



Approval Standard for Flame Arresters

Class Number 6061

December 2013

Copyright © 2013 by FM Approvals LLC. All rights reserved.

Foreword

The FM Approvals certification mark 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 Approval Standards is to present the criteria for Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for Approval shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

- a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and
- b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic surveillance audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.

Table of Contents

1 INTRODUCTION.....	1
1.1 Purpose	1
1.2 Scope.....	1
1.3 Basis for Requirements	2
1.4 Basis for Approval	2
1.5 Basis for Continued Approval.....	2
1.6 Effective Date	2
1.7 System of Units.....	2
1.8 Applicable Documents	3
1.9 Definitions	3
1.10 Symbols	5
2 GENERAL INFORMATION	5
2.1 Product Information	5
2.2 Approval Application Requirements	6
2.3 Requirements for Samples for Examination	7
3 GENERAL REQUIREMENTS	7
3.1 Review of Documentation	7
3.2 Physical or Structural Features	7
3.3 Markings	10
3.4 Manufacturer's Installation and Operation Instructions.....	11
3.5 Calibration	11
4 PERFORMANCE REQUIREMENTS	12
4.1 Flame Transmission Test	12
4.2 Burning tests	20
4.3 Corrosion Resistance test.....	23
4.4 Hydrostatic Pressure test.....	23
4.5 Pneumatic Leak test	24
4.6 Flow measurements verification	24
5 OPERATIONS REQUIREMENTS.....	24
5.1 Demonstrated Quality Control Program	24
5.2 Surveillance Audit	25
5.3 Installation Inspections	25
5.4 Manufacturer's Responsibilities	25
APPENDIX A: UNITS OF MEASUREMENT	26
APPENDIX B: FM APPROVALS CERTIFICATION MARKS	27
APPROVAL STANDARD ADDENDUM - NOVEMBER 2016.....	29

1 INTRODUCTION

1.1 Purpose

- 1.1.1 This standard states Approval 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 Approval 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.
- 1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of flame arresters for the purpose of obtaining Approval. Flame arresters having characteristics not anticipated by this standard may be FM Approved if performance equal, or superior, to that required by this Standard is demonstrated, or if the intent of the standard is met. Alternatively, flame arresters which meet all of the requirements identified in this Standard may not be FM Approved if other conditions which adversely affect performance exist or if the intent of this standard is not met.

1.4 Basis for Approval

Approval 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 by FM Approvals; 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. These examinations may be repeated as part of FM Approvals' product surveillance program.

1.5 Basis for Continued Approval

Continued Approval is based upon:

- production or availability of the product as currently FM Approved;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated in the Approval Report;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory Surveillance Audits conducted as part of FM Approvals' product surveillance program.

Also, as a condition of retaining Approval, manufacturers may not change a product or service without prior authorization by FM Approvals.

1.6 Effective Date

The effective date of an Approval standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products FM Approved either previously or under a previous edition shall comply with this new version by the effective date or else forfeit Approval.

The effective date of this Standard is January 1, 2016 for compliance with all requirements.

1.7 System of Units

Units of measurement in this standard are International System (SI) units. Appendix A lists conversion formulas for equivalents in United States (U.S.) Customary units. All pressures are absolute values. Values stated without parenthesis are the requirement. Values in parenthesis are explanatory or approximate information for reference.

1.8 Applicable Documents

The following standards, test methods, and practices are referenced in this standard. Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

- NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum)
- NFPA 69, Standard on Explosion Prevention Systems
- FM Approvals Class 3600, Approval Standard for Electrical Equipment for Use in Hazardous (Classified) Locations, General Requirements.
- FM Approvals Class 3615, Approval Standard for Explosionproof Electrical Equipment, General Requirements
- ASTM Standards A395 Ferritic Ductile Iron Pressure-Retaining Castings For Use At Elevated Temperatures
- F722 Welded Joints for Shipboard Piping Systems
- F1155 Standard Practice for Selection and Application of Piping System Materials
- ANSI Standards B16.5 Pipe Flanges and Flanged Fittings
- ASME Boiler and Pressure Vessel Code Section VIII, Division 1, Pressure Vessels Section IX, Welding and Brazing Qualifications
- 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
- ANSI/ASME B46.1, Standard for Surface Texture

1.9 Definitions

For purposes of this standard, the following terms apply:

- 1.9.1 *Atmospheric conditions*
Conditions with atmospheric pressures ranging from 80 kPa (800 mbar) to 110 kPa (1100 mbar) and temperatures ranging from -20°C (68°F) to 60°C (140°F)
- 1.9.2 *Deflagration*
Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.
- 1.9.3 *Detonation*
Propagation of a combustion zone at a velocity greater than the speed of sound in the unreacted medium.

- 1.9.3.1 *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.
- 1.9.3.2 *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.
- 1.9.4 *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.
- 1.9.4.1 *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).
- 1.9.4.2 *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
- 1.9.4.3 *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.
- 1.9.4.4 *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)
- 1.9.4.5 *In-line flame arrester* - Flame arrester that is fitted with two pipe connections, one on each side of the flame arrester
- 1.9.4.6 *Type I flame arrester* - Type I flame arresters (detonation or deflagration type) are acceptable for applications where stationary flames may rest on the device.
- 1.9.4.7 *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.
- 1.9.4.8 *Uni-directional flame arrester* - In-line flame arrester that prevents flame transmission from one side only
- 1.9.5 *Flame arrester element*
Portion of a flame arrester whose principal function is to prevent flame transmission
- 1.9.6 *Flame passage*
The transmission of a flame through a device
- 1.9.7 *Flashback*
The transmission of a flame through a device back upstream into a combustible mixture
- 1.9.8 *Flame velocity*
The speed at which a flame propagates within a pipe or other system

1.9.9 *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

1.9.10 *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 μ s 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 μ s
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 $p_0 \leq p_{TB}$, and the application is limited to mixtures with an MESG equal to or greater than that tested.

The specific hazards covered by this 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 Approval Application Requirements

To apply for an Approval examination the manufacturer, or its authorized representative, should submit a request to

Electrical Director
FM Approvals
1151 Boston-Providence Turnpike
PO Box 9102
Norwood, MA 02062
U.S.A.

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

- A completed Application/Request for Quote form.
- A complete list of all models, types, sizes, and options for the products or services being submitted for Approval consideration;
- General assembly drawings, complete set of manufacturing drawings, materials list, anticipated marking format, nameplate format, brochures, sales literature, spec. sheets, installation, operation and maintenance manuals; and
- The number and location of manufacturing facilities.
- 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 an Approval examination, the manufacturer shall submit samples for examination and testing based on the review of the preliminary information.
- 2.3.2 The test samples will typically be a complete assembly with all components mounted in a manner consistent with the manufacturer's instructions and intended application; but the exact sample requirements will be specified by FM Approvals as part of the proposal.
- 2.3.3 Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.
- 2.3.4 The manufacturer shall submit samples representative of production. Any decision to use data generated using prototypes is at the discretion of FM Approvals.
- 2.3.5 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 Approval investigation shall define the limits of the Approval.

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.