Why use a flame arrester?

A concise guide

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Elmac Technologies®
Innovative Safety Solutions

Contents

An introduction to Elmac Technologies

Elmac Technologies® are the international technical leaders in flame and explosion prevention systems for some of the world's most challenging industrial environments.

This brief guide provides an introduction to flame arresters, including their construction and how they work.

There are useful notes explaining different flame types and where they occur, as well as the different types of gases and vapours.

In addition, there are also details of current flame arrester standards.

For comprehensive technical advice regarding the selection and use of flame arresters, please contact:

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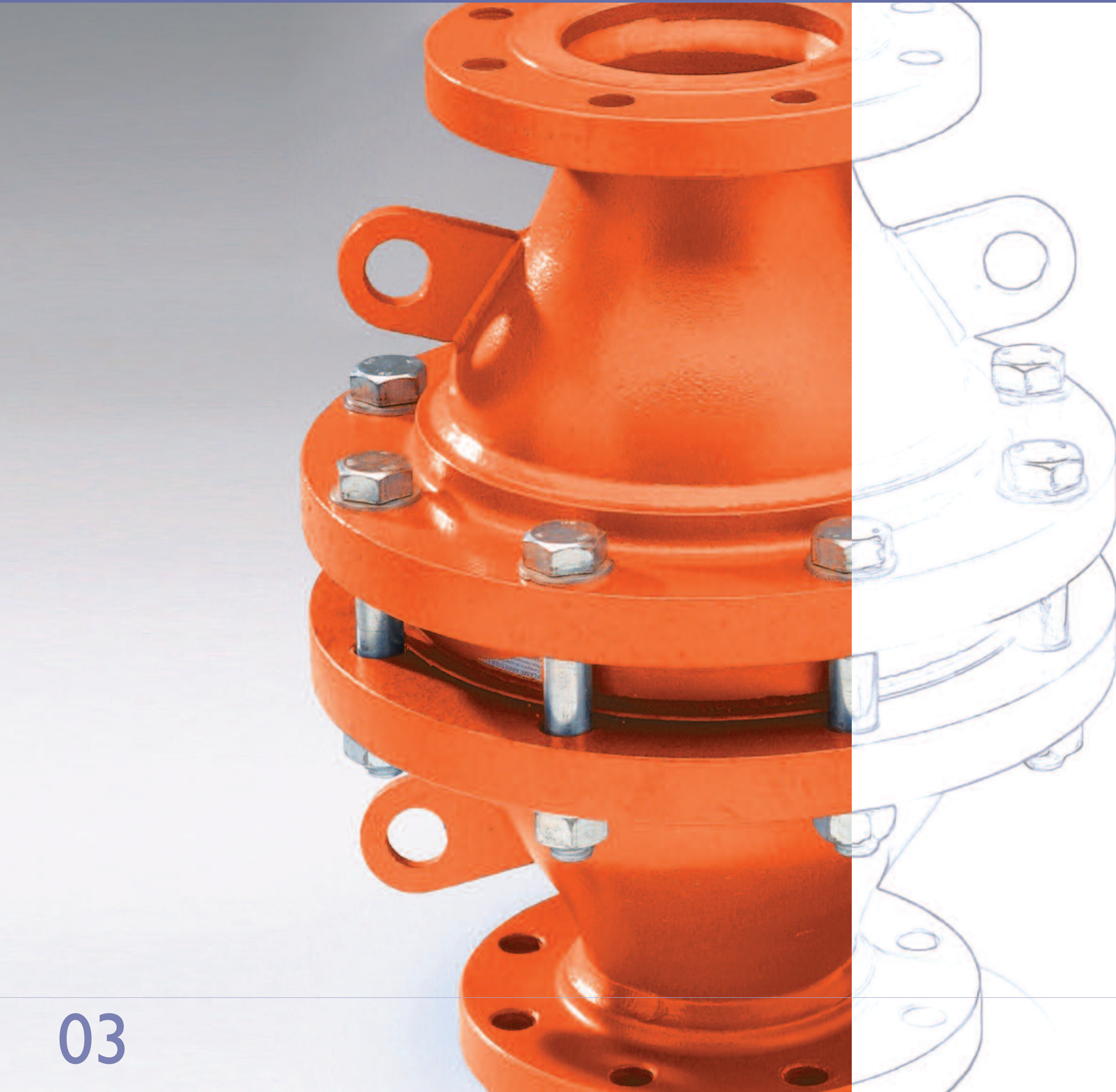
Definition of a flame arrester



