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

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Contents

Page

Foreword ... **v**
Introduction ... **vii**
1 Scope ... **1**
2 Normative references ... **1**
3 Terms and definitions ... **1**
4 Abbreviated terms and symbols ... **5**
5 Hazards and flame arrester classifications ... **6**
5.1 Flame transmission: deflagration, stable and unstable detonation ... 6
5.2 Flame transmission: stabilized burning ... 7
6 General requirements ... **7**
6.1 Measuring instruments ... 7
6.2 Construction ... 7
6.3 Housings ... 7
6.4 Joints ... 8
6.5 Pressure test ... 8
6.6 Leak test ... 8
6.7 Flow measurement (air) ... 8
6.8 Flame transmission test ... 8
6.8.1 General ... 8
6.8.2 Test mixtures ... 9
6.9 Summary of tests to be conducted ... 10
7 Specific requirements for static flame arresters ... **11**
7.1 Construction ... 11
7.2 Design series ... 11
7.3 Flame transmission test ... 12
7.3.1 General ... 12
7.3.2 Deflagration test ... 12
7.3.3 Detonation test ... 16
7.3.4 Short time burning test ... 21
7.3.5 Endurance burning test ... 23
7.4 Limits for use ... 25
7.4.1 General ... 25
7.4.2 In-line flame arrester ... 26
7.4.3 Pre-volume flame arrester ... 26
7.4.4 Detonation flame arrester ... 26
7.4.5 Short time burn flame arresters ... 26
8 Specific requirements for liquid product detonation flame arresters ... **27**
8.1 Liquid seals ... 27
8.2 Foot valves ... 27
8.3 Flame transmission test ... 28
8.4 Limits for use ... 29
9 Specific requirements for dynamic flame arresters (high velocity vent valves) ... **29**
9.1 General ... 29
9.2 Flame transmission tests ... 30
9.2.1 Low flow flame transmission test ... 30
9.2.2 Flame transmission test by opening and closing ... 31
9.2.3 Deflagration test ... 32
9.2.4 Endurance burning test ... 32
9.3 Limits for use ... 33
10 Specific requirements for hydraulic flame arresters ... **33**

10.1 Equipment 33
10.2 Flame transmission test 33
10.2.1 General 33
10.2.2 Short time burning test 33
10.2.3 Deflagration test 34
10.2.4 Detonation test 34
10.3 Limits for use 34

11 Test of flame arresters installed on or within gas conveying equipment 37
11.1 General 37
11.2 Flame transmission test 37
11.2.1 General 37
11.2.2 Test procedure for gas conveying equipment with inlet pressure >600 hPa 39
11.2.3 Test procedure for gas conveying equipment with inlet pressure ≤600 hPa 39

12 Information for use 40
12.1 Instructions for use 40
12.2 Marking 41
12.2.1 Flame arrester 41
12.2.2 Flame arrester element 43

Annex A (normative) **Flow measurement 44**

Annex B (informative) **Information for selecting flame arresters 48**

Annex C (informative) **Best practice 49**

Bibliography 50

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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

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

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

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

— 3.18: definition of dynamic flame arrester revised;

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

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

— 6.7: flow measurement (air) revised;

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

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

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

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

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

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

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

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

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

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

Introduction

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1 Scope

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

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

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

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

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

This International Standard is not applicable to the following:

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

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

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

— flame arresters used for carbon disulphide, due to its special properties;

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

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

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

2 Normative references

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

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

3 Terms and definitions

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

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

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

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

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

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

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

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

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

3.8
deflagration
explosion (3.7) propagating at subsonic velocity

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

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

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

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

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

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

Note 1 to entry: The transition occurs in a limited spatial zone, where the velocity of the combustion wave is not constant and where the explosion pressure is significantly higher than in a stable detonation. The position of this transition zone depends, amongst other factors, on pipe diameter, pipe configuration, test gas and explosion group.

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

3.12 Characteristic safety data of explosive mixtures

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4 Abbreviated terms and symbols

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

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

All pressure values are absolute pressures.

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

5 Hazards and flame arrester classifications

5.1 Flame transmission: deflagration, stable and unstable detonation

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

A deflagration when confined in a pipe may accelerate and undergo transition through an unstable to a stable detonation, provided sufficient pipe length is available. This pipe length may vary depending upon the initial conditions of the mixture and the pipe work configuration.

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

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

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

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

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

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

Application	Flame arrester classification
a) unconfined deflagration into an enclosure or vessel	end-of-line deflagration
b) confined deflagration propagating along a pipe into connecting pipe work	in-line deflagration
c) deflagration confined by an enclosure or pipe work to the outside atmosphere or into connecting apparatus	pre-volume deflagration

Table 1 *(continued)*

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

5.2 Flame transmission: stabilized burning

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

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

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

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

6 General requirements

6.1 Measuring instruments

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

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

6.2 Construction

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

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

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

Where stabilized burning is considered as an additional hazard, flame arresters for short time burning shall be fitted with one or more integrated temperature sensors, taking into account the intended orientation of the flame arrester.

6.3 Housings

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