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Examination Standard for Flame Arresters

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Foreword

This standard is intended to verify that the products and services described will meet stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of this standard is to present the criteria for examination of various types of products and services.

Examination in accordance with this standard shall demonstrate compliance and verify that quality control in manufacturing shall ensure a consistent and reliable product.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states testing and certification requirements for static (dry type) flame arresters. These flame arresters are for vent pipes of storage tanks (end-of-line), in-line deflagration type and in-line detonation type arresters.

1.1.2 Flame arresters for vent pipes of storage tanks are intended to prevent propagation of flame into a storage tank.

1.1.3 In-line detonation flame arresters are intended to qualify detonation flame arresters for all in-line applications independent of piping configuration provided the operating pressure is equal to or less than the maximum operating pressure limit specified in the manufacturer's certification and the diameter of the piping system in which the detonation arrester is to be installed is equal to or less than the piping diameter used in the testing. These flame arresters are uni-directional type or bi-directional type and are intended to prevent the transmission of a detonation and deflagration. In-line detonation arresters as examined and tested to this standard are suitable for in-line detonations and deflagrations, stable and unstable. In-line deflagration flame arresters are in-line flame arrester devices suitable for explosions with subsonic flame velocities and therefore the pipe length between potential ignition source and the in-line deflagration flame arrester is limited. In-line deflagration arresters are suitable in-line deflagrations only.

1.1.4 Testing and certification criteria may include, but are not limited to, design, construction, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a surveillance program.

1.2 Scope

1.2.1 This standard specifies the requirements for flame arresters protecting systems containing vapors of flammable or combustible liquids where vapor temperatures do not exceed 60°C.

1.2.2 This 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;
- flame arresters used for explosive mixtures of vapors 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 vapor-air mixtures (e.g. higher oxygen-nitrogen ratio, chlorine as oxidant, etc.);
- flame arresters for internal-combustion compression ignition engines;
- fast acting valves, extinguishing systems and other explosion isolating systems;
- flame arresters integrated or combined with explosion-protected equipment, such as blowers, fans, compressors or pumps.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and / or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of flame arresters for the purpose of obtaining certification. Flame arresters having characteristics not anticipated by this standard may be certified if performance equal, or superior, to that required by this standard is demonstrated.

1.4 Basis for Certification

Certification is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate

- the suitability of the product;
- the performance of the product as specified by the manufacturer and required for certification; and as far as practical,
- the durability and reliability of the product.

1.4.2 An examination of the manufacturing facilities and audit of quality control procedures is made to evaluate the manufacturer's ability to consistently produce the product which is examined and tested, and the marking procedures used to identify the product. Subsequent surveillance may be required by the certification agency in accordance with the certification scheme to ensure ongoing compliance.

1.5 Basis for Continued Certification

The basis for continual certification may include, but is not limited to, the following based upon the certification scheme and requirements of the certification agency:

- production or availability of the product as currently certified;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated by the certification;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory surveillance audits conducted as part of the certification agency’s product surveillance program.

1.6 Effective Date

The effective date of this certification standard mandates that all products tested for certification after the effective date shall satisfy the requirements of this standard.

The effective date of this standard is eighteen (18) months after the publication date of the standard for compliance with all requirements.

1.7 System of Units

Units of measurement used in this Standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Conversion of U.S.

customary units is in accordance with ANSI/IEEE/ASTM SI 10.

1.8 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 cited edition applies.

FM Approvals Examination Standard 3615, Explosionproof Electrical Equipment, General Requirements

ASTM Standards A395 Ferritic Ductile Iron Pressure-Retaining Castings For Use At Elevated Temperatures

F 722 Welded Joints for Shipboard Piping SystemsF1155 Standard Practice for Selection and Application of Piping System Materials

ASME Boiler and Pressure Vessel Code Section VIII, Division 1, Pressure Vessels Section IX, Welding and Brazing Qualifications

ANSI/ASME B46.1, Standard for Surface Texture

1.9 Terms and Definitions

For purposes of this standard, the following terms apply:

Atmospheric conditions — Conditions with atmospheric pressures ranging from 80 kPa (800 mbar) to 110 kPa (1100 mbar) and temperatures ranging from −20°C (-4°F) to 60°C (140°F)

Deflagration — Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.

Detonation — Propagation of a combustion zone at a velocity greater than the speed of sound in the unreacted medium.

Detonation Stable — A stable detonation is a detonation that propagates through a tube or pipe without significant variation in its propagation velocity and pressure; typical propagation velocities are in the range of 1600 – 1800 m/s.

Detonation Unstable — An unstable (overdriven) detonation refers to the highly transient state subsequent to the onset of detonation in deflagration-to-detonation transition; the explosion pressure and propagation velocity is significantly higher than that of a stable detonation.

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 a deflagration, detonation or shock wave.

Bi-directional flame arrester — In-line flame arrester that prevents flame transmission from both sides. These flame arresters may be determined bi-directional by test or by design (i.e., determined to be symmetrical in design and each end is determined as identical when approached by a detonation or deflagration from either direction).

Deflagration flame arrester — Flame arrester that quenches the flame/reaction zone. A deflagration arrester can be an end-of-line or an in-line flame arrester.

Detonation flame arrester — Flame arrester that quenches the flame/reaction zone and attenuates the precursor shock wave. A detonation flame arrester can be an end-of-line or an in-line flame arrester.

Downstream flow restriction - A restriction downstream on the protected side of the arrester. A restriction is considered, but not limited to, a valve, change in direction of pipe (any pipe angle change), or a reduction in the pipe diameter.

End-of-line flame arrester (Storage tank vent) — Flame arrester that is fitted with one pipe connection only (a flame arrester for storage tank facilities).

In-line flame arrester — Flame arrester that is fitted with two pipe connections, one on each side of the flame arrester.

Type I flame arrester — Type I flame arresters (detonation or deflagration type) are acceptable for applications where stationary flames may rest on the device.

Type II flame arrester — Type II flame arresters are acceptable for applications where stationary flames are unlikely to rest on the device, and further timely methods are provided to prevent flame passage when a stationary flame occurs. One example of further timely methods is a temperature monitor and an automatic shutoff valve.

Uni-directional flame arrester — In-line flame arrester that prevents flame transmission from one side only.

Flame arrester element — Portion of a flame arrester whose principal function is to prevent flame transmission.

Flame passage — The transmission of a flame through a device.