A flame arrester is a device fitted to the opening of an enclosure or to the connecting pipe work in a system of enclosures and which permits gases or vapours to flow under normal operating conditions but prevents the transmission of a flame should an ignition take place.

In this guide, consideration is limited to flame arresters for use where the flame burns in air (and not in oxygen where there are special problems). Furthermore, the guide is restricted to passive flame arresting devices with no moving parts.

Why use a flame arrester?

One of the greatest dangers involved with the transport or storage of flammable liquids or gases is that ignition of the flammable vapour may occur, resulting in fire or worse, an explosion. This guide sets out to introduce the subject of flame arresters, and the principles and concepts behind their specification and use. For those seeking a more detailed understanding, full technical advice and support is available from Elmac Technologies®.

Whenever a flammable gas or vapour is mixed with air/oxygen, there is the potential for an explosion. Accidental ignition of the flammable mixture will result in a flame that will travel through the unburnt mixture until the fuel is consumed by the reaction. In an enclosed space, such as a vessel or a pipe, the significant temperature increase of the mixture caused by the combustion process will lead to a rapid increase in the volume of the gas mixture. The resulting increase in pressure will induce turbulent effects which will further accelerate the flame front.

What is a flame arrester?

A flame arrester is a safety device whose principal purpose is to prevent a flame entering or leaving a pipe or vessel or to prevent it travelling further down a pipe. In many cases it is used in conjunction with other components to create a safety system. Failure to stop a flame can result in catastrophic damage to equipment, loss of production, injury to people and even loss of life and potentially large litigation costs.

There are different types of flame arrester, each of which is designed to handle certain conditions. It is essential that the flame arrester is correctly specified to ensure that a flame is extinguished (or properly contained) and that an explosion is prevented from propagating through the equipment.

The first step in specifying a flame arrester is to determine the location of the potential ignition source. Only when this has been established can one start to understand what is to be protected and how.

Determining the location of the possible initial source of ignition is the key to selecting the right flame arrester.

Types of flame

and conditions where they are found

Unconfined Deflagration

An unconfined deflagration occurs when there is an ignition of a flammable atmosphere outside a container or other process equipment. For example, a breathing or ventilation outlet from a tank storing gasoline may produce an unconfined cloud of flammable vapour in its immediate vicinity. Ignition sources such as a lit cigarette, a static electrical discharge or a lightning strike could ignite this vapour cloud and the resulting flame front may enter the tank through the outlet.

Confined Deflagration

Where a flammable mixture in a pipeline is ignited, the flame front will initially travel along the pipe at subsonic velocities in what is known as a confined deflagration. Typically this could occur in industrial or process plant. For example, many coal mines generate flammable and poisonous methane gas below ground which is pumped to the surface along a pipe and then burnt in a boiler for heating purposes. Problems with the boiler or the pumping system could ignite the pipe contents and the flame could travel back down the pipe resulting in an explosion below ground.

