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INTERNATIONAL STANDARD

Explosive atmospheres –
Part 49: Flame arresters – Performance requirements, test methods and limits for use

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FOREWORD

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ISO/IEC 80079-49 has been prepared by subcommittee 31M: Non-electrical equipment and protective systems for explosive atmospheres, of ISO/IEC joint technical committee 1: Information technology.

This edition cancels and replaces ISO 16852:2016, which has been technically revised. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to ISO 16852:2016:

a) adaptation of the relevant IEC TC 31 requirements on standards;
b) modification of the upper limit of the temperature range from 150 °C to 200 °C under the condition that T_0 shall be not larger than 80 % of the auto ignition temperature of the gas-air-mixture;
c) change of the term "explosion group" to "equipment group" due to editorial requirements in IEC/TC 31;
d) clarification of the conditions and requirements for flame arresters whose intended operating conditions are outside the atmospheric conditions in 7.3.4 and 7.3.5;

e) clarification of the requirements on the information for use in Clause 12 f) concerning the burn time;

f) addition of a permission to the construction requirements both in 7.1 and 14.1 to substitute visual inspection by performing a flow test;

g) addition of a flow chart for the evaluation of test results as Annex D.

The text of this International Standard is based on the following documents:

Draft	Report on voting
31M/212/FDIS	31M/223/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

A list of all parts in the ISO/IEC 80079 series, published under the general title *Explosive atmospheres*, can be found on the IEC website.

NOTE The following print types are used:

- Words in *italic* font in the text are defined in Clause 3.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1, available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

INTRODUCTION

Flame arresters are protective systems fitted to openings of enclosures or to pipe work and are intended to allow fluid flow but prevent flame transmission if a flammable mixture is ignited. They have widely been used for decades in the chemical and oil industry, and a variety of national standards is available. This document was prepared with an aim to establish an international basis by harmonizing and incorporating recent national developments and standards as far as reasonable.

This document addresses performance requirements and test methods, as well as limits for use for flame arresters.

Only the minimum safety requirements for flame arresters to prevent flame transmission are specified.

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 document 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, for example for electrical equipment, where the importance of process gas flow through any gaps is negligible and importance is placed on the flame quenching effect of the gap.

Consequently, in this document, the testing and classification related to Equipment Groups and installation conditions have been subdivided more than is usually the case in other parts of the ISO/IEC 80079 and IEC 60079 series of standards. In particular,

– Equipment Group IIA is subdivided into sub-groups IIA1 and IIA,
– Equipment 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 user. This document 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 the user and regulators. Annex B and Annex C offer some guidance on these aspects.

EXPLOSIVE ATMOSPHERES –

Part 49: Flame arresters – Performance requirements, test methods and limits for use

1 Scope

This document 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 document is applicable to pressures ranging from 80 kPa to 160 kPa and temperatures ranging from −20 °C to +200 °C.

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

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

This document does not apply 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 3 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), are within the scope of this document.

– flame arresters used for explosive mixtures of vapours and gases, which tend to self-decompose (for example, acetylene) or which are chemically unstable;
– flame arresters used for carbon disulfide, due to its special properties;
– flame arresters whose intended use is for mixtures other than gas-air or vapour-air mixtures (for example, higher oxygen-nitrogen ratio, chlorine as oxidant);
– flame arrester test procedures for reciprocating internal combustion engines;

  NOTE 4 Flame arresters for specific applications (e.g. reciprocating internal combustion engines) can use this document as a guide for design but be subject to testing related to their specific use.

– fast acting valves, extinguishing systems and other explosion isolating systems;
– Flame arresters used in gas detectors (those being covered for example, by IEC 60079-29-1 and IEC 62990-1).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

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

ISO/IEC 80079-34, *Explosive atmospheres – Part 34: Application of quality management systems for Ex Product manufacture*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60079-0 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

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 document, 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* (3.10)

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 of a joint of 25 mm in width which prevents any transmission of an explosion during tests made under the conditions specified in ISO/IEC 80079-20-1

[SOURCE: ISO/IEC 80079-20-1:2017, 3.4, modified – "in ISO/IEC 80079-20-1" added and Note 1 to entry deleted.]

3.12.2
safe gap
maximum gap of a joint of 25 mm in width which prevents any transmission of an explosion during tests made under the conditions specified in ISO/IEC 80079-20-1 for the specified vapour/gas mixture

3.12.3
equipment grouping
classification system of equipment related to the explosive atmosphere for which they are intended to be used

Note 1 to entry: In a large part of the safety equipment industry "explosion group" is used as an alternative term.

[SOURCE: ISO/IEC 80079-20-1:2017, 3.7, modified – Note 1 to entry replaced.]

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
deflagration proof (see 3.14) 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 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 stable or unstable detonation without restriction (type 4 or type 2)

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 (for example, 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

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 can 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

$\dot{V}_\mathrm{max}$ 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 $Z_\mathrm{0min} > Z_\mathrm{Rmin}$

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 classification: 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.

NOTE 1 A deflagration when confined in a pipe will usually accelerate and can undergo transition through an unstable to a stable detonation provided sufficient pipe length is available. This pipe length will 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.

NOTE 2 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.

The specific hazards covered by this document, 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
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 classification: 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.

5.3 Index of tests

Flame arresters shall be tested to the specific Equipment Group of the explosive gas-air or vapour-air mixture (see Table 3, columns 1 and 2).

The tests to be conducted are given in Table 2.

