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BSI Standards Publication

Guide for the selection, application and use of flame arresters

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National foreword

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Guide for the selection, application and use of flame arresters

Guide pour la sélection, l'application et l'utilisation des arrête-flammes

Richtlinie für die Auswahl, die Anwendung und den Einsatz von Flammendurchschlagssicherungen

This Technical Report was approved by CEN on 22 December 2014. It has been drawn up by the Technical Committee CEN/TC 305.

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European foreword

This document (CEN/TR 16793:2016) has been prepared by Technical Committee CEN/TC 305 "Potentially explosive atmospheres - Explosion prevention and protection", the secretariat of which is held by DIN.

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Introduction

The document provided is general in nature and for specific applications further expert advice should be sought.

In addition to the content of operating manuals from manufacturers, the local accident prevention regulations, environmental protection and general safety provisions for the devices' area of use, as well as relevant laws and national directives, this paper will support the user for a proper use of flame arresters.

In Europe, the "Directive 2014/34/EU on equipment and protective systems intended for use in potentially explosive atmospheres" (ATEX – Atmosphères Explosibles) is mandatory for the production and test intended for use of products in potentially explosive atmospheres. Flame arresters are defined as a Protective System.

Flame arresters should be tested according to EN ISO 16852, *Flame arresters – Performance requirements, test methods and limits for use,* to fulfill the health and safety requirements of this directive.

Flame arresters are subjected to an EC type examination and are designed for use in areas at risk from explosion.

The Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres - gives the minimum requirements for the improvement of health protection and safety of employers who could be endangered by explosive atmospheres. The main issues are assessment of explosion risk, zone classification and the explosion protection documents (including requirements for personnel to do engineering, equipment selection, installation, maintenance, repair, etc.).

National regulations and/or codes relating to specific industries or applications may exist which have to followed.

Flame arresters are required to protect against many types of explosion events within equipment.

The safety obtained depends heavily upon correct choice, installation and maintenance of the flame arrester. This cannot be achieved without responsible, informed management.

1 Scope

This Technical Report is aimed primarily at persons who are responsible for the safe design and operation of installations and equipment using flammable liquids, vapours or gases.

This document applies to both industrial and mining applications

This document describes possible risks and gives proposals for the protection against these risks by the use of flame arresters.

This document gives some guidance to choice of flame arresters according to EN ISO 16852 for different common scenarios and it gives best practice for the installation and maintenance of these flame arresters.

2 Normative references

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

EN 60079-20-1, *Explosive atmospheres — Part 20-1: Material characteristics for gas and vapour classification — Test methods and data (IEC 60079-20-1)*

EN ISO 16852:2010, *Flame arresters — Performance requirements, test methods and limits for use (ISO 16852:2008, including Cor 1:2008 and Cor 2:2009)*

EN ISO 28300:2008, *Petroleum, petrochemical and natural gas industries — Venting of atmospheric and low-pressure storage tanks (ISO 28300:2008)*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

3.1.1
atmospheric condition
pressure ranging from 80 kPa to 110 kPa (0,8 bar to 1,1 bar); temperatures ranging from -20 °C to +60 °C

3.1.2
end-of-line flame arrester
flame arrester that is fitted with one pipe connection only

3.1.3
explosion
abrupt oxidation or decomposition reaction producing an increase in temperature, pressure, or in both simultaneously

3.1.4
explosion group
Ex.G
ranking of flammable gas-air mixtures with respect to the MESG

Note 1 to entry: See EN ISO 16852:2010, 3.12.2.

3.1.5
explosion-pressure-resistant
property of vessels and equipment designed to withstand the expected explosion pressure without becoming permanently deformed

3.1.6
explosion-pressure-shock resistant
property of vessels and equipment designed to withstand the expected explosion pressure without rupturing, but allowing permanent deformation

3.1.7
deflagration
explosion propagating at subsonic velocity

[SOURCE: EN ISO 16852:2010, 3.8]

3.1.8
detonation
explosion propagating at supersonic velocity and characterized by a shock wave

[SOURCE: EN ISO 16852:2010, 3.9]

3.1.9
stable detonation
detonation 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.

[SOURCE: EN ISO 16852:2010, 3.10]

3.1.10
unstable detonation
detonation during the transition of a combustion process from a deflagration 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.

[SOURCE: EN ISO 16852:2010, 3.11]

3.1.11
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

[SOURCE: EN ISO 16852:2010, 3.1]

3.1.12
flame arrester element
part of a flame arrester whose principal function is to prevent flame transmission

[SOURCE: EN ISO 16852:2010, 3.3]

3.1.13
in-line flame arrester
flame arrester that is fitted with two pipe connections, one on each side of the flame arrester

[SOURCE: EN ISO 16852:2010, 3.22]

3.1.14
mixture
used to represent any mixtures of gas and/or product vapour/air

3.1.15
product
equipment, protective systems, safety devices, components and their combinations

3.1.16
protected side
side of the plant component to be protected

3.1.17
protective system
autonomous devices to stop an explosion immediately and/or limit the effects of explosion flames and pressures

3.1.18
stabilized burning
steady burning of a flame stabilized at, or close to, the flame arrester element [short time (max. 30 minutes) or endurance burning (for unlimited time)

3.1.19
unprotected side
ignition source side

3.1.20
restriction
reduction of the diameter of the pipe on the protected side of a flame arrester

Note 1 to entry: For example, a restriction can be a not fully opened valve.

3.2 Abbreviated terms

DN

lower explosion limit of the explosion range

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_0 maximum operational pressure

T_0

net positive suction head

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
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
$\dot{V}_{max}$	safe volume flow rate
$\dot{V}_s$	safe volume flow rate including a safety margin

4 Explosion risks

The following content is a summary of the non-binding guide to good practice for implementing the European Parliament and Council Directive 1999/92/EC [1].

Three components are necessary at the same time for an explosion to occur. These are visualized in the so-called explosion triangle (see Figure 1).

1) Air (oxidizer)

2) Fuel (flammable gas)

3) Ignition Source (e.g. spark, hot surface, etc.)

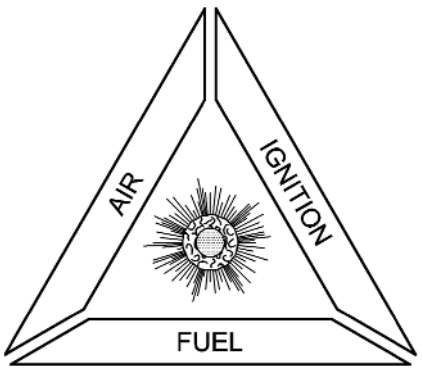


Figure 1 — Explosion triangle

Fuel mixed with air in a suitable ratio (above LEL and below UEL) is called explosive atmosphere.

Assessment of explosion risks is focused on:

— the likelihood that an explosive atmosphere will occur,

and subsequently on

— the likelihood that sources of ignition will be present and become effective.

Suitable methods for assessing the explosion risks associated with work processes or plant are those which lend themselves to a systematic approach to checking plant and process safety. An analysis is made of the existing sources of hazardous explosive atmospheres and the effective sources of ignition which could occur at the same time. Explosion risks can in practice be assessed by means of seven questions:

1) Are flammable substances present?

2) Can sufficient dispersal in air give rise to an explosive atmosphere?

3) Where can explosive atmospheres occur?

4) Is the formation of a hazardous explosive atmosphere possible?