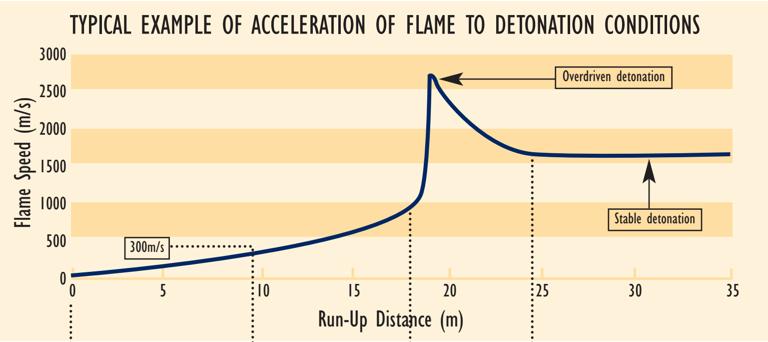
Detonation

A detonation occurs where a flame travels along a pipe, usually at supersonic velocities and is combined with a shock wave. Typically this occurs as a result of turbulence-induced flame acceleration caused by roughness in the pipe walls or interruptions such as bends, valves or changes in section of the pipe. It can also occur simply by allowing the flame to continue to accelerate along a pipe for a sufficient distance. A shock wave is characterised by a step change in pressure and density through which the flame velocity changes from being subsonic to supersonic.

Having determined where the possible source or sources of ignition may occur and exactly what is to be protected, then the objective is to place the flame arrester as close as possible to the ignition source.

Types of flame

and conditions where they are found



Condition	Deflagration	Fast Deflagration	Deflagration to Detonation	Stable Detonation
Arrestor	Deflagration	Detonation		
Location	Arrestor must be located at open end of pipe or, if in-line, within a specified maximum distance from source of ignition	Detonation arrestor can be located at any location in pipe		

Figure 1

Typical Flame Acceleration in a pipe

The chart illustrates what typically happens to a flame front when allowed to burn unhindered down a straight pipe section with a diameter in the order of 200 mm filled with a hydrocarbon gas at ambient pressure and temperature.

It can be seen from Figure 1 that the flame begins as a slow deflagration (flame speed < 300 m/s), but accelerates into a fast deflagration (still at subsonic velocities ~ 500 m/s). It is recommended that a deflagration arrester is fitted for situations in which the ignition source is within 50 pipe diameters of the arrester for hydrocarbon gases (within 30 pipe diameters for hydrogen), although this distance is reduced for systems at pressures above atmospheric.

The flame then undergoes a rapid and sudden transition from deflagration to detonation. Under these conditions, the flame may accelerate to a velocity an order of magnitude higher than the initial slow deflagration (~ 2500 m/s). This represents the worst case conditions for the flame front and the associated pressure wave and is known as an overdriven detonation, or an unstable detonation. In such circumstances, a suitably designed unstable detonation arrester must be fitted.

An unstable detonation will degrade to a less severe stable detonation as the flame proceeds further down the pipe. However, such flame fronts may suddenly undergo further transitions to unstable conditions. These events are unpredictable, and are caused by anything that may increase the turbulence of the system, including roughness in the inside surface of the pipe, or a protruding gasket or instrument port as well as bends or constrictions due to valves. Because of this unpredictability, most flame arrester manufacturers recommend that an unstable detonation arrester is fitted in the pipe. A few manufacturers will take the risk of fitting a stable detonation arrester under such circumstances, but this is not recommended by Elmac Technologies®.

Types of gases and vapours

Gases and vapours vary in their flammability and explosivity. The relative severity of an explosion from a particular component mixed with air is indicated by a variety of characteristics of the gas including the lower and upper explosive limits (LEL/UEL), the auto ignition temperature (AIT), the minimum ignition energy (MIE), the limiting oxygen concentration (LOC) and the maximum experimental safe gap (MESG).

For ease of assessment, pure gases have been classified into groups of similar reactivity. Various groupings exist, depending on the source of the information but the two most widely used are shown below in tables 1 and 2. In these tables, the gas group is indicated by a range of MESG values and a typical test gas is identified for the purpose of type testing a flame arrester.

