and test parameters for the flame transmission test of flame arresters installed on or within gas conveying equipment with inlet pressures >600 hPa

<table>
<tr><th colspan="5">Test parameters</th></tr>
<tr><th>Operating state</th><th>Mixture pressure</th><th>Ignition point</th><th>Position of the throttle valve</th><th>Number of tests</th></tr>
<tr><td rowspan="4">Rotating at max. speed</td><td>Max. inlet pressure</td><td rowspan="2">Inlet side</td><td>Open</td><td>3</td></tr>
<tr><td>Max. outlet pressure</td><td>Approx. 80 % closed[a]</td><td>3</td></tr>
<tr><td>Max. inlet pressure</td><td rowspan="2">Outlet side</td><td>Open</td><td>3</td></tr>
<tr><td>Max. outlet pressure</td><td>Approx. 80 % closed[a]</td><td>3</td></tr>
<tr><td rowspan="2">Stationary</td><td rowspan="2">Max. inlet pressure</td><td>Inlet side</td><td>closed</td><td>3</td></tr>
<tr><td>Outlet side</td><td>closed</td><td>3</td></tr>
<tr><td colspan="5">[a] Valve closed so far (approx. 80 %) so that the maximum outlet pressure is achieved in the equipment, but a sufficient air flow is remaining to avoid overheating of the equipment.</td></tr>
</table>

In addition, the flame arrester on the inlet side shall be subjected to a short time burning flame transmission test according to 7.3.4 with connected pipe.

The external surface temperature shall be taken into account when specifying the temperature class of the equipment.

11.2.3 Test procedure for gas conveying equipment with inlet pressure ≤600 hPa

After sufficiently purging the test apparatus with the test mixture, the specified parameters in Table 9:

— operating state of the gas conveying equipment,

— position of the throttle valve and

— test mixture pressure in the test apparatus

shall be adjusted for the respective test.

Tests shall be carried out at the maximum operational temperatures at the flame arrester element according to Table 9.

Table 9 — Number of the individual tests and test parameters for the flame transmission test of flame arresters installed on or within gas conveying equipment with inlet pressures ≤600 hPa

Test parameters				
Operating state	**Mixture pressure**	**Ignition point**	**Position of the throttle valve**	**Number of tests**
Temperature at the flame arresters: Ambient temperature (≤60 °C)				
Rotation at max. speed	Max. outlet pressure	Inlet side	Open	3
		Outlet side	Closed	5
			Open	3
Stationary	Max. inlet pressure	Inlet side	Closed	5
		Outlet side	Closed	3
In addition, if temperature at the flame arresters at outlet: >60 °C				
Rotation at max. speed	Max. outlet pressure	Outlet side	Closed	6
Stationary	Max. inlet pressure	Inlet side	Closed	3
		Outlet side	Closed	3
In addition, if temperature at the flame arrester at inlet: >60 °C				
Rotation at max. speed	Max. outlet pressure	Inlet side	Open	3
Stationary	Max. inlet pressure	Inlet side	Closed	6
		Outlet side	Closed	3

In addition, the flame arrester on the inlet side shall be subjected to a short time burning flame transmission test according to 7.3.4 with connected pipe.

The external surface temperature shall be taken into account when specifying the temperature class of the equipment.

12 Information for use

12.1 Instructions for use

The manufacturer shall provide the following minimum written instructions and information:

a) the information marked on the flame arrester and an explanation of its meaning;

b) information concerning the classification of the flame arrester as outlined in Clause 5;

c) all details of the operational requirements, including the specific limits in accordance with 7.4, 8.4, 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 that extension to other chemicals may require testing with these specific chemicals;

e) short time burning flame arresters and hydraulic flame arresters shall include a warning that additional external safety equipment is required; all data that are necessary to characterize the integrated temperature sensor used for the stabilized burning test shall be documented; if the user equips the flame arrester with any other temperature sensor, this sensor shall fulfil these requirements as a minimum;

f) the specific burn time and that this burn time was determined under atmospheric pressure;

g) the allowed installation direction of the flame arrester with regard to flow direction and protected side;

h) 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;

i) full description of the connections of the flame arrester;

j) flame arresters may be used in combination with additional protection measures, the overall safety of the combined installation shall be assessed, taking account of any hazardous area classification (zones) and of the likelihood of possible ignition sources;

k) for end-of-line deflagration arresters, a minimum distance shall be given for any external installation that might impair flame or flow.