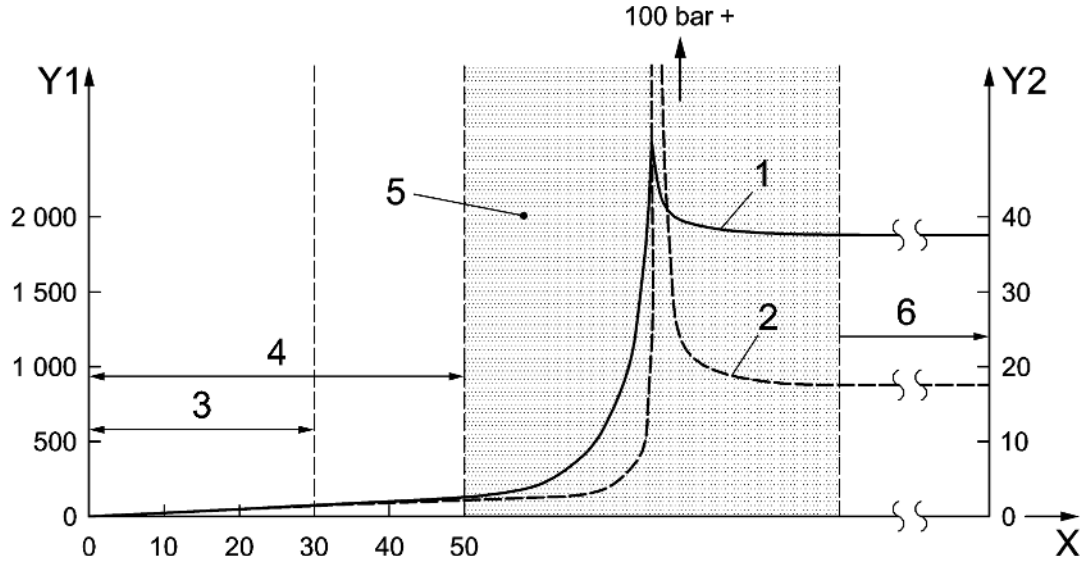
5) Is the formation of hazardous explosive atmospheres reliably prevented?

6) To what zones can the places with hazardous explosive atmospheres be assigned?

7) Is the ignition of hazardous explosive atmospheres reliably prevented?

Depending on the answers of these questions, it could be necessary to apply adequate explosion protection measures. "Explosion protection measures" mean all measures that prevent the formation of hazardous explosive atmospheres, avoid the ignition of hazardous explosive atmospheres or mitigate the effects of explosions. One of the possible measures is to use flame arresters.

An idealized representation of the flame acceleration process is presented in Figure 2.



Key

X	pipe L/D	3	deflagration IIB - IIC
Y1	flame speed in $m \cdot s^{-1}$	4	deflagration IIA – IIB3
Y2	pressure in bar	5	deflagration to detonation transition
1	flame speed	6	stable detonation
2	pressure		

Figure 2 — Development of an explosion in a pipeline

5 Technical measures for explosion protection

5.1 General

Priority shall be given to the prevention of the formation of hazardous explosive atmospheres. This can be done by avoiding or reducing the use or by limiting the concentration of flammable substances. Preventing of hazardous explosive atmospheres can also be realized by inerting.

If it is not possible to prevent the formation of a hazardous explosive atmosphere, its ignition shall be avoided. This can be achieved by protective measures which avoid or reduce the probability of ignition sources.

The probability that a hazardous explosive atmosphere and a source of ignition will be present at the same place and time is estimated and the extent of the measures required is determined accordingly. This is done on the basis of the zone concept, from which the necessary precautions are derived.

NOTE It is, however, recognized that there can be sources of ignition that cannot be determined with a high degree of accuracy (e.g. an electrostatic discharge within a pipe or a lightning strike).

5.2 Mitigation of the effects of explosion

5.2.1 General

In many cases, it is not possible to avoid explosive atmospheres and sources of ignition with a sufficient degree of certainty. Measures shall then be taken to limit the effects of an explosion to an acceptable extent. Such measures are:

— explosion-resistant design;

— explosion relief;

— explosion suppression;

— prevention of flame and explosion propagation.

These explosion protection measures generally relate to mitigation of the hazardous effects of explosions.

5.2.2 Prevention of explosion propagation – explosion decoupling

An explosion occurring in one part of a plant can propagate to upstream and downstream parts, where it may cause further explosions. Acceleration caused by plant fittings or propagation in pipes may intensify the explosion effects. The explosion pressures can be much higher than the maximum explosion pressure under normal conditions and may destroy items of plant even if they are of explosion pressure resistant or explosion pressure shock resistant design. It is therefore important to limit possible explosions to single parts of the plant. This is achieved by explosion decoupling. Explosion decoupling can be performed, e.g. by isolation valves or flame arresters.

5.3 Safety concept

Hazardous areas are classified in zones by the operator of a facility according to the frequency and duration of the explosive atmosphere as given in Table 1.

Table 1 — Hazardous areas

Definition	Explosive atmosphere	Example
zone 0	constantly, for a long period or frequently present	interior of a tank, pipe, device containing an explosive mixture
zone 1	sometimes present	the immediate vicinity of zone 0, the surrounding area of loading and unloading stations, the immediate vicinity of the outlet openings of vent pipes
zone 2	rare and during a short time of period present	areas which surround zone 0 and zone 1 areas, the immediate vicinity of detachable pipe connections

Openings of explosion-pressure-resistant or explosion-pressure-shock resistant plant components where explosions can occur internally have to be equipped with pre-volume deflagration flame arresters to prevent an explosion transmission from the inside to the outside if they are connected to other plants which are not explosion-pressure-resistant or explosion-pressure-shock resistant.

The safety concept depends on the likelihood of adverse events (e.g. flame transmission from ignition source), and the extent of the consequences (e.g. range of devastating explosion pressures).

The number of independent measures against flame transmission when facing high-level consequences is shown in Table 2.

Table 2 — Number of independent measures – zone concept

Ignition source	**Number of independent measures Explosive atmosphere**			
	permanent zone 0	sometimes zone 1	rare zone 2	never (non-hazardous area)
permanent	3	2	1	0
sometimes	2	1	0	0
rare	1	0	0	0
never	0	0	0	0

Depending on the hazardous area classification and the likelihood of ignition sources, flame arresters in series can be used, as well as measures for concentration control and for ignition source control.

If flame arresters are to be used in series it has to be ensured that they function as independent measures and are not subject to common mode failure, for example deflagration flame arresters in series may not be independent measures.

If flammable mixtures are emitted or processed during operation in relatively large volumes and over a relatively long period (e.g. when filling a tank or vapour processed to a vapour destruction unit), it shall be anticipated that after any ignition there may be stabilized burning at the flame arrester element. In such cases, suitable additional measures need to be taken to protect the plants, if the installed flame arrester is not designed / approved for stabilized burning.

6 Flame arresters

6.1 General

The purpose of a flame arrester is to allow gas to pass through but stop a flame in order to prevent an explosion or fire propagation. There are many different situations in which flame arresters are applied. Flame arresters are designed to meet specific requirements of applications.

The severity of explosion depends on the operating conditions, the physical piping conditions, and environmental factors. Flame arresters are designed for specific applications. Therefore, a wide variety of flame arrester types are available.

The user shall ensure that a flame arrester has been tested for conditions that match or exceed the intended application.

Figure 3 shows possible and typical locations of flame arresters, for example:

— tanks;

— processing systems;

— vapour combustion systems, incinerators, flares;

— ships, offshore platforms, vehicles and loading systems;

— vapour recovery units;

— as integrated components of pumps, blowers and other rotating machines.