Table 2 – Summary of tests to be conducted

Type of flame arrester		Flame transmission test	Burning test	Flow test
End-of-line deflagration flame arrester (DEF)	Short time burn proof	7.3.2.1	7.3.4	A.3
	Endurance burn proof		7.3.5	
	No stabilised burn rating		—	
In-line deflagration flame arrester (DEF)	Short time burn proof	7.3.2.2	7.3.4	A.2
	Endurance burn proof		7.3.5	
	No stabilised burn rating		—	
Pre-volume flame arrester (VDEF)	No stabilised burn rating	7.3.2.3	—	A.2 or A.3
Stable detonation flame arrester without restriction (DET4)	Short time burn proof	7.3.3.2	7.3.4	A.2
	Endurance burn proof		7.3.5	
	No stabilised burn rating		—	
Stable detonation flame arrester with restriction (DET3)	Short time burn proof	7.3.3.3	7.3.4	A.2
	Endurance burn proof		7.3.5	
	No stabilised burn rating		—	
Unstable detonation flame arrester without restriction (DET2)	Short time burn proof	7.3.3.4	7.3.4	A.2
	Endurance burn proof		7.3.5	
	No stabilised burn rating		—	
Unstable detonation flame arrester with restriction (DET1)	Short time burn proof	7.3.3.5	7.3.4	A.2
	Endurance burn proof		7.3.5	
	No stabilised burn rating		—	
Liquid product detonation flame arrester (DET4+DET2)	No stabilised burn rating	8.3	—	—
Dynamic flame arrester (high velocity vent valve) (DEF)	Deflagration proof	9.2.1, 9.2.2 and 9.2.3	—	A.3.2 and A.4
	Endurance burn proof		9.2.4	
Hydraulic flame arrester	Short time burn proof	10.2.3, 10.2.4	10.2.2	—

Flow charts showing the decision processes for the evaluation of test results of a stable detonation arrester (DET3 and DET4) and an unstable detonation arrester (DET1 and DET2) are given in Annex D.

6 General requirements

6.1 Measuring instruments

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

The uncertainty of measurement in the tests shall be such that it can be shown that all the required test parameter limits are met.

6.2 Flow measurement (air)

The pressure drop across the flame arrester shall be tested before and after flame transmission tests in accordance with Annex A 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.

6.3 Flame transmission test

6.3.1 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 specified in Table 2 and 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 functionally equivalent.

All flame transmission tests shall be carried out with gas-air mixtures at ambient temperatures. If operational temperature is higher than 60 °C, tests shall be carried out at the maximum operational temperature or higher, with only the flame arrester being heated to the required temperature, $T_{TB} \leq 200$ °C. Gas-air or vapour-air mixtures shall be as specified in 6.3.2. The temperature shall be measured on the surface of the flame arrester element at the protected side, as close to the centre of the element as possible.

For the purposes of this document, Equipment Group IIC covers hydrogen and other gas-air or vapour-air mixtures with MESG less than 0,5 mm, and Equipment Group IIB is divided into four sub-groups: IIB1, IIB2, IIB3 and IIB. Equipment Group IIA is divided into two sub-groups: IIA1 and IIA. This document 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 Equipment Groups IIA1, IIA, IIB1, IIB2, IIB3, IIB and IIC, are shown in Table 3.

A flame arrester for a particular Equipment Group is suitable for explosive mixtures of another group having a greater MESG.

6.3.2 Test mixtures

Table 3, Table 4 and Table 5 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 3 – Specification of gas-air mixtures for deflagration and detonation tests

Range of application (marking)		Requirements for test mixture			
Equipment Group	**MESG** mm	**Gas type**	**Gas purity by volume** %	**Gas in air by volume** %	**Safe gap of gas-air mixture** mm
IIA1	≥ 1,14	Methane	≥ 98	8,4 ± 0,2	1,16 ± 0,02
IIA [a]	≥ 0,90	Propane	≥ 95	4,2 ± 0,2	0,94 ± 0,02
IIB1 [a]	≥ 0,85	Ethylene	≥ 98	5,2 ± 0,2	0,83 ± 0,02
IIB2 [a]	≥ 0,75			5,7 ± 0,2	0,73 ± 0,02
IIB3 [a]	≥ 0,65			6,6 ± 0,3	0,67 ± 0,02
IIB [a]	> 0,50	Hydrogen	≥ 99	45,0 ± 0,5	0,48 ± 0,02
IIC	≤ 0,50	Hydrogen	≥ 99	28,5 ± 2,0	0,31 ± 0,02

NOTE 1 The rankings in columns 1 and 2 are not comparable with the ranking in IEC 60079-1.

NOTE 2 All stated limit deviations relate to the uncertainty of the measuring equipment.

[a] With small diameters, it can be difficult to generate stable detonations. Tests may be carried out using a gas-air mixture of a lower safe gap.

Table 4 – Specification of gas-air mixtures for short time burning tests and burning tests of dynamic flame arresters

Range of application (marking)	Requirements for test mixture		
Equipment Group	**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 (see also 9.2.4)

Table 5 – Specification of gas-air or vapour-air mixtures for endurance burning tests of static flame arresters

Range of application (marking) Equipment 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 combustion reactions of pure hydrocarbons are different to other flammable gases and vapours including alcohols, amines, acids, ketones, and aldehydes,) and therefore the range of applications is limited to pure hydrocarbons (compounds containing only carbon and hydrogen).

7 Specific requirements for static flame arresters

7.1 Construction requirements for prototype arresters

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 of the quenching gap over 90 % of the entire surface. The measurement of the gaps shall be done at random sample points.

As an alternative to gap measurement, equivalent performance may be demonstrated by performing a flow test according to Annex A and comparing the results with a reference pressure drop curve provided by the manufacturer. The pressure drops shall be equal to or lower than the reference curve.

NOTE The intention of this requirement is to cover the worst-case scenario.

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, specifically the quenching gaps. The length of the flame-quenching path can increase with the diameter, in which case all intermediate sizes in between tested sizes shall have the same flame-quenching path length as the larger tested size.

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;

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

– 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:

$$R_A = \frac{A_u}{A_p} \tag{1}$$

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	65	80	100	125	150	200	250	300	350	400	450	500	600	700	800	900	1 000

7.3 Flame transmission tests

7.3.1 General

Non-measurable types of flame arresters shall be 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/vacuum valve(s) integrated on the protected side shall have the valve secured in the fully open position, or the pressure/vacuum valve pallets shall be taken out during the test.

Flame arresters with pressure/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.