If a flame arrester is satisfactorily flame tested for a given gas group then it is suitable for use with any other gas in the same group or a lower group. For example in practice propane is normally used for testing the lowest level of flame arrester and success here means that it may be used for any Group IIA gas as well as for Group I or methane. Other standards also group gases in a similar but not identical manner.

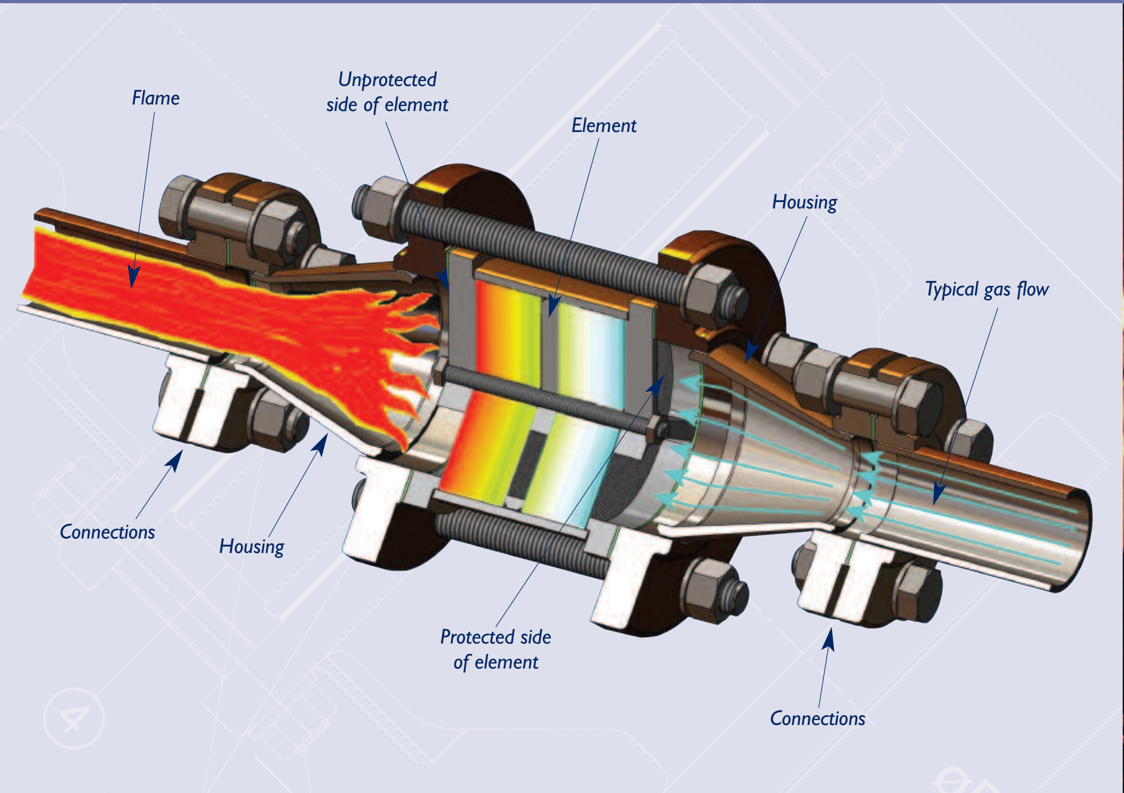
Gas Group	MESG (mm)	Test Gas	Test Gas Concentration (% $^{v}/_{v}$ in air)	Typical Gases
IIA	>0.90	Propane	4.2	Methane, alkanes, alcohols, acetone, benzene
IIB3	≥0.65	Ethylene	6.5	Ethylene, ethylene ether
IIB	≥0.50	Hydrogen	45.0	Ethylene oxide, Butadiene
IIC	<0.50	Hydrogen	28.5	Hydrogen

Table 1 – European Standard Gas Groups

Gas Group	MESG (mm)	Typical Gases
D	>0.75	Methane, alkanes, alcohols, acetone, benzene
C	>0.45	Ethylene, ethylene oxide
B	≤0.45	Hydrogen
A	–	Acetylene