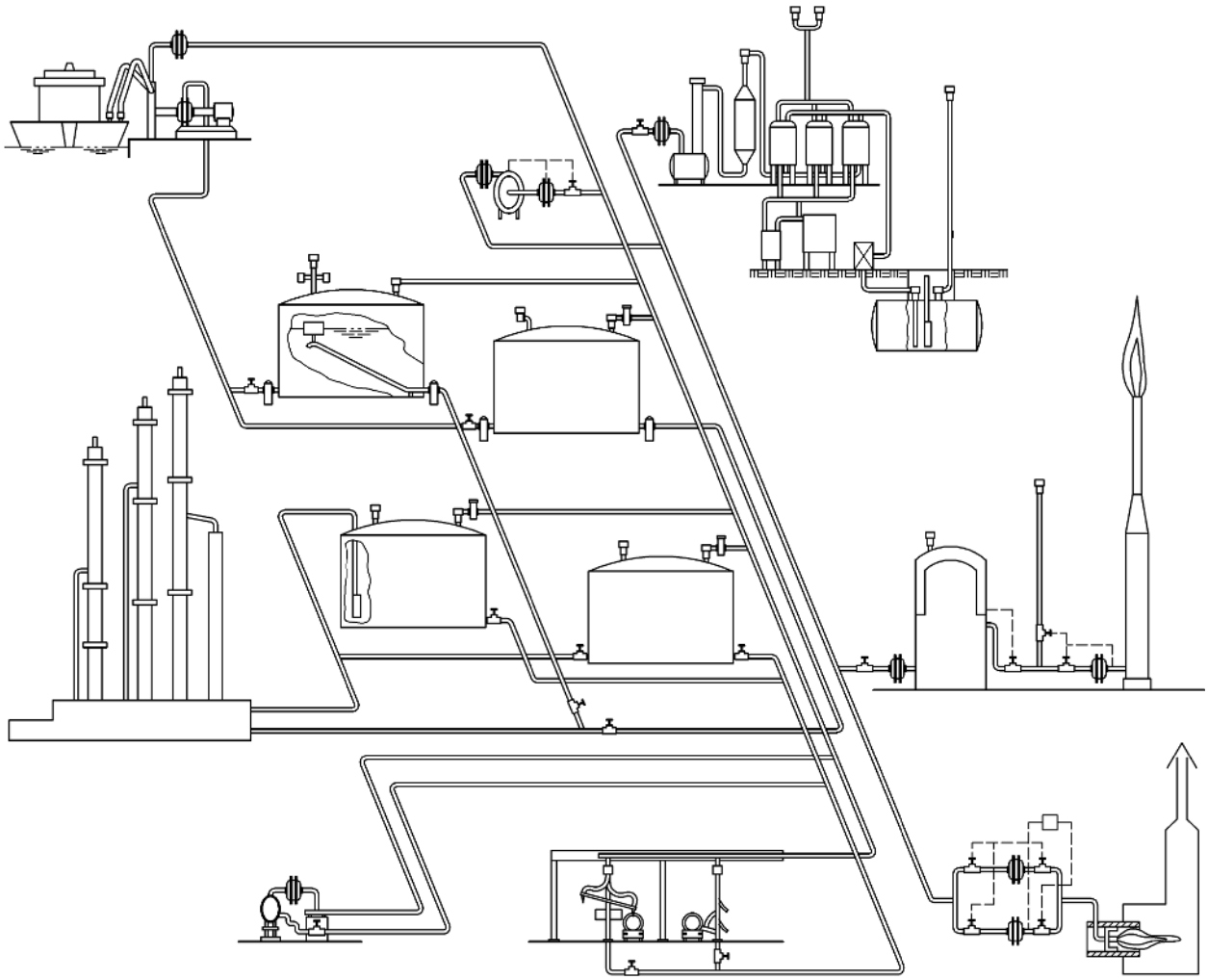


Figure 3 — Typical locations for flame arresters

6.2 Principle of operation of flame arresters

Depending on the selected technical solution to prevent flame transmission flame arrester types according to Table 3 are available.

Table 3 — Flame arrester principle

Types of flame arresters	Remark	Safeguard principle
Static flame arrester	measurable type; flame arrester element with quenching gaps that can be drawn, measured and controlled non-measurable type; flame arrester element with quenching gaps that cannot be drawn, measured or controlled	Flame quenching
Liquid product detonation flame arrester	liquid seal flame arrester; foot valve flame arrester	Prevention of flame transmission at a barrier formed by the liquid product
Hydraulic flame arrester	—	Prevention of flame transmission at a barrier formed by water
Dynamic flame arrester	high-velocity pressure relief valve	Nominal flow velocity at the outlet exceed flame velocity thus prevent flame transmission

Flame arresters can be distinguished in several ways.

6.3 Types of flame arresters

6.3.1 End-of-line deflagration flame arrester

End of line deflagration flame arresters are used to stop flames coming from outside and avoid explosion entering the pipe work or tank.

6.3.2 In-line deflagration flame arrester

In-line deflagration flame arresters are designed and tested for stopping deflagrations developing in a pipeline. For use of in-line deflagration flame arresters there is a maximum allowable L / D ratio.

6.3.3 In-line detonation flame arrester

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

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

6.3.4 Stabilized burning

6.3.4.1 Short time burning flame arresters

For operation conditions leading to stabilized burning of the mixtures directly on the flame arrester element, there will be only limited safety against stabilized burning, i.e. flame transmission protection.

Then flame arresters can be fitted with temperature sensors to detect the flame and trigger measures to suppress the stabilized burning (e.g. emergency functions such as switching the plant off/over, inerting, etc.) within half the time for which the flame arrester is resistant to short time burning.

An explosion-proof temperature sensor shall be designed for measuring temperatures both in liquid and gaseous media. A common design is a resistance thermometer with a PT100 measuring resistance. The measuring probe can be installed in zone 0. The length of the probe depends on the flame arrester

design and its function should be tested with the flame arrester according to the standard for flame arresters.

A temperature sensor shall respond within half of the time for which the flame arrester is safe against short-time burning.

Check that the system for preventing stabilized burning activates after the trigger temperature (to be set in each instance) is exceeded. Ensure adherence to the permitted response time for activation. The trigger temperature may be no more than 60 K above the operating temperature for the flame arrester. It is recommended a trigger temperature of 20 K above the maximum operating temperature. For heated flame arresters it is recommend a trigger temperature of 30 K to 40 K above the maximum operating temperature.

A fire with high temperatures can destroy the measuring resistance (PT100). Exchange the measuring probe, if the flame temperature exceeded the operating temperature of the temperature sensor.

If the operating company installs any temperature sensors of their work standards, these shall comply with the safety specifications of the temperature sensor tested with the flame arrester. It further has to be proven that in the event of short time burning the same response times are met and (in the case of in-line deflagration and detonation arresters) the mechanical strength matches that of the model approved.

6.3.4.2 End-of-line endurance burning flame arrester

End-of-line endurance burning flame arresters are designed and tested for stopping both atmospheric deflagrations and flame transmission in case of stabilized burning for unlimited time (endurance burning).

The safe use of static flame arresters is limited to hydrocarbons. For flammable fluids that are not pure hydrocarbons (e.g. alcohols, ketones, etc.) a separate testing is necessary.

6.3.5 Pre-volume flame arresters

Flame arrester 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.