In line flame arresters directly combined with separate pressure/vacuum valves shall be tested according to the procedure in 7.3.2.2 with L_u = 10 × D and at the intended maximum relieving pressure of the system.

NOTE These end-of-line venting systems can 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 temperature at which the testing is performed 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.

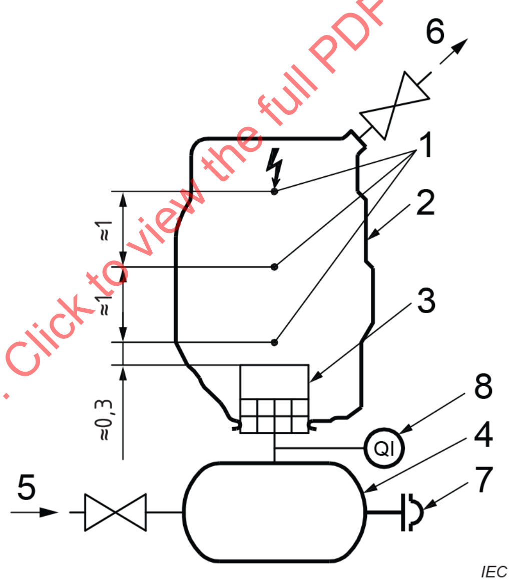
For end-of-line flame arresters with non-measurable elements, it might be necessary to pressurize the plastic bag (see 14.1). In this case, the mixture outlet (item 6 in Figure 1) shall be fitted with a shut-off valve.

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 6.3.2. Isolate the mixture supply and ignite. The ignition source shall be a spark plug or a 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 recording

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

7.3.2.2 In-line flame arrester

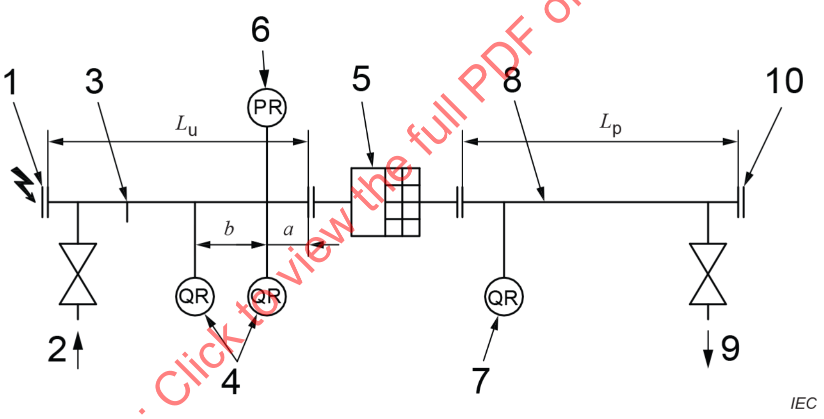
The test apparatus is shown in Figure 2. The ignition source shall be a spark plug fitted in the centre of the blind flange.

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.

NOTE It is common practice 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 E.2.1).

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, with a 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 recording

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

9 mixture outlet

10 blind flange or other closure

$a \leq 2 \times D$, 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 6.3.2 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 for the arrester to pass. 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 documented.

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 14.1). In this case, the mixture outlet (item 6 in Figure 3) needs to be fitted with a shut-off valve.

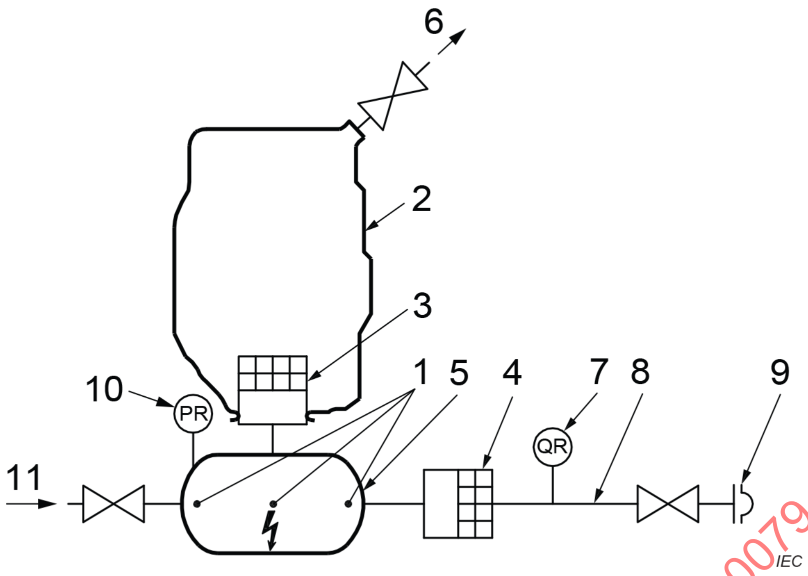
Pre-volume flame arresters shall be tested using the original configuration or equivalent full-scale model configuration.

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 visual observation of the ignition of the mixture in the plastic bag (2); a flame detector in addition is optional;
b) for in-line types, by the flame detector (7).



Key

1 ignition sources (for example, spark plug)

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 recording

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 6.3.2. 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 for the arrestor to pass.

All types and sizes shall be tested.

7.3.3 Tests for detonation flame arresters

7.3.3.1 General

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.

7.3.3.2 Stable detonation without restriction (Type 4)

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 with a 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.

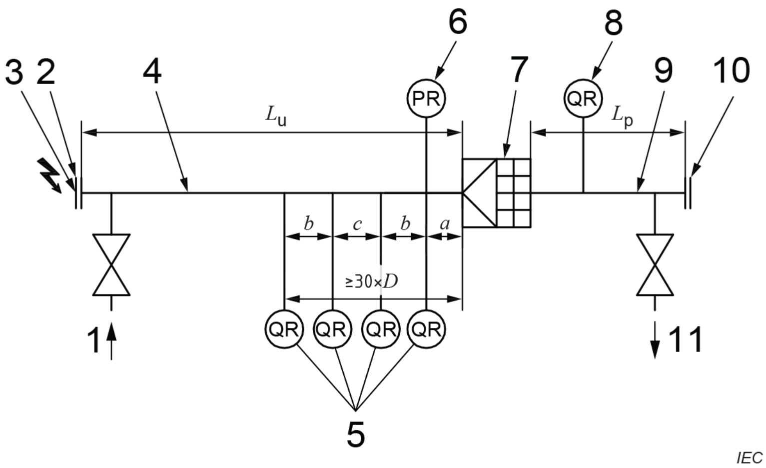
One flame detector shall be fitted to the pipe on the protected side to indicate flame transmission.