Flashback — The transmission of a flame through a device back upstream into a combustible mixture.

Flame velocity — The speed at which a flame propagates within a pipe or other system.

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.

Maximum Experimental Safe Gap (MESG) — The maximum clearance between two parallel metal surfaces that has been found, under specified test conditions, to prevent an explosion in a test chamber from being propagated to a secondary chamber containing the same gas or vapor at the same concentration.

1.10 Symbols

A_0	*free area of a 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*
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*
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_{TB}	*pressure before ignition*
p_0	*maximum operational pressure*
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*
v_l	*laminar burning velocity*
$\dot{V}_c$	*critical volume flow rate*
$\dot{V}_m$	*volume flow rate leading to maximum temperature*

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 Flame Transmission

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 to detonation, provided sufficient pipe length is available. This length to transition varies depending upon the initial conditions of the mixture and the pipe work configuration.

In-line detonations are a specific hazard requiring higher performance flame arresters than for in-line deflagrations.

A detonation flame arrester is suitable for deflagrations, and detonations.

A deflagration arrester is suitable for deflagrations only. For in-line deflagration arresters, the distance/pipe length between potential ignition source and flame arrester is limited.

These hazards relate to specific installations and in each case the flame arrester successfully tested at p_{TB} is suitable for operational pressures $p0 \leq p_{TB}$, and the application is limited to mixtures with an MESG equal to or greater than that tested.

The specific hazards covered by this standard, the classification and the testing required for the appropriate flame arresters are covered in Section 3.

2.1.2 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. If the flow of the explosive mixture cannot be stopped or, for operational reasons, is not intended to be stopped within 30 minutes, Type I flame arresters which prevent flame transmission for this type of stabilized burning are suitable for that hazard, and they are classified as safe against endurance burning.

Type II flame arresters are not considered safe against endurance burning. However, Type II flame arresters are acceptable for short time burning applications where stationary flames are unlikely to rest on the device. Type II flame arresters require timely further methods to prevent flame passage when a stationary flame does occur. An example of further methods is a temperature monitor and an automatic shutoff valve. Type II flame arresters are tested for short time burn in accordance with the test procedures within this standard. From the short time burn test, the maximum temperature reached and the minimum time reached without flame transmission is recorded and provided within the manufacturer's installation and operation manual.

2.2 Certification Application Requirements

The manufacturer shall provide the following preliminary information with any request for certification consideration:

- A complete list of all models, types, sizes, and options for the products or services being submitted for certification consideration;
- general assembly drawings, complete set of manufacturing drawings, materials list, anticipated marking format, nameplate format, brochures, sales literature, product specification sheets, installation, operation and maintenance manuals;

- the number and location of manufacturing facilities; and
- all documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All documents shall be provided with English translation.

2.3 Requirements for Samples for Examination

2.3.1 Following authorization of a certification examination, the manufacturer shall submit samples for examination and testing based on the following:

- As defined within the proposal; or
- Sample requirements to be determined by the certification agency after product drawings review.

2.3.2 Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.

2.3.3 The manufacturer shall submit samples representative of production. Any decision to use data generated using prototypes is at the discretion of the certification agency.

2.3.4 It is the manufacturer's responsibility to provide any necessary test fixtures, such as those which may be required to test their specific design.

3. GENERAL REQUIREMENTS

3.1 Review of Documentation

During the initial investigation and prior to physical testing, the manufacturer's specifications and details shall be reviewed to assess the ease and practicality of installation and use. The certification examination results may further define the limits of the final certification.

3.2 Physical or Structural Features

3.2.1 Construction

- Flame arresters shall consist of a flame arrester element and 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 limit over 90% of the entire surface. For production reasons, the gap dimensions may be less than the lower tolerance limit in the inner and outer areas of the flame arrester element. The total affected area shall not exceed 10% of the total surface area.
- Evidence shall be available that manufacture is controlled within tolerances to ensure reproducibility.
- Materials for flame arresters shall be suitable for the intended use (e.g., temperature range, chemical properties of the gases and vapors).
- The detonation flame arrester casing or housing, and other parts or bolting used for pressure retention, shall be constructed of materials listed in ASTM F 1155 or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code. Cast and malleable iron shall not be used; however, ductile cast iron in accordance with ASTM A395 may be used, or equivalent.

  Note: Cast, malleable or ductile iron may be used for an end-of-line flame arrester or tank vent flame arrester.

- Arresters, elements, gaskets, and seals shall be made of materials resistant to attack by seawater and the liquids and vapors contained in the system being protected. The possibility of galvanic corrosion shall be considered in the selection of materials.
- Nonmetallic materials, other than gaskets and seals, shall not be used in the construction of pressure retaining components of the detonation flame arrester. Nonmetallic gaskets and seals shall be non-combustible (i.e., a material classed UL94-5VA) and suitable for the service intended.
- Production flame arresters shall have flame quenching capabilities no less than the tested flame arrester.
- Flame arresters shall be fitted with appropriate flanges or other means to facilitate installation.
- Flame arrester housings shall be gas tight to prevent the escape of vapors.
- Flame arrester elements shall fit in the housing in a manner that will ensure tightness of metal-to-metal contact in such a way that flame cannot pass between the element and the housing. A flat joint in a flame arrester and a flat surface to be mounted to a tank or pipe shall be machined to provide an arithmetical average roughness of not more than 250 micro inches in accordance with the Standard for Surface Texture, ANSI/ASME B46.1. The machined surface shall provide for a joint having a metal-to-metal width of not less than ¼ inch (6.4mm).
- All flat joints of the housing shall be machined true and shall provide for a joint having adequate metal-to-metal contact.