6.4 Selection of flame arresters

Flame arresters should be selected for the intended use (see Figure 4). For the correct selection of a flame arrester an assessment should be carried out to identify:

— what should be protected;

— where the potential ignition sources are;

— where an explosive atmosphere may arise;

— what kind of explosive atmosphere can occur;

— operating parameters (temperature, pressure, etc.) of the explosive atmosphere.

NOTE For additional information, see also EN ISO 16852:2010, Annex B.

Flame arresters are designed and tested to meet particular operating conditions. To ensure that an effective flame arrester is selected, it is essential that the conditions in which it will be used are specified carefully (see Figure 4).

A first selection is to decide whether to use an end-of line or an in-line flame arrester. In some special applications, pre-volume flame arresters are used to prevent 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. End-of-line detonation flame arresters are devices in liquid product lines to protect the filling and emptying line of a tank. End-of-line flame arresters are designed mainly to stop atmospheric deflagrations. A typical application is the protection of storage tanks for flammable liquids against atmospheric deflagrations initiated by lightning strikes or other external ignition sources.

Stabilized burning for out-breathing tanks is a risk. Depending on the duration of the steady flow out, an endurance burning or a short time burning flame arrester shall be selected. The maximum time a short time burning proof flame arrester will withstand a stabilized flame is less than 30 min and is marked on the marking plate as burning time (t_{BT}). Note that the time needed to fill a tank can be many hours.

The selection of in-line flame arresters depends on the distance between the identified ignition source and the installation location of the flame arrester. Deflagration flame arresters are designed and tested for limited distance in accordance with the IOM (Installation and Operating Manual) of the manufacturer (maximum $L_u/D = 50$ for explosion groups IIA1, IIA, IIB1, IIB2 and IIB3 and $L_u/D = 30$ for explosion groups IIB and IIC). For applications with longer distances or where the location of the ignition source is not identified, deflagration arresters shall not be used.

For stabilized burning of mixtures due to the operating conditions directly at the flame arrester element a flashback can only be prevented for a limited period of time. Therefore, additional safety measures are necessary. This time limited safety against stabilized burning generally applies to most in-line flame arresters. If due to special operating conditions stabilized burning of mixtures is possible at the flame arrester element – this includes for example the application within closed pipeline systems of process-technical plants with operationally force-actuated volume flows – flame arresters with integrated temperature sensors shall be used, in order to trigger an alarm to start measures to stop the stabilized burning on the element (by a shut down or by-pass, inerting, etc.). For stabilized burning check the likelihood on which side or on both sides it may burn and a temperature sensor(s) shall then be installed accordingly – either on one side only or on both sides.

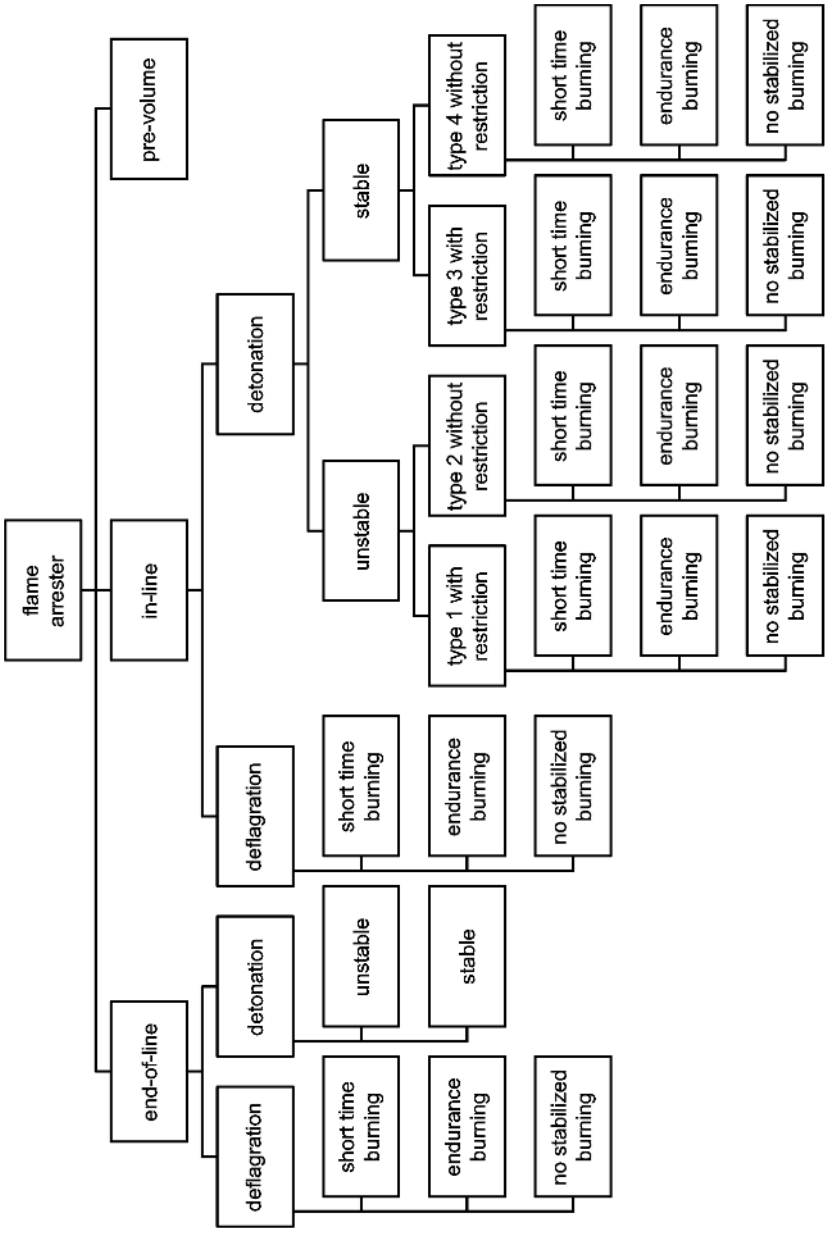


Figure 4 — Selection of flame arresters

After selection of the flame arrester type the explosive atmosphere should be checked (see Figure 5). Vapour and gases are classified in Explosion Groups by means of the safety classification number Maximum Experimental Safe Gap (MESG) [9], [10]. MESG is independent of the actual gap size (also called gap width or gap height) of a static flame arrester's element. EN ISO 16852 classifies into the explosion groups according to Table 4.

Table 4 — Explosion groups and the corresponding MESG

Explosion group	Maximum experimental safe gap mm
IIA1[a]	≥ 1,14
IIA	> 0,90
IIB1	≥ 0,85
IIB2	≥ 0,75
IIB3	≥ 0,65
IIB	≥ 0,5
IIC	< 0,5
a Group IIA1 was designated as Group I previously.	

NOTE MESG is a safety characteristic of the material and depends on the measurement system. In this document, the MESG is determined according to EN 60079-20-1; other methods may give different results. The determination of the MESG of the process media is the responsibility of the user of a flame arrester. Flame arresters are tested with vapours/gases of the respective explosion group and are marked accordingly. The application is limited to mixtures with an MESG equal to or greater than that tested.

Be aware if you use flame arresters marked according to other standards e.g. American code NFPA 70 (NEC) because the explosion groups can differ from the international explosion groups of EN ISO 16852.

Mixtures which tend to self-decompose (e.g. acetylene or ethylene oxide), are chemically unstable, and mixtures with higher oxygen concentration (chlorine as oxidant, etc.) are excluded from the standard approval procedure according to EN ISO 16852. Carbon disulphide is also excluded. Flame arresters intended for the mentioned gas mixtures have to be tested with the special mixture directly and be marked accordingly.