12.2 Marking

12.2.1 Flame arrester

12.2.1.1 General information

The flame arrester shall be marked with the following information:

a) the name and address of the manufacturer;

b) the designation of series;

c) the serial number;

d) the year of construction [if not incorporated in point c)];

e) the number of this International Standard, i.e ISO 16852;

f) set pressure and/or set vacuum for flame arresters with integrated pressure and/or vacuum valve, or for dynamic flame arresters;

g) protected side (directional types only);

h) maximum flow rate (hydraulic flame arresters);

i) explosion group.

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

12.2.1.2 Warning information

Flame arresters shall have a hazard sign with the following information:

a) warning;

b) flame arresters have installation and application limits;

c) type designation in accordance with this International Standard;

d) for deflagration flame arresters, the sign “DEF” and the ratio L_u/D; for end-of-line flame arresters, L_u/D is not applicable (“n/a”);

e) for detonation flame arresters, the sign “DET” in combination with the type number:

— “1” – tested for unstable detonation with restriction;

— "2" – tested for unstable detonation without restriction;

— "3" – tested for stable detonation with restriction;

— "4" – tested for stable detonation without restriction;

f) pre-volume flame arresters , the sign "VDEF" and the relevant limits (i.e. pressure, temperature and volume) according to the test report, see 7.4.3;

g) for burn rating, the sign "BC" plus the classification "a", "b" or "c" (as specified below), together with the burn time t_{BT} (in min) for class "b", i.e.:

— "a" – endurance burn (no time limit);

— "b" – short time burn according to 7.3.4;

— "c" – no burn time;

NOTE When a flame arrester has been tested against short-time burning, this will be marked with "Burning Class: b" and "Burning Time: t_{BT} = ..." (irrespective of the fact if the temperature sensors are installed or not) because this is a tested property of the safety system.

h) explosion group;

i) maximum operational temperature T_0;

j) maximum operational pressure p_0 (absolute pressure).

NOTE For end-of-line flame arresters, the maximum operational pressure is not applicable.

Examples of marking plates are shown in Figures 14 and 15 below.

Figure 14 shows an example of a marking plate for an end-of-line deflagration arrester safe for burn classification "a" for explosion group (Ex. Gp) IIA, for an operational temperature, T_0, of 60 °C.

Warning			
Flame arresters have installation and application limits. Type designation in accordance with ISO 16852.			
DEF	L_u/D = n/a	BC: a	
	Ex. Gp IIA	T_0 = 60°	—

Figure 14 — Example of marking plate, burn rating "a"

Figure 15 shows an example of a marking plate for a detonation arrester of Type 2, for explosion group (Ex. Gp) IIB3, for a burn classification "b" of 15 min, an operational temperature, T_0, of 120 °C and a maximum operational pressure, p_0, of 0,16 MPa.

NOTE 1 bar = 0,1 MPa.

Warning			
Flame arresters have installation and application limits. Type designation in accordance with ISO 16852.			
DET 2	L_u/D = n/a	BC: b; t_{BT} = 15 min	
	Ex. Gp IIB3	T_0 = 120°	p_0 = 0,16 MPa abs

Figure 15 — Example of marking plate, burn rating "b"

12.2.2 Flame arrester element

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

a) the name of manufacturer or trade mark;

b) the identification code;

c) the serial number or code;

d) the protected side (directional flame arrester elements only).

Compliance with item e) in 12.2.1.1 shall not be stated unless all appropriate requirements of this International Standard are met.

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

Annex A
(normative)

Flow measurement

A.1 General

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 dynamic flame arrester 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.

Separate flame arresters and pressure and/or vacuum valves that 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:

— $L_1 \geq 10 \times D$;

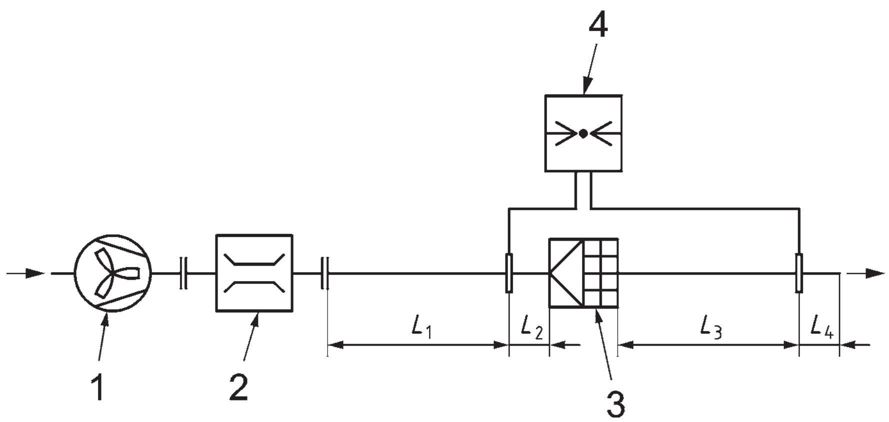
— $L_2 = 2 \times D$;

— $L_3 \geq 10 \times D$;

— $L_4 = 2 \times D$.