- The net free area through detonation flame arrester elements shall be at least 1.5 times the cross-sectional area of the arrester inlet.
- Housings, elements, and seal gasket materials shall be capable of withstanding the maximum and minimum pressures and temperatures to which the device may be exposed under both normal and the specified test conditions, and shall be capable of withstanding the hydrostatic pressure type test.
- Threaded or flanged pipe connections shall comply with the applicable B16 standards in ASTM F 1155 or equivalent.
- Welded joints shall comply with ASTM F 722 or equivalent.
- Where welded construction is used for pressure retaining components, welded joint design details, welding and non-destructive testing shall be in accordance with Section VIII, Division 1, of the ASME Code and ASTM F 722. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code or equivalent.
- The design of In-line flame arresters shall allow for ease of inspection and removal of internal elements for replacement, cleaning or repair without removal of the entire device from the system.
- In-line flame arresters shall allow for efficient drainage of condensate without impairing their efficiency to prevent the passage of flame. The housing may be fitted with one or more drain plugs for this purpose. The design of a drain plug should be such so that by cursory visual inspection it is obvious whether the drain has been left open.
- All fastenings shall be protected against loosening, such as the use of locking washers.
- The manufacture shall provide the end user with inspection recommendations so as to protect against fouling. Manufacturer shall inform the end user that flame arresters shall be periodically inspected as per the manufacturer's recommendations.
- Flame arresters shall be capable of operating over the full range of ambient air temperatures declared and anticipated.
- Flame arresters shall be of first class workmanship and free from imperfections which may affect their intended purpose.
- Flame arresters shall be tested in accordance with this standard.
- All parts of the flame arrester shall resist the expected mechanical, thermal and chemical loads for the intended use.
- 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.
- Threaded joints, which are required to prevent flame transmission, shall be in accordance with the constructional requirements of FM Approvals Examination Standard 3615.
- 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.
- Fasteners shall be torqued according to manufacturer's specifications to prevent loosening during normal operation.

3.2.2 Design series

Flame arresters of similar design, except endurance burning flame arresters, may be grouped in a design series. The design series shall comply with the following:

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

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

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

- a design series limited to four consecutive nominal sizes, in accordance with Table 1;
- for every nominal size in a design series (maximum four), the ratio, RA, as calculated in Equation (1), shall not deviate by more than ±10 % from the ratio of the largest nominal size of the four members:

$$R_A = A_u / A_p \qquad \text{Equation 1}$$

Where A_u is the effective open area of the flame arrester element on the protected side and A_p is the nominal cross-sectional area of the flame arrester connection

Concentric and eccentric shaped housings form different design series.

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

Table 1 - Design series

3.2.3 Explosion Group test mixtures

For vapors from flammable or combustible liquids with a MESG greater than or equal to 0.9 mm, technical grade hexane or gasoline vapors may be used, in lieu of technical grade propane in accordance with Table 2 and 3. The gasoline is to be Naphtha "R", a nonleaded distillate consisting essentially of aliphatic hydrocarbon compounds and having a specific gravity of 60-70 degrees API at 15.6°C (60°F).

Hexane, propane, gasoline and chemical vapors shall be mixed with air to form the most easily ignitable mixture.

For vapors with a MESG less than 0.9 mm, the specific vapor (or alternatively, a media with a MESG less than or equal to the MESG of the vapor – Refer to Tables 2 and 3 below) must be used as the test medium in all tests.

The Explosion Group Column in Tables 2 and 3 are shown for reference only. For reference to MESG mixtures in this standard, Group IIC covers hydrogen and other gas-air or vapor-air mixtures with MESG less than 0.5 mm, and Group IIA is divided into four sub-groups: IIB1, IIB2, IIB3 and IIB. Explosion Group IIA is divided into two sub-groups: IIA1 and IIA. This standard covers deflagration and detonation tests for IIA, IIB1, IIB2, IIB3, IIB and IIC. IIA1 shall only be used for the testing of deflagration flame arresters.

Gas-air mixtures for testing shall be established with a concentration measuring instrument. The mixture composition (both upstream and downstream of the flame arrester) shall be within the tolerance specified in Tables 2 and 3. Test gas mixtures measured shall be recorded in the project data record file.

MESG of mixture	Gas	Gas purity by volume %	Gas in air by volume %	Explosion Group*
≥ 1.14	methane	≥ 98	8.4 ± 0.2	IIA1
> 0.90	propane	≥ 95	4.2 ± 0.2	IIA
≥ 0.85	ethylene	≥ 98	5.2 ± 0.2	IIB1
≥ 0.75	ethylene	≥ 98	5.7 ± 0.2	IIB2
≥ 0.65	ethylene	≥ 98	6.6 ± 0.2	IIB3
≥ 0.50	hydrogen	≥ 99	45.0 ± 0.5	IIB
< 0.50	hydrogen	≥ 99	28.5 ± 2.0	IIC

Table 2 — Gas-air mixtures for deflagration and detonation tests

* Corresponding International Explosion Group is shown for reference only

Gas	Gas purity by volume %	Gas in air by volume %	Explosion Group*
methane	≥ 98	9.5 ± 0.2	IIA1
propane	≥ 95	4.2 ± 0.2	IIA
ethylene	≥ 98	6.6 ± 0.3	IIB1
ethylene	≥ 98	6.6 ± 0.3	IIB2
ethylene	≥ 98	6.6 ± 0.3	IIB3
ethylene	≥ 98	6.6 ± 0.3	IIB
hydrogen	≥ 99	28.5 ± 2.0	IIC

Table 3 — Gas-air mixtures for burn tests

* Corresponding International Explosion Group is shown for reference only

3.3 Markings

3.3.1 Marking on the product or, if not possible due to size, on its packaging or label accompanying the product, shall include the following information:

- Name and address of the manufacturer or marking traceable to the manufacturer;
- date of manufacture or code traceable to date of manufacture or lot identification;
- model number and serial number;
- size of the inlet and outlet;
- direction of flow (unless bidirectional type);
- lowest MESG of gases for which the flame arrester is suitable;
- ambient air operating temperature range;
- maximum operating pressure, if higher than the absolute pressure of 14.7 psi (101kPa)
- maximum operational temperature;
- continuous burn time / endurance burn rating Type – That is, Type I – for greater than 30 minutes or Type II – for up to 15 minutes (i.e., marked, Type I or Type II);

  Note – For Arresters that flash back within 15 minutes shall be marked, Type II, but also with the following - “Caution: Not Suitable for Continuous Flame” and the Burn Time (t_{BT}) in minutes to flashback.

- its applicable type: Detonation or Deflagration;
- the words “Caution: Read and Understand Installation and Operation Manual’

- A flame arrester which has been tested with a specific gas or vapor shall be marked "Tested With (name of material)", or the equivalent.
- Detonation Flame Arresters tested under alternate test protocol (Refer to 4.1) shall also be marked with the following - "NOT TO BE INSTALLED WITH A RESTRICTION ON PROTECTED SIDE OF FLAME ARRESTER FOR AT LEAST 3 METERS IN LENGTH OR 10 PIPE DIAMETERS, WHICHEVER IS GREATER – SEE INSTALLATION MANUAL" or equivalent.