Flame arresters according to EN ISO 16852 are designed and tested for gas/air or vapour/air mixtures, not for oxygen enriched mixtures or self-decomposing substances. The explosion group shall be verified depending on the components of the mixture. To be on the safe side, the explosion group of the component with the smallest MESG value may be used. Other methods and models are available to estimate the MESG of the worst case gas mixture composition. In case of any doubt, it is recommended to contact the manufacturer of flame arrester.

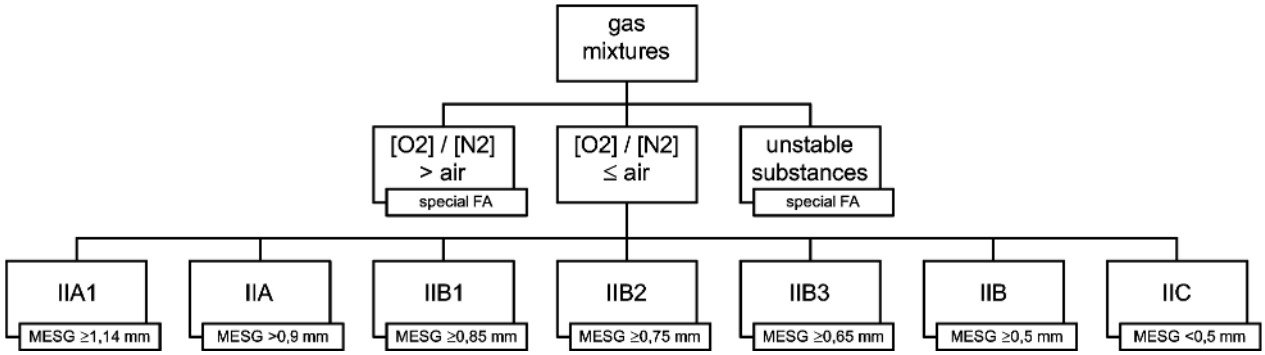


Figure 5 — Flame atmosphere

6.5 Application limits

The marking of a flame arrester according to EN ISO 16852 contains, amongst others, application limits as shown in Table 5. Ensure that this and the further data specified according to Table 6 conform to the intended operating conditions. According to EN ISO 16852 the warning "flame arresters have installation and application limits" has to be marked on the flame arrester.

Flame arresters for special purposes may have different application limits.

Table 5 —Application limits marked on the flame arrester according to EN ISO 16852

Explosion group of the gas, starting with the sign 
Maximum operating temperature T
Maximum operating pressure p_0
Type designation: "DEF" for deflagration flame arresters in combination with maximum allowable L_u/D for in-line flame arresters
"BC" for burn rating in combination with the burn classification "a", "b" or "c". "a" – endurance burn (no time limit) "b" – short time burn from 1 min to 30 min "c" – not burn time In case of class b the burn time t_{BT} in minutes the flame arrester was tested for (from 1 min to max. 30 min) shall be given.
Maximum flow rate for hydraulic flame arresters

Table 6 — Further application limits

Application limits	Remarks
Working direction for in-line flame arresters	Directional (the protected side shall be marked) or bi-directional
Oxygen concentration	Flame arresters are tested for mixtures with air normally. Air has approximate 21 vol. % oxygen (O_2). Flame arresters for oxygen-enriched mixtures have to be tested and approved accordingly.
Housing test pressure (6.5 of EN ISO 16852:2010) for deflagration flame arresters ≥ $1{,}1 \cdot 10^6$ Pa (10^6 Pa = 1 MPa = 10 bar) for detonation flame arresters ≥ 10 x p_0	Necessary for in-line flame arrester to know the maximum test pressure for pipework
Endurance burning (static flame arresters)	The safe use is limited to pure hydrocarbons, admissible use for other chemicals (e.g. alcohols, ketones, etc.) have to be explicitly tested. Endurance burning is guaranteed for a specified installation position only under atmospheric conditions (p ≤ 0,11 MPa, T ≤ 60 °C) at the flame arresting element.
Maximum suction rate for emptying	Has to be observed for liquid product detonation flame arresters
Surface temperature	Limit the maximum surface temperature to 80 % of the flammable mixture's auto-ignition temperature
Material resistance	When selecting the flame arrester the user shall ensure that they are sufficiently resistant (e.g. against corrosion) with regard to the substances present in the system. This also applies to possible coatings. Information in this matter the user can find in the instruction for use.

6.6 Installation limits

6.6.1 General

6.6 includes information about specific types of flame arresters and specific installation based on experience. Where limited knowledge is available guidance is not provided.

For information on use of inline stable detonation flame arresters, see EN ISO 16852:2010, Annex D.

Installation limits apply; these are summarized in Table 7.

Table 7 — Installation limits

Installation limits	Remarks
Installation orientation	Arresters may have limits on their installation orientation. The worst case for in-line flame arresters under stabilized burn condition is flow vertically downwards and potential ignition source from below. The user shall take into account the instructions for use given by the manufacturer.
Plugging	Plugging, e.g. accumulation of condensate due to incorrect installation can lead to uncertain operating conditions; the plants operating pressure could be exceeded.
Max. permitted L_u/D ratio	L_u/D is the ratio between pipeline length on the unprotected side and the nominal pipe size.
Nominal pipe sizes	The nominal sizes of the pipelines connected on the side of the ignition source (unprotected side) have to be less or equal to the flame arresters' nominal size. The nominal sizes of the pipelines connected on the protected side have to be equal to or larger than the nominal size on the unprotected side.

6.6.2 Arrangement of flame arresters at pipe branches [5]

Installation of flame arresters at or near pipe branches may require special consideration, and advice should be sought from the manufacturer. Specific proven examples are given below.

At pipe branches stable detonation flame arresters shall be placed in a way that any instability caused by the propagation of a detonation through the pipe does not cause any unsafe stresses.

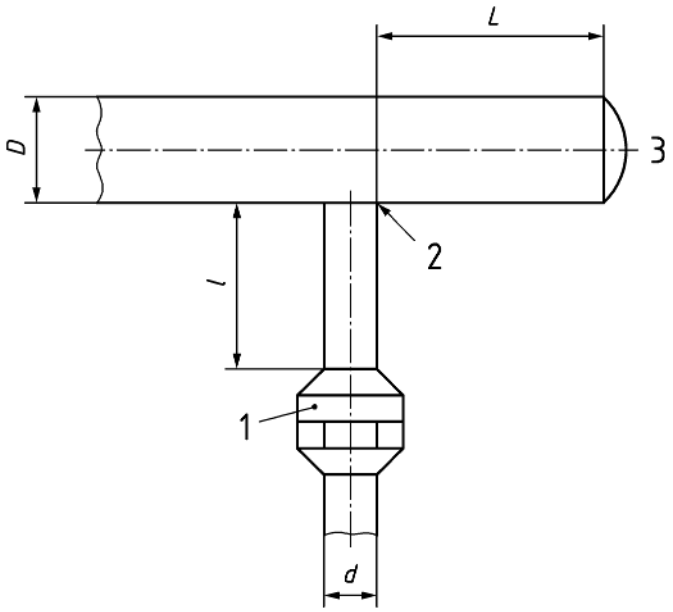
This is achieved by a certain distance from a branch to a sudden cross-sectional reduction in the straight pipe section or at a pipe end which is at least 20 times the diameter of this straight pipe section, being at least 3 m. In addition, the following has to be maintained (see also Figure 6 and Figure 7):

— at pipe branches, not designed right-angled and not sharp-edged, flame arresters for stable detonations are used, which are placed in the branch pipe at a distance of at least 120 pipe diameters from the branch connection;

— at pipe branches, designed right-angled and sharp-edged, flame arresters for stable detonations are used, which are placed in the branch pipe at a distance from the branch connection of either:

  — at least five pipe diameters of this pipe, at least 0,5 m, up to at most 50 pipe diameters;

  — at least 120 pipe diameters of this pipe.