The apparatus shall be filled with a test mixture as specified in 6.3.2, 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 difference between the flame velocities measured by two pairs of flame detectors (see Figure 4) shall not exceed 10 % of the lower value.

NOTE Typical detonation velocities are ≥ 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 (for example, spark plug)

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 recording

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

10 blind flange or other closure

11 mixture outlet

a = (200 ± 100) mm

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

$c \geq 100$ 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 %.

When the p_{md}/p_{TB} ratio 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}

Equipment 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 measurements are not required to be reported.

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.

An arrester of this type shall prevent flame transmission in any of these stable detonation and deflagration tests.

7.3.3.3 Stable detonation with restriction (Type 3)

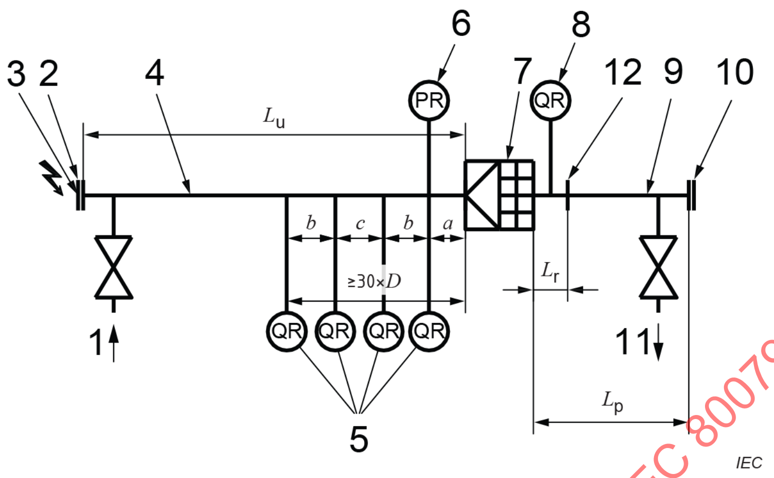
The test apparatus is shown in Figure 5.

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 with a 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 recording

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

10 blind flange or other closure

11 mixture outlet

12 restriction (L_r = 4 × D)

a = (200 ± 100) mm

b ≥ 3 × D, but b ≥ 100 mm

c ≥ 100 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 6.3.2, 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 difference between the flame velocities measured by two pairs of flame detectors (see Figure 5) shall not exceed 10 % of the lower value.

NOTE Typical detonation velocities are ≥ 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 %.

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 × D and L_p = 54 × 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 measurements are not required to be reported.

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.

An arrester of this type shall prevent flame transmission in any of these stable detonation and deflagration tests.

7.3.3.4 Unstable detonation without restriction (Type 2)

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 × 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 document, a characteristic of an unstable detonation is p_{mu} of not less than 2,5 × p_{md} for pipe diameters <100 mm, and 3 × 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, for example, by solid detonators, or long accelerator sections should be avoided.

The apparatus shall be filled with a test mixture as specified in 6.3.2, 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 × 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 measurements are not required to be reported.

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

An arrester of this type shall prevent flame transmission in any of these deflagration and unstable detonation tests.

7.3.3.5 Unstable detonation with restriction (Type 1)

The test apparatus is shown in Figure 5.

The pipe on the protected side shall have a length, L_p, of 54 × 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.

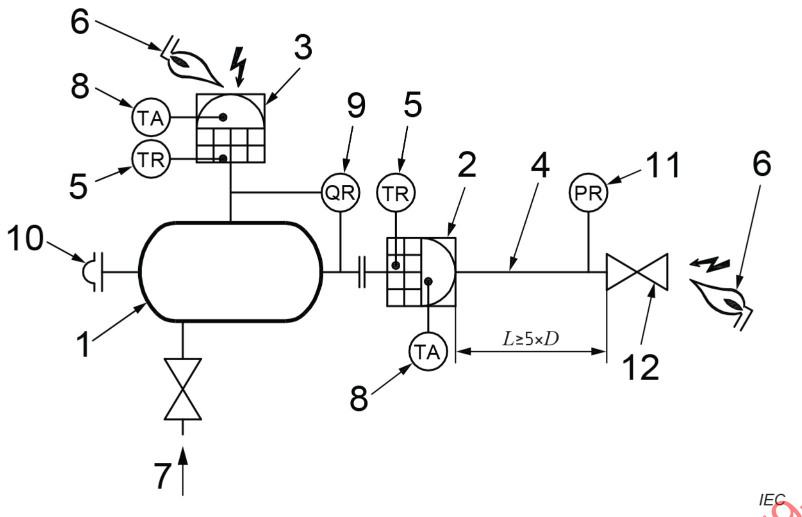
The test procedure for unstable detonation testing as well as the characteristic of an unstable detonation shall be in accordance with 7.3.3.4.

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

An arrester of this type 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 recording

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

For flame arresters whose intended operating conditions are outside the atmospheric conditions as given in Annex E, the test of inline flame arresters shall be carried out with the test pressure equal or greater than the intended maximum operation pressure and test gas temperature equal or greater than the intended maximum operating temperature. The test of inline flame arresters with t_{BT} = 1 min may be carried out under atmospheric conditions.

A flow measurement system 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 4. 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):

$$\dot{V}_c = 0{,}75 \times A_0 \times v_l \tag{3}$$

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):

$$A_0 = R_U \times A_t \quad (4)$$

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 or detonation test.