All markings shall be legible and permanently marked on a stainless steel nameplate(s) which is permanently attached. The markings shall be etched or stamped. Alternatively, markings may be embossed, stamped, cast or molded into the housing. No adhesive labels are allowed.

3.3.2 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the certification agency's mark of conformity.

3.3.3 The certification agency's mark of conformity shall be displayed shall be displayed visibly and permanently on the product and/or packaging as appropriate and in accordance with the requirements of the certification agency. The manufacturer shall exercise control of this mark as specified by the certification agency and the certification scheme.

3.3.4 Flame Arresters for Vent Pipes of Storage Tanks –

Each flame arrester for vent pipes of storage tanks shall also be marked with the following as applicable:

- The maximum length of pipe to be connected to the vent end;
- a statement that the flame arrester may open directly to the atmosphere; and
- the specific type of vent valve with which the flame arrester has been tested.

3.4 Manufacturer's Installation and Operation Instructions

The manufacturer shall

- prepare manual / instructions for the installation, maintenance, and operation of the product;
- include in the manual the Specific Condition of Use - "NOT TO BE INSTALLED WITH A RESTRICTION ON PROTECTED SIDE OF FLAME ARRESTER FOR AT LEAST 3 METERS IN LENGTH OR 10 PIPE DIAMETERS, WHICHEVER IS GREATER – SEE INSTALLATION MANUAL" or equivalent for devices tested under alternate test protocol (Refer to 4.1);
- provide facilities for repair of the product and supply replacement parts, if applicable;
- provide services to ensure proper installation, inspection, or maintenance for products of such nature that it would not be reasonable to expect the average user to be able to provide such installation, inspection, or maintenance; and
- provide the flow characteristics as declared by the manufacturer and verified within this standard.

3.5 Calibration

3.5.1 Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment is required. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard and certified by an ISO/IEC 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A

copy of the service provider's accreditation certificate as an ISO/IEC 17025 accredited calibration laboratory should be available.

3.5.2 When the inspection equipment and/or environment is not suitable for labels or stickers, other methods such as etching of control numbers on the measuring device are allowed, provided documentation is maintained on the calibration status of this equipment.

4. PERFORMANCE REQUIREMENTS

	Flame Transmission Performance Type Tests Required			
Flame Arrester	Flashback tests of 4.1.2	Deflagration Tests of 4.1.3 (with and without restriction)	Detonation Tests of 4.1.4 (both stable and unstable with and without restrictions)	Burning Tests of 4.2.1 (for Type I) or 4.2.2 (for Type II)
Flashback or Storage Tank Vents	x			x
Deflagration Arresters	x	x		x
(*) Detonation Arresters	x	x	x	x

4.1 Flame Transmission Test

Flame arresters shall be flame transmission tested according to the table above in Section 4. For example - Flame arrestors for storage tank vents shall be tested according to 4.1.2, and then to the applicable burning test in 4.2.1 or 4.2.2, depending on Type I or Type II burning classification.

(*) Alternate Test Protocol for Detonation Arresters –

Detonation Flame Arresters to be installed without downstream flow restriction shall be subjected to all tests specified in Section 4 with the following exceptions:

a. 4.1.4.3 Stable Detonation (with restriction)
b. 4.1.4.5 Unstable Detonation (with restriction)

These tests have been omitted in lieu of Specific Conditions of Use that place limitations on the installation of these Detonation Flame Arresters to assure that these devices are installed in a manner consistent with the way they were tested and certified.

4.1.1 General

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

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

Flame arresters with pressure and/or vacuum valve(s) integrated on the unprotected side shall have the valve pallets installed and blocked for an opening gap of (2.5 ± 0.5) mm during each test.

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

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

Flame arresters which are provided with a heating arrangement designed to maintain the surface temperature of the device above 60°C shall pass the required tests at the maximum heated operating temperature.

The temperatures, flame velocities and explosion pressures (mixture, pipe, flame arrester) during testing shall be maintained in the project data record file.

4.1.2 Flashback tests

4.1.2.1 The following flashback tests are required for flame arresters for storage tank vents.

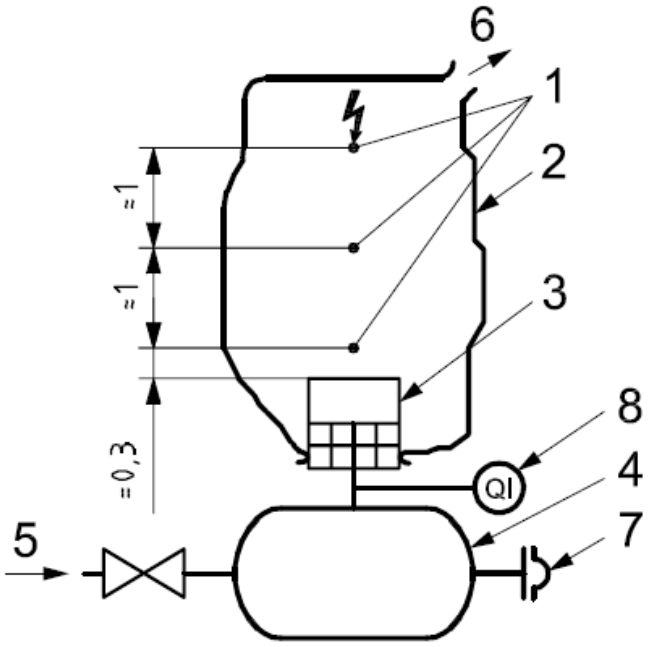
The test apparatus is as shown in Figure 1. Distances shall be measured from the top of the complete flame arrester.

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

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

Fill the apparatus, fully inflating the bag with a mixture as specified in 3.2.3. Disconnect the mixture supply and ignite. The ignition source shall be a spark plug or equivalent. 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.



Key
1 ignition sources
2 plastic bag (Ø ≥ 1.2 m; length ≥ 2.5 m; foil thickness ≥ 0.05 mm)
3 flame arrester
4 explosion-pressure-resistant containment (vessel or closed pipe work)
5 mixture inlet with shut-off valve
6 mixture outlet
7 bursting diaphragm
8 flame detector for indication
Dimensions in meters

Figure 1 — Test apparatus for flame arrester for storage tank vent test

4.1.3 Deflagration tests

The following deflagration tests, without restriction and with restriction, are required for in-line deflagration flame arresters and for in-line detonation flame arresters.