L/D > 20; L at least 3 m

l/d > 5; l at least 0,5 m and l/d < 50

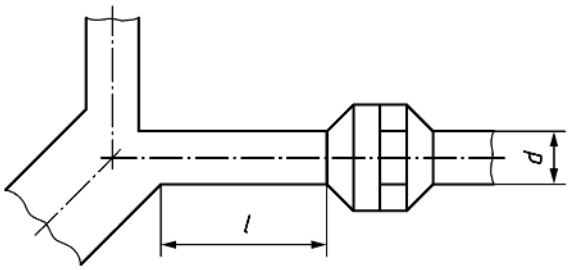
or

l/d > 120

Key

1 detonation flame arrester
2 branch with sharp edge
3 pipe end, e.g. bumped pipe end

Figure 6 — Recommended branch design for rectangular and sharp edged branch pipes



l/d > 120

Figure 7 — Recommended branch design for not rectangular and not sharp edged branch pipes

The nominal pressure (PN) of pipelines and pipe fittings has to withstand the expected explosion pressure without being ruptured.

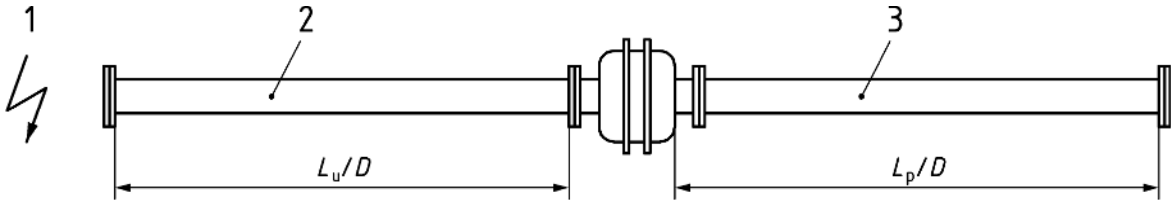
6.6.3 In-line deflagration flame arrester

In-line deflagration flame arresters are designed and tested for stopping deflagrations developing in a pipeline. For in-line deflagration flame arresters the maximum allowable L_u/D ratio according to EN ISO 16852 is listed in Table 8 and an example is shown in Figure 8.

Table 8 — Maximum permitted L_u/D ratio (EN ISO 16852:2010, 7.3.2.2)

Pipe length	Explosion group
$L_u/D \leq 50$	IIA1, IIA, IIB1, IIB2, IIB3
$L_u/D \leq 30$	IIB, IIC

The ratio of pipe length (distance between the potential ignition source and the location of the flame arrester) and pipe diameter shall not exceed the tested ratio L_u/D.



Key

1 side of potential ignition source

2 unprotected side

3 protected side

Figure 8 — Installation limits for deflagration flame arresters

To calculate the maximum allowable pipe length, take the permitted L_u/D ratio for your flame arrester and use the formula:

$$L = \frac{DN \times L_u / D}{1000} \quad (1)$$

where

L is pipe length (m);

D is inner pipe diameter (mm).

EXAMPLE For a flame arrester with DN 150 and a maximum allowable L_u/D = 50 the maximum pipe length is 7,5 m.

No cross-sectional reducing pipe fittings shall be installed between the potential ignition source and a deflagration flame arrester unless it is written in the instruction for use given by the manufacturer and the operating manual. Shut-off valves can be installed in a pipeline if they are full open during operation and do not reduce the free flow area. Pipe branches and valves on the unprotected side shall be installed as close as possible to the in-line deflagration flame arrester. For in-line deflagration flame arresters at least 10 % of the cross sectional area of the pipe shall be open at the ignition source. This provides a safety factor compared to the tested configuration. In-line deflagration flame arresters should be installed as close as possible to the ignition source.

6.6.4 End-of-line deflagration flame arrester

6.6.4.1 End of line flame arrester (no burn time)

These arresters are for use where there is no risk of continuous flow of flammable vapour, i.e. no risk of stabilized burning.

This type of flame arrester is classified as burn class c according to EN ISO 16852 (BC: c).

6.6.4.2 End of line short time burning flame arrester

These flame arresters are for use where there is a risk of continuous flow of flammable vapour, which can be stopped within 1 min to 30 min depending on the maximum burn time.

This type of flame arrester is classified as burn class b according to EN ISO 16852 (BC: b).

The burn time (BT) should be selected as appropriate for the application.

A temperature sensor is supplied with this classification of flame arrester. This shall form a part of the overall protective system.

Some flame arresters are fitted with a weather hood (cowl). This flame arrester shall be installed in a way that the weather hood opening is unobstructed in the event of a stabilized burn on the flame arrester.

6.6.4.3 End of line endurance burning flame arrester

These flame arresters are for use where there is a risk of continuous flow of flammable vapour.

This type of arrester is classified as burn class a according to EN ISO 16852 (BC: a).

The burn time (BT) is unlimited.

Ensure that, after ignition of the escaping mixtures, the flames may burn unhindered vertically upwards. A safe area extending vertically upwards from the flame arrester should be provided in order to avoid heating-up the flame arrester element due to heat reflection.

Some flame arresters are fitted with a weather hood (cowl). This flame arrester shall be installed in a way that the weather hood opening is unobstructed in the event of a stabilized burn on the flame arrester.

If two or more flame arresters are installed on a tank or in a plant this may lead to unallowable heat interference between the flame arresters in case the escaping mixtures ignite.

Therefore:

— Keep a minimum distance between the flame arrester which is more than five times the maximum flame arrester element diameter.

— When installing different types of flame arrester, always keep the larger minimum distance between them.

— Ensure that the installation level of the flame arrester is on the same height.

Endurance burning flame arresters do not need an integrated temperature sensor.

6.6.5 Liquid seal flame arrester

Liquid seal flame arresters made for liquid discharging pipelines have to have a special design so that the liquid seal cannot be pumped empty. If necessary, the flow rate for pumping out has to be restricted and stated in the operating manual.

Pay attention to the installation direction of a liquid seal flame arrester so that the liquid product cannot flow out.

Fast running pumps may get electrostatically charged during filling and discharging a tank. Take care of the national regulations regarding filling and emptying of tanks and the corresponding limited flow velocities for different products and process modes, see CLC/TR 50404. Depending on type and composition of the stored product, foam may develop inside the containment. This may have an effect on the pump when the tank is being emptied. Foot valves may help to reduce the NPSH but shall be detonation proof to protect the tank against explosions/detonations initiated by a dry running pump.

6.6.6 Foot valve flame arrester

A foot valve flame arrester is an end-of-line flame arrester which incorporates a non-return valve. It is normally installed in a suction pipeline of a storage tank to provide a necessary NPSH. The valve normally is closed and opens if product is pumped out.