Table 2 – US Equivalent Gas Groups

Construction of a flame arrester



Typically a flame arrester comprises a housing, an element and connection(s) to secure it to pipe work or equipment. The element is the device that quenches the flame and the majority of constructions used incorporate a form of "filter" that provides small apertures through which the process gas will flow but will prevent flame transmission. The flame front is broken down in the "filter" into smaller flamelets which are cooled by the large heat capacity of the element thus extinguishing the flame. Materials used for the "filter" element include crimped metal ribbons, woven wire gauze, sintered materials and honey comb materials. Because of its construction, the element will cause a pressure drop or an obstruction to process flow. In order to mitigate this increased resistance to flow, the element area is usually larger than the cross sectional area of the pipe work. Larger elements also have a greater heat capacity.

The housing of the flame arrester can be integral to or separate from the element housing. In the latter case it is joined together with fastenings. The end connections are usually either flanged or screwed fittings to match the adjacent pipe work.

Other types of flame arrester include devices which incorporate a small aperture that ensures the velocity of the gas being emitted exceeds the burning velocity of that gas and thus will not transmit the flame. Alternatively, the gas may be bubbled through a liquid or water in a manner that provides a liquid barrier to flame transmission.

Regular inspection and maintenance of flame arresters is essential. If a flashback is known or believed to have occurred then the arrester should be inspected for damage.

The heart of a flame arrester is its element. Typically this incorporates a "filter" that permits the process gas flow but prevents flame transmission. The flame front is broken down into smaller flamelets and cooled until it extinguishes itself.

Types of flame arrester

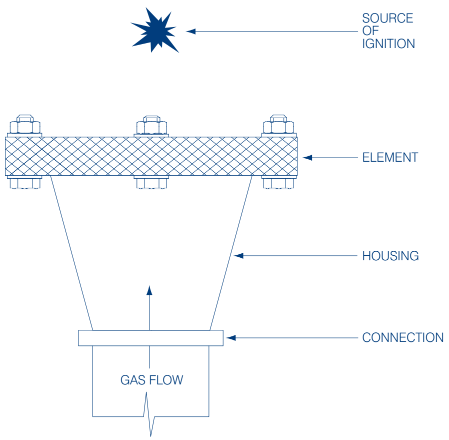
This section should be read in conjunction with the attached sketches showing the principles rather than all the constructional details of different types of flame arrester.