4.1.3.1 Deflagration tests (without restriction)

If the largest and smallest nominal size of a design series are satisfactorily tested, the two intermediate nominal sizes according to Table 1 may be considered acceptable without testing. Each size larger than 1000 mm shall be tested.

The test apparatus is shown in Figure 2. The ignition source shall be a spark plug or equivalent fitted in the center of the blind flange. A total of 10 deflagrations without restriction is required consisting of 5 slow deflagrations (where $L_u = 5 \times D$) and 5 fast deflagrations (where $L_u = 30$ or $50 \times D$, depending on the explosion group, and $\Delta p/p_0 > 5$).

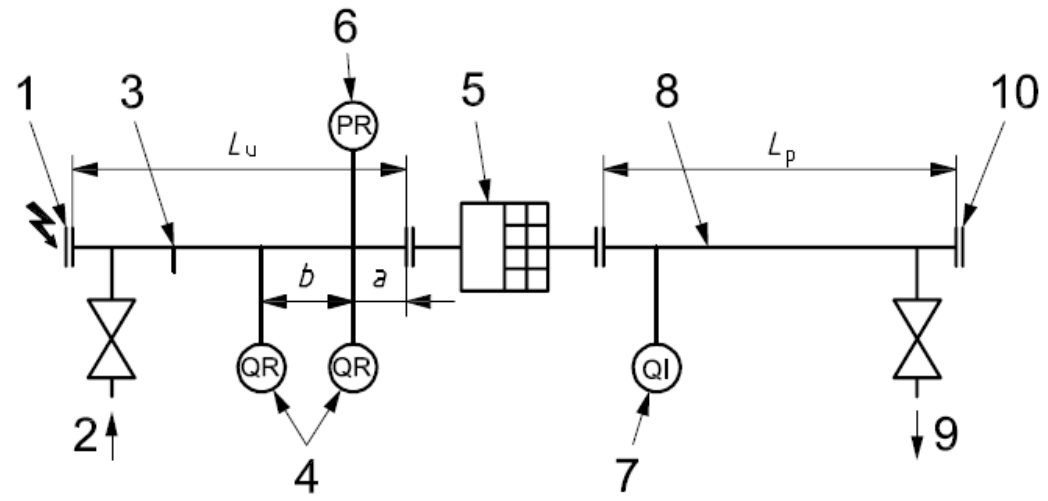
The pipe diameter D shall have the same size as the flame arrester connection. The pipe length L_u shall be not less than $5 \times D$ and not greater than $50 \times D$ for hydrocarbon-air mixtures (IIA1, IIA, IIB1, IIB2 and IIB3), and $5 \times D$ and not greater than $30 \times D$ for hydrogen-air mixtures (IIB and IIC). The pipe length L_p shall be $50 \times D$ for hydrocarbon-air mixtures (IIA1, IIA, IIB1, IIB2 and IIB3) and $30 \times D$ for hydrogen-air mixtures (IIB and IIC).

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

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

NOTE 3: For ease of use and reference only, the International Explosion Groups (IIA1, IIA, IIB1, IIB2, IIB3, IIB, and IIC) are used.

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



Key
1 Blind flange with ignition source
2 Mixture inlet
3 Unprotected pipe
(length L_u, diameter D)
4 Flame detectors for recording
5 In-line deflagration flame arrester
6 Pressure transducer for recording
7 Flame detector for indication
8 Protected pipe
(length L_p, diameter D)
9 Mixture outlet
10 Blind flange or other closure
a ≤ 2 x D (± 10%, max ± 50 mm); but ≤ 250 mm
b ≤ 3 × D

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

Fill the apparatus with a test mixture as specified in 3.2.3 and pressurize to p_{TB} when $p_{TB} \geq p_0$ (p_0 = maximum operational pressure requested by the manufacturer or user). Carry out the 10 tests. Flame transmission will be indicated by the flame detector on the protected side located not more than 8 inches (200 mm) from the arrester element. No flame transmission shall occur in any of the tests.

The temperatures, flame velocities, maximum explosion pressures and pipe length (L_u) in each test shall be maintained in the project data record file.

4.1.3.2 Deflagration tests (with restriction)

The tests as described above in 4.1.3.1 shall be repeated but only with a restriction implemented in the test apparatus. The restriction, Item 12 in Figure 4, shall be added to Figure 2 above, refer to Figure 2 and 4.

The pipe on the protected side shall have a length Lp of 54 × D. A restriction shall be fitted at Lr/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 explosion pressures.

Carry out the 10 tests consisting of 5 slow deflagrations (where $L_u = 5D$) and 5 fast deflagrations (where $L_u = 30$ or $50D$, depending on the explosion group, and $\Delta p/p_0 > 5$). Flame transmission will be indicated by the flame detector on the protected side. No flame transmission shall occur in any of the tests.

The temperatures, flame velocities, maximum explosion pressures and pipe lengths (L_u) in each test shall be maintained in the project data record file.

4.1.4 Detonation tests

The following stable and unstable detonation tests, both with and without restriction, are required for in-line detonation flame arresters.

4.1.4.1 General

If the largest and smallest nominal sizes of a design series are satisfactorily tested for detonations, the two intermediate nominal sizes, according to Table 1, may be considered acceptable without testing. Each nominal size larger than 1000 mm shall be tested.

4.1.4.2 Stable detonation (without restriction)

The test apparatus is shown in Figure 3.

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 Lp of 10 x D, but not less than 3 meters. The blind flange or other closure shall resist the shock pressures during testing.

For measuring flame velocities and detonation pressures, four flame detectors and a pressure transducer (limiting frequency ≥ 100 kHz) shall be fitted to the pipe on the unprotected side. The position of the flame detectors and the pressure transducer shall be in accordance with Figure 3.