6.6.7 Hydraulic flame arrester

Hydraulic flame arresters are in-line detonation flame arresters with the following limited conditions according to EN ISO 16852:

— the flow rate shall not exceed the safe value $\dot{V}_s = 0,9 \quad \dot{V}_{max}$

— the operational immersion depth shall be kept above the tested minimum value Z_{0min};

— the mixture on the unprotected side shall be at ambient temperature and pressure.

If for operational reasons the mixture flow cannot be stopped, it shall be inerted. The immersion depth at rest Z_R and the operational immersion depth Z_0 shall not be less than the manufacturer's recommended safety margin and greater than the minimum water seal immersion depth at rest Z_{Rmin} and the minimum operational water seal immersion depth Z_{0min} at which the maximum volume flow $\dot{V}_{max}$ has been established. The operational immersion depth Z_0 shall be maintained by automatic control of the water supply to ensure that the minimum operational immersion depth Z_{0min} is not reached.

6.6.8 High velocity valves

The high velocity valve is an end-of-line dynamic flame arrester designed and tested for stopping atmospheric deflagrations and endurance burning. The use of a dynamic flame arrester is limited to ambient temperatures in general. The pipe length on the protected side shall not exceed the pipe length upstream of the dynamic flame arrester and the diameter shall not be less than the diameter of the pipe on the protected side, as successfully tested. To avoid hammering in all operating conditions the maximum pipe length shall not be exceeded.

6.7 Insulation and heating

Under particular operating conditions (e.g. steam in the stored product's evaporation phase) and in extreme weather conditions (e.g. frost) there is a risk that mixtures in the cooled flame arrester may condense, freeze and block the flame arresting element gaps. This can lead to an increase in pressure in the plant component and thus to danger. It is advisable to take preventative measures (e.g. heating) against the formation of ice.

Thermal insulation and heating can sometimes be required. To avoid explosion hazards ensure that:

— end of line flame arresters shall not be fully enclosed such as to restrict the outlet or operation of any moving parts.;

— openings, e.g. condensate drains and pressure compensation openings are kept clear;

— clear passage into the inlet/outlet cross sections is not covered over or obstructed. The insulation shall not impair flame arrester venting. It is recommended to keep a minimum distance of 1 x DN, and in any case at least 50 mm from the flame arrester exit;

— in the case of end-of-line flame arresters resistant to short time or endurance burning the insulation cannot lead to a hot-spot that causes any rapid heating up of the flame arresting element. On endurance burning flame arresters the weather hoods shall not be insulated;

— endurance burning proof in-line flame arresters are not insulated;

— any loose insulation materials (e.g. rock wool) are enclosed, secured and covered in such a way that fibres or particles of the material do not get sucked in;

— the functionality of the flame arresters and the ability to maintain them is assured in every respect;

— electrical resistance trace heating is approved for such uses;

— the maximum temperature of the heat media should be not more than 25 K above the maximum operating temperature of the flame arrester and does not exceed 80 % of the auto ignition temperature;

— the thickness of the insulation is adapted to each application.

7 Application of flame arresters

7.1 General

National regulations and/or codes relating to specific industries or applications may exist and shall be consulted.

7.2 Protection of process units, containments and tanks [5]

7.2.1 Necessity of flame arresters

Flame transmission into tanks, vessels and/or piping systems can be prevented by the correct use of flame arresters.

Flame arresters are used to prevent a flame transmission through the openings of containments and system parts. A well designed and tested flame arrester in accordance with EN ISO 16852 can be selected on the basis of requirements driven by the operating conditions and the chosen type of installation (see Figure 4 and Figure 5).

Typically flame arresters are not designed to prevent explosions propagating out of an enclosure but to prevent an explosion getting in. The pre-volume effect generated by an explosion getting out of a containment that resist to explosion pressure leads to a higher load for the flame arrester. If such a situation is to be taken into consideration, pre-volume explosion tests need to be conducted with the original configuration or equivalent full-scale model configuration in accordance with EN ISO 16852.

For explosion pressure shock resistant containment, the need to use flame arresters only applies in the following cases:

— There are openings to the atmosphere during normal operation.

A danger to working personnel or third parties can occur due to the venting out of flames. Information is available in EN ISO 28300:2008, Annex F regarding limitations to requirements on flame arresters for inerted tanks.

7.2.2 Protection against flame transmission during deflagration or detonation

Openings of tanks, vessels and/or piping systems where mixtures are not vented during normal operation, but where explosive atmosphere may enter, for example vacuum valves at tank openings, have to be equipped with deflagration flame arresters. This is to prevent flame transmission into the tank, the tank system or the pipes, in case an explosion occurs close to these locations (end-of-line deflagration flame arresters).

Openings in explosion-pressure resistant or explosion-pressure-shock resistant tanks or systems, where an internal explosion can occur, have to be equipped with pre-volume deflagration flame arresters to prevent the propagation of an explosion towards components, which are neither explosion-pressure resistant nor explosion-pressure-shock resistant.

If tanks, vessels and/or piping systems, which are not explosion-pressure resistant and not explosion-pressure-shock resistant are connected to long lengths of pipelines not continually filled with flammable liquid during normal operation, in-line detonation flame arresters have to be placed between a potential ignition source and the equipment to be protected.

Detonation flame arresters are required for example in the following cases:

— at the connection of a vapour venting line, vapour balancing line, vapour collecting line to the tank nozzle;

— at filling and discharging pipes not continually filled with flammable liquid during normal operation and which therefore can contain explosive mixtures. This also applies to filling and discharging pipes, which lead into the tank from the top and pass through to the bottom of the tank;

— if the pipe length between a potential ignition source and the location of the flame arrester exceeds the maximum permitted pipe lengths L_u for deflagration;

— at openings with a detachable hose for tank filling/discharging or vapour venting, if the length of the hose connections exceed the maximum permissible pipe lengths for deflagration flame arresters.

7.2.3 Protection against flame transmission during endurance burning

Openings of tanks and systems leading to the atmosphere, from which explosive mixtures can be vented for more than short periods of time, have to be equipped with flame arresters safe against endurance burning. These fittings have to withstand the combustion of vented explosive mixtures without allowing flame transmission (endurance burning proof flame arresters) under all operating conditions and also comply with the end-of-line deflagration flame arrester requirements mentioned above.

Protection measures against endurance burning are required for example at outlets and all other openings connecting the vapour space of the tank to the atmosphere. They are also required at emergency vent stacks for vapour venting systems and for systems from which explosive mixtures can be exhausted for longer periods of time during normal operation.

In-line deflagration as well as in-line detonation flame arresters which are not safe against endurance burning, through which explosive mixtures flow for short or long periods of time, shall be equipped with temperature sensors to ensure that a stabilized burning is detected and emergency measures are activated. The reacting time shall be not more than half of $t_{BT.}$ These emergency measures can include the following:

— the flow of explosive mixtures is stopped upstream of the flame arrester by a quick-action shut-off valve controlled automatically;

— the explosive mixture is inerted;

— the concentration of flammable gas components in the mixture is enriched above the upper explosion limit;

— air is added to dilute the mixture below the lower explosion limit.

The case of a stabilized burning on the inline flame arrester should be considered in the explosion safety concept of the plant regardless of the flame arrester´s endurance burn capability.

7.2.4 Operating conditions [5]

7.2.4.1 General remarks

Flame arresters shall be attached as close to the vessel or tank as possible and shall be installed in a way that they can easily be maintained.

Vessel and tanks, which are aerated or vented via a common venting pipe, shall be equipped with a suitable flame arrester at the tank nozzle, unless the tanks are explosion-pressure resistant or explosion-pressure-shock resistant.