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

7.3.5 Endurance burning test

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

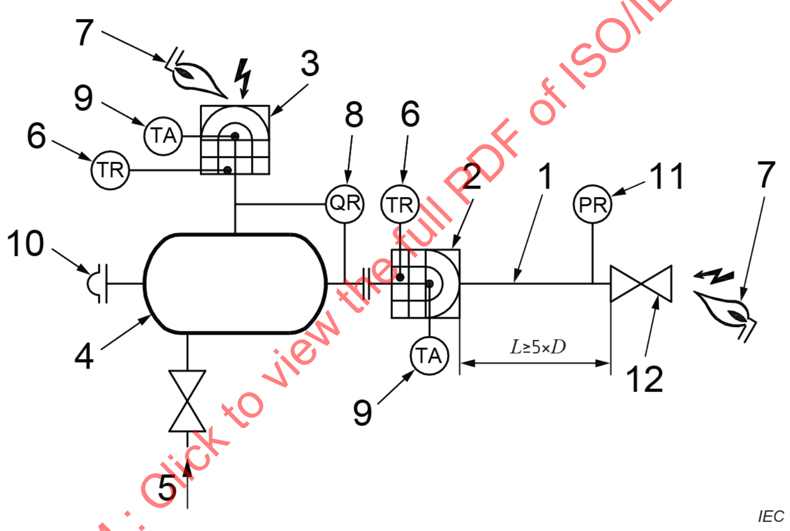
For flame arresters whose intended operating conditions are outside the atmospheric conditions as given in Annex E, the test of inline flame arresters shall be carried out with the test pressure equal or greater than the intended maximum operation pressure and test gas temperature equal or greater than the intended maximum operating temperature.

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 5.



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 recording

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 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 at least 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.

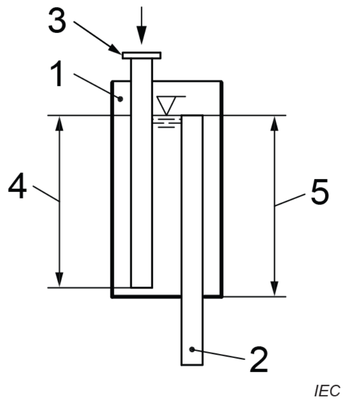
Modifications that do not change the flame arrester element and are part of the housing to which the flame arrester element is fitted do not require retesting, for example, flame arresters with integrated pressure/vacuum valves.

8 Specific requirements for liquid product detonation flame arresters

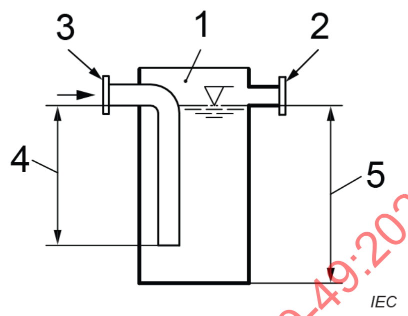
8.1 Liquid seals

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

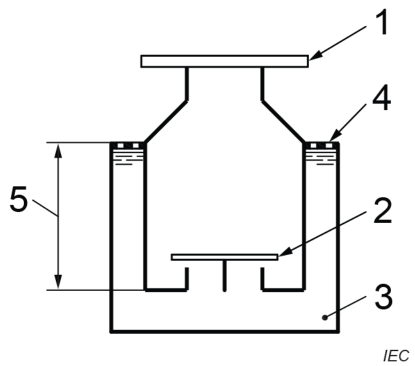
4 immersion depth

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)

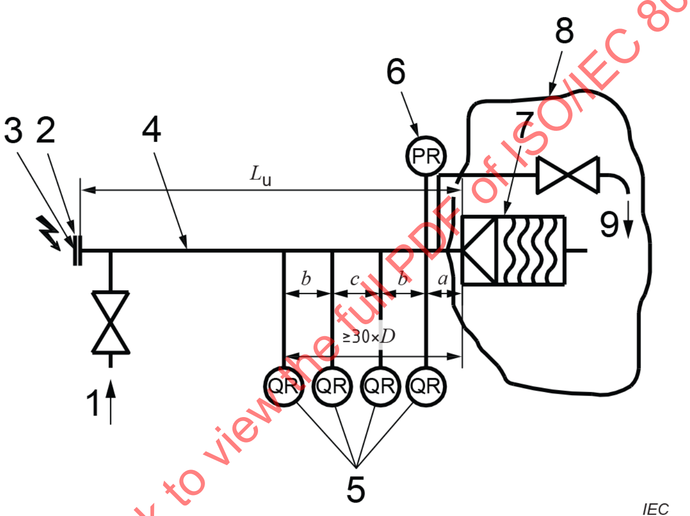
8.3 Flame transmission test

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 Figure 8 and Figure 9).

In-line and end-of-line flame arresters shall be tested so that the detonation characteristics as given in 7.3.3.2 and, if necessary, in 7.3.3.4, are met, but using the test apparatus shown in Figure 10. On the basis of the operational conditions for these flame arresters, only three detonation tests with the respective characteristics 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 ± 100) mm

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

$c \geq 100$ mm

Figure 10 – Test apparatus for liquid product detonation flame arresters

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 specified by the manufacturer.

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 (for example, drain plug) shall 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 shall 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 shall be carried out 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 1 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 (for example, 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 4 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 $\dot{V}_{\mathrm{CL}} > 0$, 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.