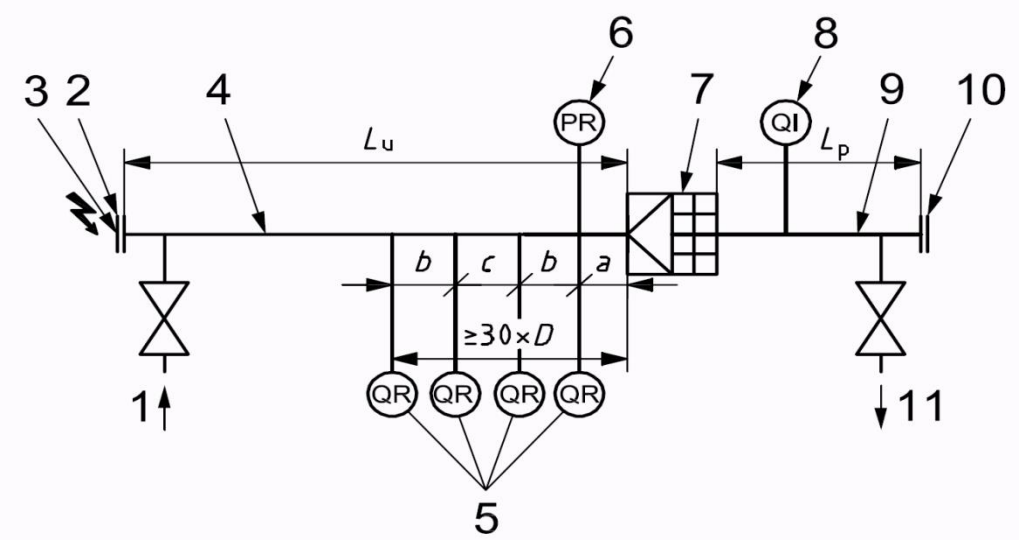
One flame detector shall be fitted to the pipe on the protected side located not more than 8 inches (200 mm) from the arrester element to indicate flame transmission.

The apparatus shall be filled with a test mixture as specified in 3.2.3, and at a pressure of p_{TB} when $p_{TB} \geq p_0$. Under these conditions, five tests shall be carried out.

In each test, the flame velocities from the two pairs of flame detectors (see Figure 3) shall be constant, i.e. the difference between the two flame velocities shall not exceed 10% of the lower value.

The velocities shall be ≥ 1600 m/s for hydrocarbon-air mixtures (IIA, IIB1, IIB2 and IIB3) and ≥ 1900 m/s for hydrogen-air mixtures (IIB and IIC).

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



Key
1 mixture inlet
2 explosion-pressure-resistant containment (vessel or closed pipe work) or blind flange
3 ignition source
4 unprotected pipe (length *L*u; diameter *D*)
5 flame detectors for recording of the flame velocity measurement
6 pressure transducer for recording
7 detonation flame arrester
8 flame detector for indication
9 protected pipe (length *L*p; diameter *D*)
10 blind flange or other closure
11 mixture outlet
a = (200 ±50) mm
$b \geq 3 \times D$, but $b \geq 100$ mm
$c \geq 500$ mm

Figure 3 — 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 3) 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 4 with a maximum deviation of ±20%.

Explosion group **	**Ratio p_{md}/p_{TB} for pipe diameter D** mm			
	$D \leq 80$*	$80 < D \leq 150$	$150 < D < 1000$	$D \geq 1000$
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
* 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. ** Corresponding International Explosion Group is shown for reference only				

NOTE When p_{md}/p_{TB} exceeds the quoted values of Table 4 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.

The initial pressure, stable detonation pressure, the values of p_{md}/p_{TB} and also any flame velocities recorded during the tests shall be maintained in the project data record file.

The flame arrester shall prevent flame transmission in any of these stable detonation tests.

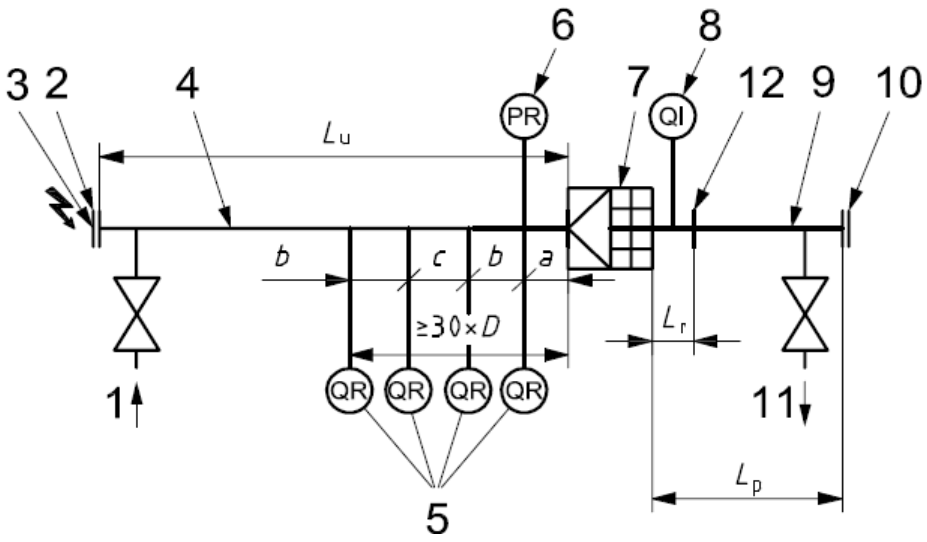
4.1.4.3 Stable detonation (with restriction)

The test apparatus is shown in Figure 4.

The pipe diameter D shall have the same size as the flame arrester connection. The pipe on the unprotected side shall have a length L_u sufficient to develop a stable detonation and shall have a blind flange or an explosion-pressure-resistant containment (vessel or closed pipe work) fitted with an ignition source which may consist of a spark plug. 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 Lp of $54 \times D$. A restriction shall be fitted at Lr/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.

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



Key
1 mixture inlet
2 explosion-pressure-resistant containment (vessel or closed pipe work) or blind flange
3 ignition source
4 unprotected pipe (length *L*u; diameter *D*)
5 flame detectors for recording the flame velocity
6 pressure transducer for recording
7 detonation flame arrester
8 flame detector for indication
9 protected pipe (length *L*p; diameter *D*)
10 blind flange or other closure
11 mixture outlet
12 restriction (Lr = 4 × D)
a = (200 ± 50) mm
$b \geq 3 \times D$, but $b \geq 100$ mm
$c \geq 500$ mm

Figure 4 — Test apparatus for detonation flame arrester for detonation with restriction

One flame detector shall be fitted to the pipe on the protected side located not more than 8 inches (200 mm) from the arrester element to indicate flame transmission.

The apparatus shall be filled with a test mixture as specified in 3.2.3, and at a pressure of p_{TB} when $p_{TB} \geq p_0$. Under these conditions, five tests shall be carried out.