Flame-accelerating design features, such as flaps, sudden cross-sectional modifications and the like should be avoided between the location of the potential ignition source and the in-line deflagration flame arrester, unless it is allowed in the instructions for use for this arrangement. These limitations do not apply to shut-off devices with the same cross-section like the pipes, if they are kept full open during normal operation.

7.2.4.2 Protection against endurance burning

Endurance burning proof flame arresters at emergency vent pipes of tank systems and vapour venting systems or at vent pipes leading from tanks have to be arranged in such a way that in the case of stabilized burning the flame has no effect on the pipe itself. Parallel arrangements of endurance burning proof flame arresters are permissible. They have to be arranged in a way that they do not affect each other by heating. This is for example given if the minimum axial distance of the protection devices is at least five times the diameter of the flame arrester element, and the installations are at the same level. The free exhaust flow should not be impeded during burning.

7.2.4.3 Protection along vapour venting or recovery pipes

Provided they are not built to be explosion pressure-resistant or explosion pressure shock-resistant, tanks have to be protected against flame transmission from deflagrations or detonations during vapour venting or during vapour balancing in recovery pipes. This requirement may be satisfied by equipping the tanks with a detonation flame arrester. Regarding inerted tanks, refer to EN ISO 28300:2008, Annex F.

Vent openings of vapour venting lines or vapour return pipes have to be designed for endurance burning.

7.3 Changing the process

If process conditions change, the flame arresters shall be verified as being suitable for the new application.

8 Installation, operating and maintenance

8.1 General

The operating manual should describe the set-up, function, assembly, operation, maintenance and disposal of flame arresters. The manual provides the operating company and personnel with all of the knowledge required to make full use of the flame arresters' capabilities. It is part of the documentation package supplied with the flame arresters and shall be made available to the operating personnel. The operating manual contains information required to operate flame arresters safely and in the event of any problems arising provides advice on possible causes and how to correct them.

Operating conditions shall always be in line with the flame arresters intended use and their limitations of use shall be observed.

The aim of maintenance is to keep the functionality, quality and safety to a high level and to reduce the environmental pollution as well as to elongate the life cycle of a flame arrester. The operating company is responsible for the proper plant operation.

Whilst specific maintenance requirements will depend upon the flame arrester design and application common maintenance requirements to be aware of are:

— blockage;

— corrosion;

— mechanical damage.

In addition, inspection for undetected flame events should be routine.

8.2 Safety information

Use flame arresters only for the intended purpose. Ensure that the flame arrester specifications conform to the conditions in which the flame arrester shall be used on site.

— For handling flame arresters use lifting gear (if appropriate) of adequate size.

— The flame arresters shall be installed, operated and maintained only by trained and appropriately instructed technicians. Perform all work carefully, adhering to all necessary safety measures.

— In order to avoid safety risks and to ensure optimum efficiency, do not undertake any modifications or conversions to the flame arresters without the manufacturer's written consent.

— Prior to installation, check the flame arresters for any damage and ensure that they are in good condition.

— Damaged flame arresters shall not be used or shall be taken out of operation immediately and shall be repaired or replaced.

— Operate the flame arresters only with the connections provided and designed for the purpose.

Follow and adhere to all safety information in an operating manual and in all other documentation supplied with the flame arresters.

— Where appropriate, take protective measures, e.g. use breathing apparatus. Decontaminating procedure shall be observed.

— Only use spare parts that meet original equipment manufacturer´s specifications (e.g. fusible elements).

8.3 Checking and installing

In addition to the installation limits, see 6.4, ensure the following:

— Prior to installation check the flame arrester meets the ordered specification (e.g. size, material, explosion group, etc.).

— Ensure that the flow through the flame arrester in the inlet and outlet cross-sections is unobstructed.

— Remove protective caps from the connections.

— Remove bags filled with desiccants, if applicable.

— After installation, however, before commissioning it is vital to remove all transport locks, e.g. if the flame arrester is combined with valves.

— Check connections for damage.

— Secure flame arrester properly for the relevant type of connection. Ensure in the process that the fitted flame arrester is not under any strain.

— Check and firmly tighten all screw connections.

— Connect all optional components, e.g. heating jacket, temperature sensors, differential pressure meter, proximity switch, control lines, etc.

— Any unused openings have to be sealed gas-tight.

— Ensure that it is possible for potential equalization to take place across the flame arrester connections.

— Ensure that correct seals, bolts and nuts are available for the mounting of the flame arrester. Tighten bolts and nuts with appropriate torque.

8.4 Inspection and maintenance intervals

The necessary intervals for inspection and maintenance are dependent on the characteristics (e.g. condensation, sublimation, polymerization, consistency) of the products in the plant on the mixtures flowing through the flame arresters and on the mechanical strain to which they are subjected.

In the absence of any operational experience, the operating company has to inspect the flame arresters regularly following commission to determine at what intervals maintenance work is necessary. Based on these findings, define the maintenance intervals and document them in the operating guidelines.

Even for ‘clean’ products and normal mechanical strain it is best practice to conduct a first inspection within 3 months of service followed by annual inspections as a minimum.

If there is evidence of explosion, flash back or surrounding fire, the complete flame arrester shall be inspected including all gaskets and sealing elements as well as element matrix. The procedure for doing this is part of the instructions for use.

The service life of, for example, gaskets and diaphragms (if present), is dependent on environmental influences, the substances being processed and mechanical strain. It is recommended to inspect these parts on a regular basis.

8.5 Liquid seal flame arrester

Flammable mixtures may develop in empty filling and draining lines and get ignited through external influences. When the flame arresters are free of liquid, in-line deflagrations or detonations may get directly into the plant component to be protected (tank or container) and destroy it.

Fill liquid product detonation flame arresters with the storage liquid before allowing the plant to enter operational service.

Make sure the flame arresters are always filled with product. This applies also to flame arresters that are taken out of service, provided they contain flammable mixtures.

9 Commissioning checklist

Model: **Serial number:**		**Place of use:**
Inspection after delivery		
	Delivery	Delivered without any in-transit damage
	Operating manual	Operating manual is present
	Declaration of conformity	Declaration of conformity (if required) is present
Inspection prior to installation		
	Operating manual	Operating manual read and followed in full
	Type plate	Details on the type plate and the declaration of conformity (where applicable) match the conditions of use on site
	Plant component switched off	Plant component switched off and under no pressure
	Explosive atmosphere	No explosive atmosphere present
	Protective caps	Protective caps removed from connections
	Desiccants	Bags with desiccants removed (where applicable)
	Nominal size on ignition source side	Nominal size of the pipeline connected on the ignition source side is not greater than that of the flame arrester
	Nominal size on the protected side	Nominal size of the pipeline connected on the protected side is not less than that on the ignition source's side
	Flame arresting elements	Flame arresting elements are undamaged
Inspection prior to commissioning		
	Installation	The flame arrester has been installed in such a way that it is not under any strain
	Limitations of use	The installation has kept within the flame arresters' limitations of use
	Flow	The flow through of media in the inlet and outlet cross-sections can take place unhindered
	Installation orientation	Attention has been paid to the installation orientation in accordance with the limitations of use
	Earth	An earth cable has been connected to each part (e.g. housing, cage etc.) of the flame arrester
	Screws and nuts	Screws and nuts facing each other have been firmly tightened to an equal degree
	External connections	External connections have been connected as stipulated and checked for tightness, any unused openings sealed gas-tight
	Potential equalization	The electrical connection to the flame arrester's earth is in order

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