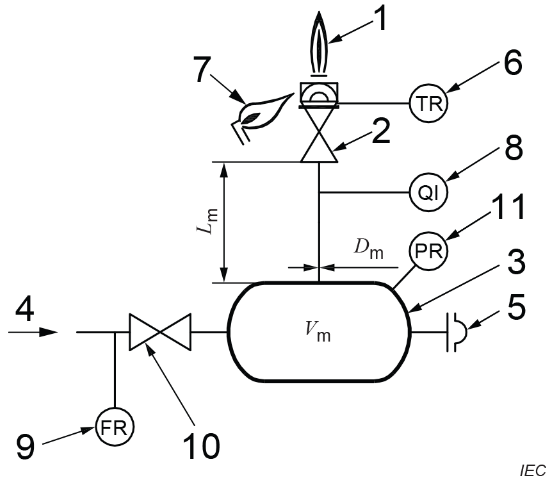
a) If at some point during the sequence of tests the dynamic flame arrester remains in the open position while steadily relieving, the test shall be stopped (for example, by a shut-off valve), thereby forcing the dynamic flame arrester to close.
b) If the dynamic flame arrester varies periodically between 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 2 Testing in the inclined position is intended to simulate motion of the dynamic flame arrester, for example, 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 1 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 (for example, 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 4. 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 2 Testing in the inclined position is intended to simulate motion of the dynamic flame arrester, for example, 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 (for example, 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 4, 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 4) keeping the flame stabilized. The flow shall be stopped and no flame transmission shall occur.

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 tests

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 measured 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 6.3.2.

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 × D;

– L_{u} = 100 × D.

Three tests shall be carried out 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 $\dot{V}_{\text{max}}$.

10.2.4 Detonation test

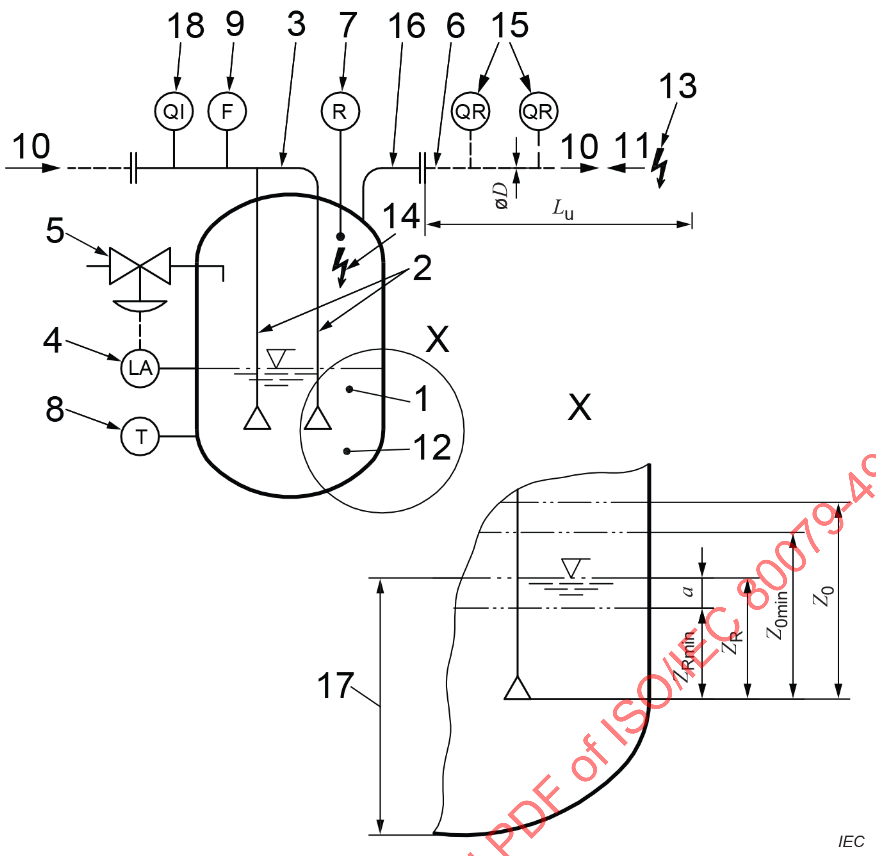
The test apparatus is shown in Figure 12, with the mixture outlet pipe (6) in place and equipped with four flame detectors (15) in the straight part of the pipe close to the outlet (16) (see also Figure 4). All tests shall be carried out with the mixture outlet pipe (6) with the maximum diameter, D, 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 6.3.2.

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 for the flame arrestor to pass.



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_u; 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 arresters

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 types of gas conveying equipment have pipe connections on the suction/inlet side and the 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.

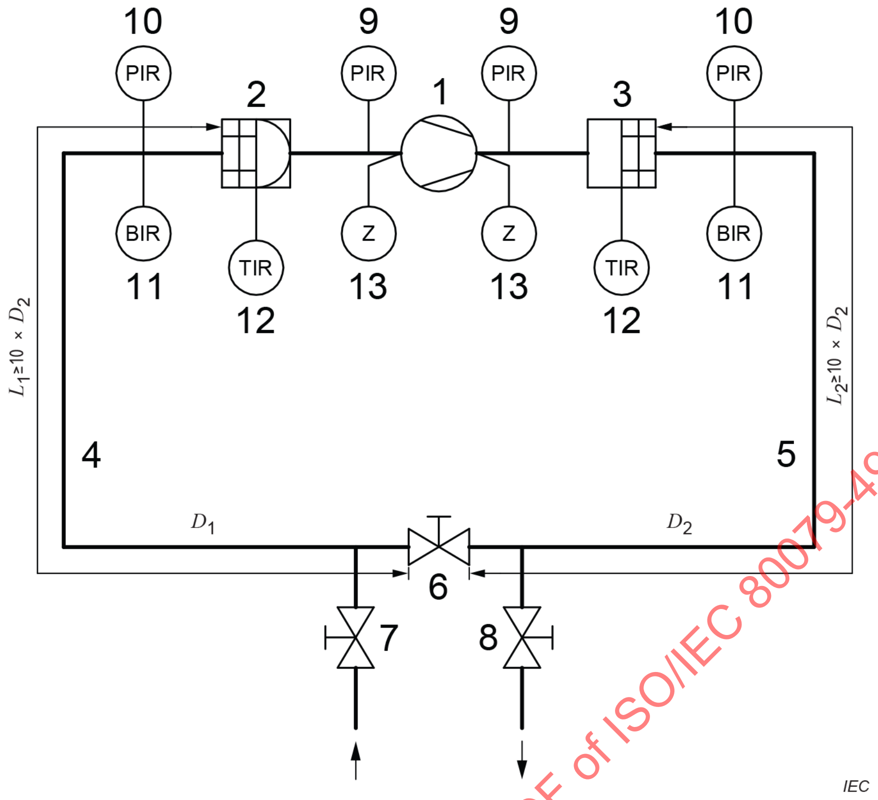
The results of the tests with ambient temperatures ≤60 °C at the flame arresters apply to temperatures from −20 °C up to +60 °C at the flame arrester elements. If, during operation of the gas conveying equipment, temperatures of more than 60 °C arise at the flame arrester element, additional tests shall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

11.2 Flame transmission tests

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 3.