In each test, the flame velocities from the two pairs of flame detectors (see Figure 4) shall be constant, i.e. the difference between the two flame velocities shall not exceed 10% of the lower value. The velocities may be greater but not less than 1600 m/s for hydrocarbon-air mixtures (IIA, IIB1, IIB2 and IIB3) and 1900 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 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 ratio p_{md}/p_{TB}, with regard to mixture and pipe size shall correspond to the values given in Table 4, with a maximum deviation of ±20%.

NOTE When p_{md}/p_{TB} exceeds the quoted values of Table 4 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.

The initial pressure, stable detonation pressure, the values of p_{md}/p_{TB} and also any flame velocities recorded during the tests shall maintained in the project data record file.

A detonation flame arrester shall prevent flame transmission in any of these stable detonation tests.

4.1.4.4 Unstable detonation (without restriction)

The test apparatus is shown in Figure 3.

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 meters. 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 standard, a characteristic of an unstable detonation is *p*mu of not less than $2.5 \times p_{md}$ for pipe diameters < 100 mm, and $3 \times p_{md}$ for pipe diameters ≥ 100 mm. Values of p_{md} shall be taken from Table 4 with regard to p_{TB}.

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

The apparatus shall be filled with a test mixture as specified in 3.2.3, at a pressure p_{TB} when $p_{TB} \geq$ p0.

Under these conditions, five tests shall be carried out.

The initial pressure, unstable detonation pressures and also any flame velocities shall be maintained in the project data record file.

A flame arrester shall prevent flame transmission in any of these unstable detonation tests.

4.1.4.5 Unstable detonation (with restriction)

The test apparatus is shown in Figure 4.

The pipe on the protected side shall have a length L_p of 54 x 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 an area equal to 2.5% of the cross-section area of the pipe. The closed pipe end and the restriction shall resist the shock pressures during testing.

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 pipe may also contain a flame accelerator to reduce the pipe length for unstable detonation conditions.

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 located not more than 8 inches (200 mm) from the arrester element to indicate flame transmission.

For the purposes of this standard a characteristic of an unstable detonation is p_{mu} of not less than 2.5 x p_{md} for pipe diameters < 100 mm and 3 x p_{md} for pipe diameters ≥ 100 mm. Values of p_{md} shall be taken from Table 4 with regard to p_{TB}.

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

The apparatus shall be filled with a test mixture as specified in 3.2.3 and at a pressure of p_{TB} when $p_{TB} \geq p_0$. Under these conditions five tests shall be carried out.

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 maintained in the project data record file.

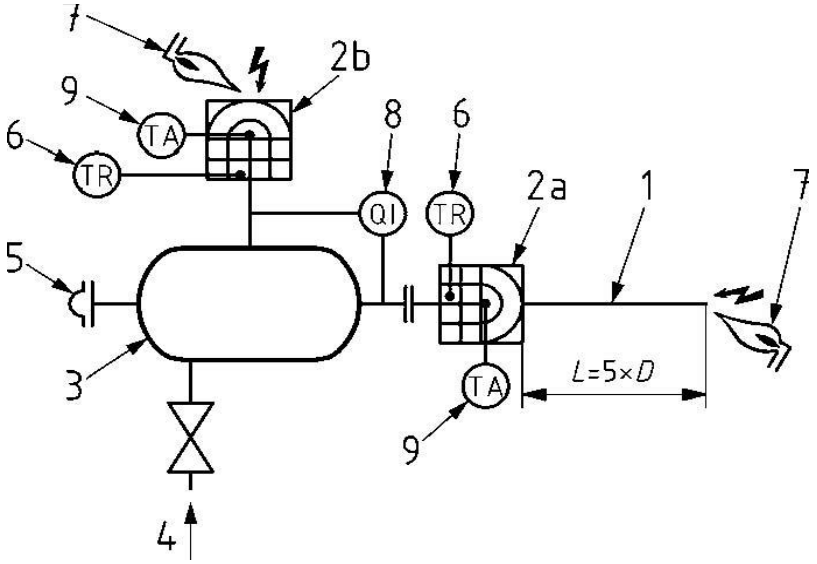
The flame arrester shall prevent flame transmission in any of these unstable detonation tests.

4.2 Burning tests

All arresters shall be tested for Endurance burning test (Type I) or Short time burning test (Type II) as described below.

4.2.1 Endurance burning test (Type I)

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



Key
1 Outlet pipe
2a In-line flame arrester
2b End-of-line flame arrester
3 Explosion-pressure-resistant-containment (vessel or closed pipe work)
4 Mixture inlet
5 Bursting diaphragm (0.0015 to 0.010 inch thick cellulose acetate film, polyester film, polyethylene terephthalate film or equivalent)
6 Temperature sensors for recording for tests only
7 Pilot flame or spark igniter
8 Flame detector for indication
9 Test temperature sensor for alarm to detect stabilized flame

Figure 5 – Test apparatus for endurance burning test

As applicable, the flammable mixture for the test is to be a 2.5 percent mixture by volume of hexane in air or a 1.9 percent mixture by volume of gasoline vapor in air. Otherwise, a flammable mixture as described in Section 3.2.3, Table 3 shall be used. A flow meter shall be used to measure the mixture flow rate.

The flame arrester shall be fitted with four temperature sensors. Three temperature sensors (item 6 in Figure 5) shall be mounted on the protected side. Temperatures shall be measured at its center, at its edge and halfway between the center and the edge.

Another temperature sensor (item 9 in Figure 5) shall be fitted to the unprotected side to detect the stabilized flame (start of burning load).

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 the burning velocity v_l of the mixture across this area, calculate a critical flow rate $\dot{V}_c$ according to

$$\dot{V}_c = 0{,}75 \times A_0 \times v_l \qquad \textit{Equation 2}$$

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

$$A_0 = R_U \cdot A_t \qquad \textit{Equation 3}$$

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 100°C (180°F) and then stop the flow. Record the time from stabilization of the flame to the 100°C (180°F) temperature increase.

Carry out this test procedure with flow rates $\dot{V}_c$, 0.5 x $\dot{V}_c$ and 1.5 x $\dot{V}_c$. 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 100°C (180°F) temperature increase, then $\dot{V}_m = \dot{V}_c$. If not, carry out two further tests with flow rates 50% and 150% of the flow rate which gave the shortest time in the first three tests. $\dot{V}_m$ will be the flow rate that results in the shortest time in all five tests. When determining the flow rate $\dot{V}_m$, flame arrester elements may be replaced between the tests.