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 (see item 4 in Figure A.1).

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



Key

1 blower or fan

2 flow detector for recording

3 in-line flame arrester

4 pressure sensor for recording

L_1, L_2, L_3, L_4 length of apparatus pipes

Figure A.1 — Test apparatus for recording the pressure drop/flow rate curve for in-line flame arresters

A.3 End-of-line flame arrester

A.3.1 General

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 shall have a length $L_1 \leq 10 \times D$ (see Figure A.2). 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 (see item 4 in Figure A.2).

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

Vacuum valves shall have the direction of flow reversed.

A.3.2 Special flow measurement for dynamic flame arresters

Flow measurements for dynamic flame arresters shall be made using the lowest possible setting for the specific model without changing its characteristics, as defined in 9.2.

The flow measurement shall consist of three phases:

— phase 1 (opening phase): the capacity from shut to fully open;

— phase 2 (working area): the capacity from fully open and upward;

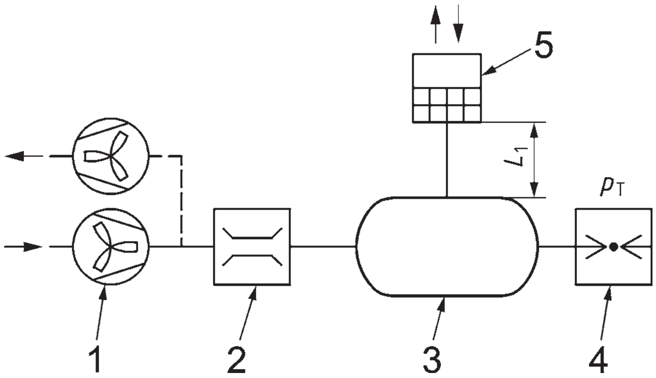
— phase 3 (closing phase): the capacity from fully open to shut.

The flow measurement for phase 1 is carried out to establish pressure surges and/or pressure reductions. The flow rate to be used for this purpose is determined as the flow at which the dynamic flame arrester is fully open. Ten equally spaced measurements (10 % of the flow rate, 20 % of the flow rate, etc.) shall be recorded in the interval from shut to fully open. If the dynamic flame arrester features a system that makes it change its dynamic characteristics from modulating to full lifting, 10 additional and equally spaced measurements shall be made at this point within a span of 10 % to each side.

The flow measurement for phase 2 is carried out to establish the pressure increase from when the dynamic flame arrester is fully open and upward. The capacity shall be measured at the pressure at which the dynamic flame arrester is fully open, and at five or more increments of 10 % above this pressure.

The flow measurement for phase 3 is carried out to establish the blow-down value of the dynamic flame arrester. The flow rate to be used is the least capacity at which the dynamic flame arrester remains fully open. The pressure shall then be recorded for 10 equally spaced capacities between this flow and when the dynamic flame arrester is shut.

A flow chart shall be drawn based on the above measurements.



Key

1 blower or fan

2 flow detector for recording

3 explosion-pressure-resistant containment

4 pressure sensor for recording

5 end-of-line flame arrester

L_1 length of connecting pipe

p_T pressure in the flow test of an end-of-line flame arrester

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

A.4 Undamped oscillation tests of dynamic flame arrester (High velocity vent valves)

Dynamic flame arresters shall be tested in order to determine the maximum pipe length, L_M, that does not lead to undamped oscillations. The test apparatus is shown in Figure A.3. The test set-up shall incorporate a valve disc location monitor (e.g. video camera, position meter) to trace the position of the valve disc during the test runs.

The initial pipe length, L_2, (Figure A.3), the volume, V_M, and the pipe diameter, D_M, shall comply with the specifications by the manufacturer.

D_M, V_M and L_M are also basic parameters for the flame transmission test (9.2) and the resulting limits for use (9.3). For valves which (due to their characteristics) may perform periodic open/close cycles at certain flow rates, it is recommended to comply with the following condition: The tank volume, V_M, should be large enough to ensure that tank volume has no effect on oscillations in any of the tests.

For any dynamic flame arrester type, the following tests shall be carried out at the lowest setting intended for approval.