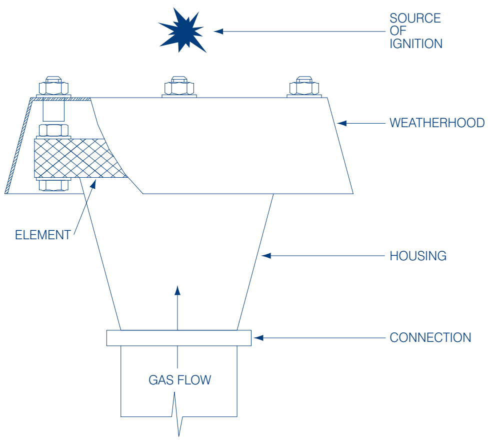
End-of-line flame arresters

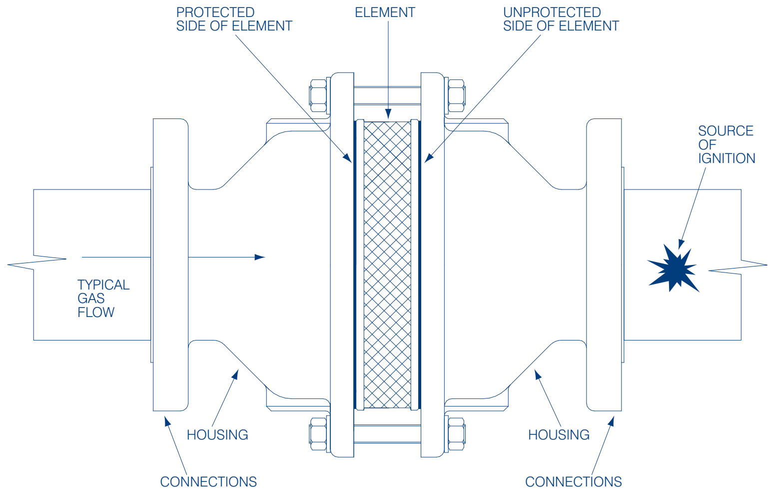
End-of-line (EOL) flame arresters are fitted to the end of a pipe line or exit to a vessel to prevent flames from entering, and not, as is sometimes believed, to prevent the flame exiting the pipe or vessel. Without a weather-hood, they may be mounted in almost any orientation, but inverted mounting is not recommended as this increases the risk of heat being trapped thus causing a flash back. With a weather-hood incorporated, they should be fitted in a conventional vertical orientation and be used outside exposed to rain and snow.

In-line flame arresters

In-line flame arresters are fitted in piping systems to protect downstream equipment. The layout shown below is typical although it is also possible that the source of ignition could cause the flame to travel with the gas flow. If the flame could come from either direction then a bi-directional flame arrester is required. In-line flame arresters can be either deflagration or detonation arresters depending on the conditions under which they are to be used. Pipe orientation is usually not a problem unless liquid is entrained in the gas flow and would tend to collect in the arrester. In such situations, an eccentric flame arrester housing may be fitted to allow collection and drainage of the liquid.



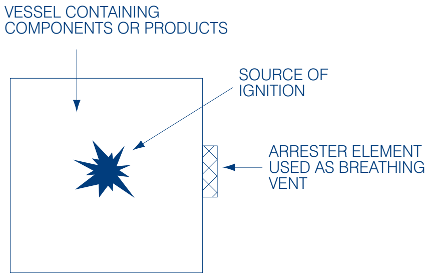


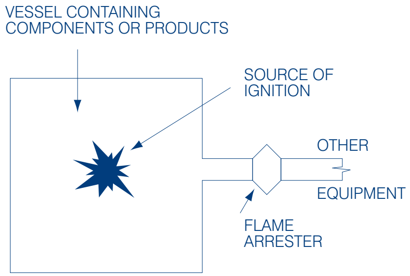


End-of-line flame arresters prevent flame from entering a vessel.

Pre-volume flame arresters

These are so called because they are designed to protect systems in which a flame may start within a container whose cross sectional area is somewhat larger than the flame arrester element or the vent pipe and the desire is to prevent the flame leaving the container. They may be simply an element, an end-of-line arrester or an in-line arrester. Extreme care must be taken when considering such a situation as it is not possible to predict the conditions that the flame arrester will have to handle because the volume of hot gases passing through the arrester will exceed the volumes produced for conventional in-line arrester flame testing. Although the conditions will tend to produce a confined deflagration it is possible that an arrester that has been satisfactorily tested under confined deflagration arrester conditions laid down in a product standard will not be satisfactory. Therefore, the only solution to ensure total confidence in the product specified is to test it under actual or simulated operational conditions.





Dirt in the gas stream will collect on the element causing obstruction and increased pressure drop. Regular inspection and cleaning are strongly advised.

Liquid product and hydraulic flame arresters

Liquid product flame arresters trap some of the liquid flowing in a pipe so that the gases may bubble through it but any flame is extinguished. Hydraulic arresters contain water whose level is automatically maintained. Similarly gases may bubble through it but any flame would be extinguished. This technique is particularly suited to a dirty gas flow with particulate matter entrained within it.

Flame arresters in use

For the majority of the time that a flame arrester is in place it will be required to permit the process gas to flow and will be expected to extinguish flames on extremely rare occasions. A key characteristic of a flame arrester is the pressure drop or degree of obstruction to process flow due to its method of construction. This can lead to problems and it is essential that the design and sizing of the flame arrester are matched to the process flow rates and pressure drop permitted in the system whilst ensuring that adequate protection is provided against accidental ignition.