The endurance burn test shall be carried out with the flow rate $\dot{V}_m$, using the original flame arrester element, without modification, that was used for the deflagration and/or detonation tests. Vary 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 highest attainable temperature is identified as being reached and stable when the temperature rise does not exceed 0.5°C (0.9°F) per minute over a 10 minute period on the protected side. At that point when the temperature is at its highest and stable, the timer will start. The arrestor shall continue to burn for 2 hours. Observation is to be made if flashback occurs. Also, the flame detector (8) shall indicate any flame transmission.

For Type I detonation flame arresters, flame passage shall not occur during this test and when the test gas valve is closed at the conclusion of the test.

All types and nominal sizes shall be tested. When a flame arrester is to be provided with cowls, weatherhoods, deflectors, and similar components, it is to be tested in each configuration in which it is to be provided.

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

4.2.2 Short time burning test

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

The calculation of the critical flow $\dot{V}_c$ will be done according 4.2.1.

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 ($1\text{min} \geq t_{BT} \geq 30$ 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 $\dot{V}_c$, $0.5x\dot{V}_c$, and $1.5x\dot{V}_c$. In each of these tests, the flame arrester shall be at ambient temperature at the beginning. If $\dot{V}_c$ results in the highest temperature reading of the three tests, then $\dot{V}_m = \dot{V}_c$. If not, carry out two further tests with flow rates 50% and 150% of the flow rate which gave the highest reading in the first three tests. $\dot{V}_m$ will be the flow rate that results in the highest temperature reading in all five tests. When determining the flow rate $\dot{V}_m$, flame arrester elements may be replaced between the tests. If the flame arrester elements have been replaced, a final test shall be carried out with the flow rate $\dot{V}_m$, using the original flame arrester element, without modification, that was used for the deflagration and/or detonation test.

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

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

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

Each size of in-line flame arresters greater than 1000mm shall be tested.

For Type II detonation flame arresters, the temperatures shall be recorded and the burning time, t_{BT} shall be marked according to this standard, Section 3.3.

4.3 Corrosion Resistance test

The flame arrester external enclosure (housing) shall not corrode or deteriorate when exposed to a salt fog environment.

4.3.1 Test

A corrosion test shall be conducted. In this test, a complete arrester, including a section of pipe similar to that to which it will be fitted and provided with blind flanges, shall be exposed to a 20% sodium chloride solution spray at a temperature of 25°C (77°F) for a period of 240 hours, and allowed to dry for 48 hours.

4.3.2 Acceptance criteria

All movable parts shall operate properly and there should be no corrosion deposits that cannot be washed off with water.

4.4 Hydrostatic Pressure test

4.4.1 Hydrostatic pressure testing of all In-line detonation flame arresters shall be carried out at a pressure of not less than 10 × p0, or 350 psi (2415 kPa), whichever is bigger, for not less than 10 minutes. No permanent deformation shall occur during the test.

4.4.2 Hydrostatic pressure testing of deflagration type and flame arresters for storage tank vents shall be carried out at a pressure of not less than 125 psi (862 kPa), for not less than 10 minutes. No permanent deformation shall occur during the test.

4.5 Pneumatic Leak test

Flame arresters shall not leak when subjected with air at $1.1 \times p_0$, with a minimum of 150 kPa (22 psi) absolute for not less than 10 minutes. No leak shall occur.

Flame arresters shall not be painted or coated on the inside and/or outside prior to the test with materials which are able to seal or cover leaks.

4.6 Flow measurements verification

Flow characteristics as declared by the manufacturer, shall be demonstrated (both positive and negative). The pressure drop shall be measured on test samples before and after deflagration flame transmission tests and burning tests at a volume flow that is suitable for identifying any alteration (deformation) of the flame arrester, particularly of the flame arrester element. After deflagration 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. The manufacturers flow characteristics, verified, shall be incorporated in the Installation and Operations manual.

5. OPERATIONS REQUIREMENTS

5.1 Demonstrated Quality Control Program

5.1.1 A quality assurance program is required to assure that subsequent Flame Arresters produced by the manufacturer shall present the same quality and reliability as the specific Flame Arresters examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests may be documented in the certification report.
- Continued conformance to this standard is verified by the certifier's surveillance program.
- Quality of performance is determined by field performance and by periodic re-examination and testing.

5.1.2 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- existence of corporate quality assurance guidelines;
- incoming quality assurance, including testing;
- in-process quality assurance, including testing;
- final inspection and tests;
- equipment calibration;
- drawing and change control;
- packaging and shipping; and
- handling and disposition of non-conforming materials.

5.1.3 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

5.1.4 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, for a minimum period of two years from the date of manufacture.

5.1.5 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the certification report, may be required to be reported to, and authorized by the certification agency prior to implementation for production.
- Records of all revisions to all certified products shall be maintained.

5.2 Surveillance Audit

5.2.1 An audit of the manufacturing facility may be part of the certification agencies surveillance requirements to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to ensure a uniform product consistent with that which was tested and certified.

5.2.2 Certified products or services shall be produced or provided at, or provided from, location(s) disclosed as part of the certification examination. Manufacture of products bearing a certification mark is not permitted at any other location prior to disclosure to the certification agency.

5.3 Manufacturer's Responsibilities

5.3.1 The manufacturer shall notify the certification agency of changes in product construction, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation.

5.3.2 On 100% of production, each flame arrester shall not leak when subjected to a 10 minute, 69 kPa (10 psi) or a 3 minute, 150 kPa (22 psi) pneumatic leakage test.

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ANSI/UL 50, Enclosures for electrical equipment, non-environmental considerations

ANSI/UL 50E, Enclosures for electrical equipment, environmental considerations

NFPA 69, Standard on Explosion Prevention Systems

ANSI Standards B16.5 Pipe Flanges and Flanged Fittings

EN 1092-1, Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, PN designated - Steel flanges

EN 14460, Explosion resistant equipment

EN 1759-3, Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, class designated - Part 3: Copper alloy and composite flanges

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

ISO 7005-1, Metallic flanges - Part 1: Steel flanges

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

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

IEC 60079-20-1 Explosive atmospheres - Material characteristics for gas and vapour classification - Test methods and data