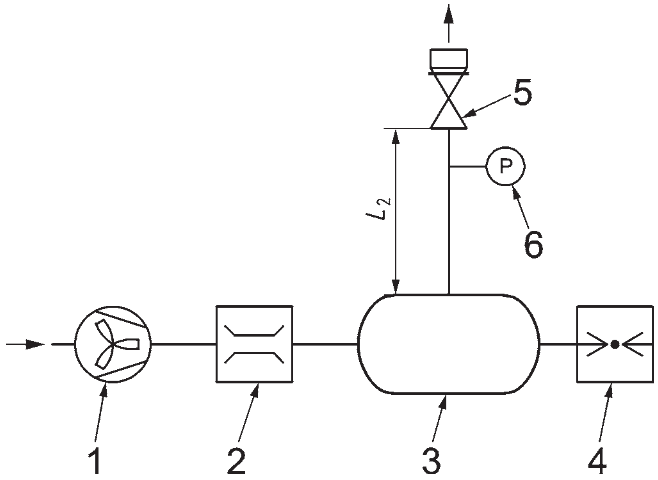
The flow rate into the containment shall be increased in 10 steps. The span and step width of the 10 flow rates shall be chosen depending on the valve characteristic, as specified below.

— For valves with $\dot{V}_{CL} > 0$, the lowest flow rate shall be $0{,}2 \times \dot{V}_{CL}$ and the highest shall be $2 \times \dot{V}_{CL}$ (step width $0{,}2 \times \dot{V}_{CL}$).

— For valves with $\dot{V}_{CL} = 0$ the lowest flow rate shall be 10 % of the rate at which the valve is fully open. This value shall also be taken as step width.

At each flow rate, an opening of the valve shall be awaited (if initially closed) and the flow shall then be maintained for additional 3 min.

If the disc location monitor indicates periodic contact with seat or upper stop with a frequency of more than 0,5 Hz (undamped oscillation), the pipe length (L_2) shall be shortened until this frequency value is not exceeded or the contacting ceases. That length shall be recorded as L_M.



Key

1 blower or fan
2 flow detector for recording
3 containment
4 pressure sensor for recording
5 dynamic flame arrester
6 pressure sensor
L_2 length of vent pipe

Figure A.3 — Test apparatus for determining the non-oscillating conditions for dynamic flame arresters

Annex B
(informative)

Information for selecting flame arresters

To help manufacturers and users decide which flame arrester is the most suitable for their application, the information outlined in Table B.1 should be considered.

Table B.1 — Information for selecting flame arresters

Characteristic		**Aspect to 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 should be 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 should be 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 an explosive 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 pipe work 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.
16.	Regulations	Applicable corporate and/or statutory regulations should be identified.

Annex C
(informative)

Best practice

Manufacturers and users should be aware of the aspects listed below.

a) Flame velocities and pressures of explosive mixtures can be enhanced by upstream turbulence, which can be caused by bends, valves or any change of cross section in the pipe. For in-line deflagration flame arresters, the pipelines on the unprotected side, i.e. the pipeline between ignition source and position of the flame arrester, should be as straight as possible without obstructions.

b) Dynamic flame arresters are sensitive to turbulence and pressure drop caused by obstructions and longer pipelines on the protected side between the tank and the dynamic flame arrester. This might cause "hammering" or undamped oscillations.

c) Flame arresters or/and flame arrester parts should be included in an existing equipotential bonding arrangement, if necessary.

d) 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. Therefore, in addition, the distance between neighbouring endurance burning end-of-line flame arresters should be more than five times the maximum diameter of the flame arrester.

e) 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.

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

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

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

i) The use of MESG as an unequivocal measure of flame arrester effectiveness has not been validated for all 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 sought (see Bibliography).

j) Possible catalytic reaction can be avoided by properly choosing the material of the flame arrester.

k) Flame arresters should be installed in accordance with the manufacturer's operation manual and should be maintained regularly, depending on the existing operation conditions. If it is detected that a flash back (deflagration or detonation) or a stabilized burning has occurred at the device, the complete device needs to be checked.

l) Flame arresters may be used in combination with additional protection measures. The overall safety of the combined installation shall be assessed, taking account of any hazardous area classification (zones) and of the likelihood of possible ignition sources.

m) High stresses can be exerted on the fixing points of the flame arrester and on the unprotected side of the piping especially in the case of a detonation (high pressure shock wave); stresses between the flame arrester and the adjoining pipe work shall be limited to acceptable levels by appropriate installation, selection of material and construction.

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