Additional protection through the use of detection and cut off systems may be requried.

Having defined where the possible source or sources of ignition may occur and exactly what is to be protected, then the objective is to place the flame arrester as close as possible to the ignition source. If a flame is allowed to proceed down a pipe then, in general, it will accelerate because of pressure build up resulting from the increased temperature and volume of burnt products and be progressively more difficult to stop. Ultimately a deflagration may undergo transition to a detonation and therefore become significantly more destructive to equipment. Where there is more than one source of ignition then it may be appropriate to install more than one flame arrester.

If the flammable mixture continues to flow after flame transmission has been prevented the flame may stabilise on or near the element and continue to burn. This will cause the element to continue to heat up and can lead to flame transmission. Specially developed and tested products are required for such eventualities and often a flame sensor is linked to a gas supply cut off system to extinguish the flame soon after detection.

Flame arresters are usually designed for use at ambient temperature and pressure. Please consult Elmac's experienced and trained engineers for advice if other conditions are encountered. Beware of cold conditions where the element, particularly in an end of line unit, may freeze over and block. Higher temperatures and pressures put increased load on the flame arrester and testing under actual or simulated conditions may be required.

If corrosive or dangerous substances are present the flame arrester may be constructed using special materials. In the majority of cases a stainless steel element together with a carbon or stainless steel housing would be adequate.

Regular inspection and maintenance of flame arresters is essential. If a flashback is known or believed to have occurred then the arrester should be inspected for damage. The small cells or components of the element are prone to collect dirt and become blocked thus increasing the pressure drop. Damaged or dirty elements should be replaced. Often it is possible to clean the element for re-use. Correctly treated, a flame arrester can give many years of service.

Legal framework for flame arresters

It is recommended that products comply with the relevant standards so that insurance cover is not compromised.

A set of European directives relating to installations in flammable and explosive atmospheres have been implemented under the general umbrella of ATEX. These directives describe the essential health and safety requirements that should be followed in industry to ensure safe, incident free operations.

There are two directives that relate directly to flame arresters. EU ATEX directive 94/9/EC requires that products sold for use in potentially explosive atmospheres within Europe since July 2003 must comply with certain standards of performance. In the case of flame arresters, this includes the type testing of designs to EN 12874:2001 (the European standard for the design and testing of flame arresters) as well as the compliance auditing and qualification of the design and manufacturing process to ensure reliability and reproducibility of the products made.

A new international standard on flame arresters was published in 2008 (ISO 16852:2008) and it is expected that this will be mandated as the European standard, replacing EN 12874:2001. Whilst this standard will not be mandatory worldwide, it is hoped that its existence will obviate the need for the many national and regional standards that currently exist. Some of the more notable alternative standards around the world include the US Coast Guard standard as well as others produced by the Underwriters Laboratories (UL) and Factory Mutual (FM).

Furthermore, since July 2006, there has been an onus on operators of plant/equipment in explosive atmospheres to ensure that their workplaces comply with the minimum requirements of EU ATEX directive 99/92/EC. This introduces the concept of zoning of the workplace according to the risk of explosion in each zone, and requires the operator to conduct a thorough risk assessment of the operation. It also places a responsibility to ensure that all new equipment is ATEX compliant.

Under certain circumstances, flame arresters that are fitted in-line may also be considered as pressurised equipment and must therefore satisfy the minimum requirements of the Pressure Equipment Directive (PED) 97/23/EC which was adopted in Europe in 1997 and became obligatory from the end of May 2002. Under this directive, any equipment sold above specified pressure and/or volume thresholds must be safe, meet essential safety requirements covering the design, manufacture and testing of the product and carry the CE mark indicating that it satisfies the appropriate conformity assessment procedures.