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 3, 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

Test parameters				
Operating state	**Mixture pressure**	**Ignition point**	**Position of the throttle valve**	**Number of tests**
Rotating at max. speed	Max. inlet pressure	Inlet side	Open	3
	Max. outlet pressure		Approx. 80 % closed [a]	3
	Max. inlet pressure	Outlet side	Open	3
	Max. outlet pressure		Approx. 80 % closed [a]	3
Stationary	Max. inlet pressure	Inlet side	closed	3
		Outlet side	closed	3

[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.

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
Additional tests if the 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
Additional tests if the 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 Instructions

The instructions prepared by the manufacturer shall include the following particulars as a minimum:

a) a recapitulation of the information with which the equipment is marked, except for the serial number (see Clause 11), together with any appropriate additional information to facilitate maintenance (for example, address of the importer, repairer). This shall include specifically points b) to g);

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 Annex E, 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 pure 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 burn time (and, if this burn time was determined under conditions outside the atmospheric conditions as given in Annex E, the pressure and temperature under which it was determined);

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

h) general instructions for safety

- putting into service;
- use;
- assembling and dismantling;
- maintenance (including cleaning instructions and the procedure to be followed after deflagration, detonation or stabilized burning conditions have taken place);
- installation (including full description of the connections of the flame arrester);
- adjustment;
- where necessary, training instructions;
- where applicable, Specific Conditions of Use that require additional protective means by the installers or users;

i) a list of the standards, including the issue date, with which the equipment is declared to comply. The certificate can be used to satisfy this requirement.

In addition to these minimum particulars, the limits for use are also a link to more general (operational) safety considerations and regulations, which remain the responsibility of the user and regulators. Annex B and Annex C offer some guidance on these aspects.

13 Marking

13.1 Location

The equipment shall be legibly marked on the flame arrester housing and the marking shall be visible, from the exterior, prior to the installation of the equipment.

NOTE The marking is intended to be in a location that is certain to be visible and recognisable for operators after installation.

Where the element is a removable part, the element shall additionally be marked according to 13.3, which can be useful during installation and maintenance by helping to avoid confusion with similar equipment.

13.2 Flame arrester housing

13.2.1 General information

The flame arrester housing shall be marked with the following information:

a) the name and address of the manufacturer or its registered trademark;
b) the manufacturer's type identification or series designation;
c) the serial number;
d) the year of manufacture (if not incorporated in point c));
e) the name or mark of the certificate issuer and the certificate reference in the following form: the last two figures of the year of the certificate followed by a "." followed by a unique four-character reference for the certificate in that year;

NOTE 1 For some regional third-party certifications, the separating character "." is often replaced by another separating designator such as "ATEX".

f) If Specific Conditions of Use apply, the symbol "X" shall be placed after the certificate reference described in d) above. The use of a warning marking giving appropriate instructions may be used as an alternative to the requirement for the "X" marking.

NOTE 2 It is the intent that the requirements of the Specific Conditions of Use, for example, mounting position or corrosion resistance, are passed to the user together with any other relevant information in the instructions for use.

g) the number of this Standard ISO/IEC 80079-49:2023;
h) set pressure/set vacuum for flame arresters with integrated pressure/vacuum valve, and/or for dynamic flame arresters;
i) protected side (directional types only);
j) any additional marking if required by the applicable safety requirements of the relevant industrial standards for the construction of the equipment.

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.

13.2.2 Warning markings

Flame arresters shall be marked with the following information:

a) "Warning" (always in English);
b) "flame arresters have installation and application limits" (always in English);
c) type designation in accordance with this 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) for hydraulic flame arresters, the sign "HDET", the minimum immersion depth at rest (in mm) and the maximum volume flow rate (m^3/h);
g) pre-volume flame arresters, the sign "VDEF" and the relevant limits (pressure, temperature and volume) according to the test report, see E.2.2;

h) 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":

- "a" – endurance burn (no time limit);
- "b" – short time burn according to 7.3.4;
- "c" – no burn time;

EXAMPLE 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.

i) Equipment Group;

j) maximum operational temperature T_0 (in °C);

k) maximum operational pressure p_0 (absolute pressure) (in MPa respectively in bar), where applicable.

13.2.3 Examples of marking

Examples of marking plates are shown in Figure 14 and Figure 15.

Figure 14 shows an example of a marking plate for an end-of-line deflagration arrester safe for burn classification "a" for Equipment Group IIA, for an operational temperature, T_0, of 60 °C.

Warning			
Flame arresters have installation and application limits			
Type designation in accordance with ISO/IEC 80079-49			
IECEx XXX 12.3456			
DEF	L_u/D = n/a	BC: a	
	IIA	T_0 = 60 °C	-

IEC

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 Equipment Group 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/IEC 80079-49			
IECEx XXX 12.3456			
DET2	L_u/D = n/a	BC: b	t_{BT} = 15 min
	IIB3	T_0 = 120 °C	p_0 = 0,16 MPa

IEC

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

13.3 Flame arrester element

In case the flame arrester element is designed to be removed from the housing (for example, for cleaning or replacement), the element itself shall be marked with the above, or, if there is limited space, as a minimum with the following information:

a) the name or registered trademark of the manufacturer;

b) an identifier to ensure traceability;

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

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

14 Manufacturing and production

14.1 Construction

ISO/IEC 80079-34 gives details for requirements of quality management systems for Ex product manufacture.

For technical reasons, the gap dimensions of crimped ribbon flame arrester elements 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.

As an alternative to visual inspection, equivalent performance may be demonstrated by performing a flow test according to Annex A and comparing the results with a reference pressure drop curve. The pressure drop of the production type shall be higher than the pressure drop of the prototype.

Light metal alloys shall not contain more than 6 % magnesium. Coatings of components which can be exposed to flames during operation shall not be damaged in a way that makes flame transmission possible.

Manufacturing process shall include control of tolerances during production to ensure reproducibility.

14.2 Housing

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

14.3 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.

14.4 Pressure test

Pressure testing of all detonation flame arresters and pre-volume flame arresters shall be carried out at each flame arrester at a pressure of not less than $10 \times p_0$, and of all in-line deflagration flame arresters at not less than $1,1 \times 10^6$ Pa for not less than 3 min.

Where documentary evidence is provided that the weld procedure and welder qualification satisfy the requirements of the design method employed, in-line deflagration and detonation flame arresters and end-of-line detonation flame arresters of welded construction need only be type tested. 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.

14.5 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 as verified by visual examination, for example, using leak detection spray or submersion under water.

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

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 flow measuring device shall be used to obtain a flow rate/pressure drop curve with a minimum of 10 suitably spaced readings from stationary flow conditions. The curve shall be provided by the manufacturer. The flow at certain points on the curve shall be verified by the ExTL in accordance with 6.2 and the pressure drops shall not differ by more than 10 % at any place of the curve.

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

As an addition, testing of the flame arrester by itself is recommended to assist in the identification of the internal damage of the flame arrester from explosion testing.

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/vacuum valves shall be recorded in accordance with A.3 in a type test. Pressure /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.

A.2 In-line flame arresters

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

– $L_1 \geq 10 \times D$;

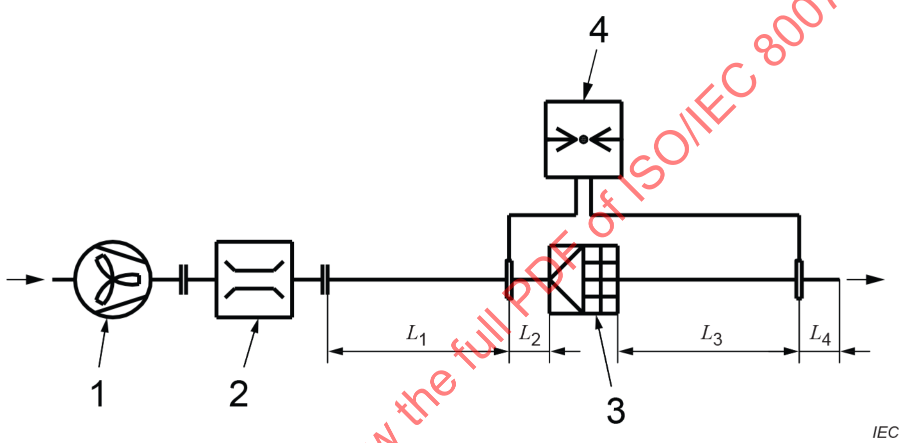
– $L_2 = 2 \times D$;

– $L_3 \geq 10 \times D$;

– $L_4 = 2 \times D$.

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 2 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/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 specified in 9.2.

The flow measurement shall consist of three phases:

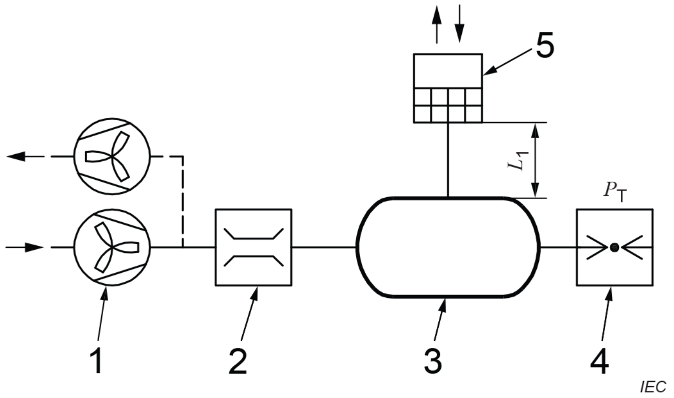
– phase 1 (opening phase): the capacity from shut to fully open;
– phase 2 (working area): the capacity from fully open and upward;
– phase 3 (closing phase): the capacity from fully open to shut.

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/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 (for example, 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 (9.2.1) and the resulting limits for use (9.2.2). For valves where (due to their characteristics) the possibility exists that they exhibit 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.

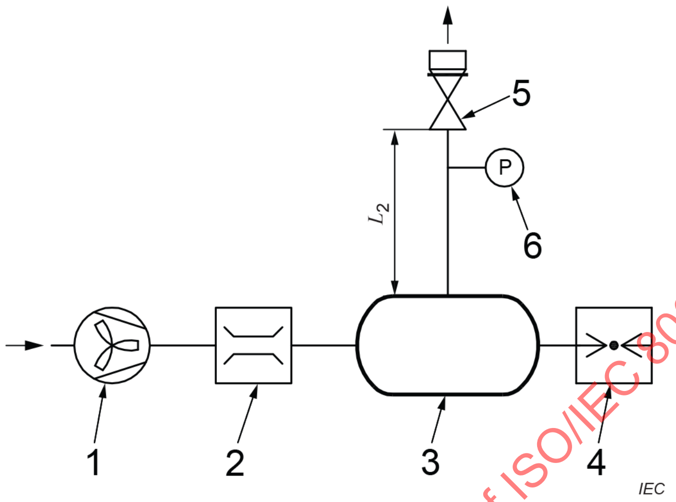
The flow rate into the containment shall be increased in 10 steps. The span and step width of the 10 flow rates shall be chosen depending on the valve characteristic, as specified below.

– 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 at least an 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