



Flame Arrester Selection Criteria

Initial Operating Pressure (IOP) vs. Normal Operating Pressure

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Purpose

This document explains the difference between the normal operating pressure of a vapor control, flare header, or process piping system and the Initial Operating Pressure (IOP) used for flame arrester selection. The distinction is important because normal operating pressure is primarily a mechanical pressure-rating consideration, whereas IOP is the flame-arrester performance condition that determines whether the arrester has been tested and rated to stop flame propagation under the applicable gas mixture and pressure.

Definitions

Normal Operating Pressure

The normal operating pressure of a system is the pressure present while the system is running under its intended operating conditions. In a properly operating vapor control system, flare header, or process piping system, the flowing vapor stream normally remains above the burn-back velocity of the process gas. Under this condition, the system pressure may be low, moderate, or high depending on the process design.

For purposes of selecting a flame arrester, normal operating pressure is mainly used to confirm the mechanical pressure rating of the arrester body, flanges, bolting, gaskets, and related pressure-retaining parts. In other words, the selected flame arrester must have a design pressure/MAWP and flange rating suitable for the system operating pressure and any required code or purchaser pressure-rating requirements.

A high normal operating pressure by itself does not automatically define the flame-arrester quenching challenge. The flame-arrester element challenge is controlled by the pressure of the flammable mixture when ignition, flashback, or flame propagation can occur. That pressure condition is the IOP.

Initial Operating Pressure (IOP)

The Initial Operating Pressure (IOP) is the absolute pressure of the flammable gas mixture in the piping system when the flow velocity falls below the burn-back velocity, also referred to as the critical velocity. The IOP is the pressure condition at which a flame can begin to propagate upstream through the gas mixture.

The IOP is often lower than the normal operating pressure of the system. For example, when a vapor control system is operating properly, the flow stream velocity exceeds the burn-back velocity, and the system pressure is within its normal operating range. During a normal shutdown, an emergency shutdown, a blocked-flow event, or another low-flow/static condition, the flow velocity may decrease. As the process stream slows down, the pressure may also fall. At some point before the velocity reaches zero, the system can pass through a flashback-capable condition. The pressure in that shutdown or low-flow condition is the IOP for that system.



Key Distinction

Normal Operating Pressure	Initial Operating Pressure (IOP)
Describes how the system normally operates during routine service.	Describes the pressure of the flammable mixture when flame propagation or flashback can occur.
Used to confirm the mechanical pressure rating, design pressure/MAWP, flange class, bolting, and pressure boundary suitability of the arrester.	Used to confirm the flame-arrester performance rating and whether the arrester was tested to stop a flame at that pressure and gas group.
Can be much higher than the IOP in some operating systems, especially systems that depressurize during shutdown or flow decay.	Can be lower than normal operating pressure, but it is the critical value for flame acceleration, flame pressure, heat release, and quenching duty.

Flare Stack / Flare Header Example

For example, a flare header or vapor control line may have a normal operating pressure of 50 psig. The flame arrester body and flanges must therefore be mechanically suitable for that pressure, including any required design margin, pressure code requirement, flange rating, gasket rating, and purchaser specification.

However, the 50 psig normal operating pressure is not automatically the pressure at which the arrester element must quench a flame. If the system depressurizes during shutdown, purge loss, emergency shutdown, or low-flow operation, the gas velocity may drop below the burn-back velocity at a much lower pressure. If the flashback-capable condition occurs at 2 psig, then the relevant IOP for flame-stopping performance is approximately 16.7 psia absolute, not the 50 psig normal operating pressure.

Therefore, when normal operating pressure is used in flame arrester selection, the design concern is mechanical: the device must be pressure-rated for the system's operating pressure. The flame-arrester element performance concern is separate and must be evaluated using the applicable IOP, gas group, pipe configuration, distance from ignition source, and tested arrester rating.

Why IOP Controls Flame Arrester Performance

Pressure directly affects flame behavior. As the initial absolute pressure of a flammable gas mixture increases, the energy released per unit volume also increases. The resulting flame is more intense, transfers more energy to the flame arrester element, and can accelerate more rapidly through the pipe.

The explosive pressure of a given gas mixture is approximately proportional to the initial absolute pressure. For example, in a stoichiometric propane-air mixture at atmospheric pressure of approximately 14.7 psia, after a flame has propagated about 33 ft in a pipe, the flame velocity may be approximately 656 ft/s and the pressure front may be approximately 116 psia. If the IOP is increased to approximately 21.8 psia, the flame velocity and pressure at the same distance may increase to approximately 984 ft/s and 174 psia. In this example, increasing the initial absolute pressure by about 50% increases the flame-front velocity and pressure by about 50%.

This increase can affect both flame arrester placement and flame arrester selection. A higher IOP can require the arrester to be installed closer to the potential ignition source, or it may require a different arrester design with a higher tested IOP rating.



Heat Absorption and Quenching Requirement

A flame arrester stops flame propagation by absorbing heat from the flame and reducing the flame temperature below the point at which combustion can continue through the arrester element. When the IOP is higher, more energy is released per unit volume of gas. The arrester must therefore absorb more heat in a shorter period of time to quench the flame.

Every arrester element has a finite heat-transfer capacity based on its element geometry, material, thickness, surface area, and tested design limits. If an arrester is installed in a system where the actual IOP exceeds the pressure for which the arrester was tested or designed, the arrester may not absorb sufficient heat to stop the flame. The result can be flame transmission through the arrester.

Manufacturer Rating Requirement

For proper selection and system design, the manufacturer should state the maximum allowable IOP for each flame arrester model and applicable gas group or gas mixture. Flame arresters should be tested at increasing pressure levels to establish the IOP performance threshold for commonly encountered flammable mixtures.

As a general guideline, a standard low-pressure deflagration arrester may have a maximum allowed IOP of approximately 5% above atmospheric pressure, or 15.4 psia. Detonation flame arresters may have higher allowable IOP ratings depending on design and gas group. For example, certain Group D detonation arrester designs may be rated up to approximately 22.7 psia, while certain Group C designs may be rated up to approximately 20.7 psia. These values are performance ratings and must not be confused with the mechanical design pressure or flange pressure rating of the arrester body.

Summary

Normal operating pressure and Initial Operating Pressure are not interchangeable. Normal operating pressure identifies the expected pressure range while the system is functioning as intended. For flame arrester selection, normal operating pressure is used to confirm that the arrester body, flanges, and pressure-retaining components are mechanically suitable for the system pressure.

IOP identifies the absolute pressure of the flammable mixture at the low-flow, shutdown, static, or other flashback-capable condition where flame propagation can occur. IOP is the pressure value that controls flame acceleration, flame pressure, flame intensity, heat release per unit volume, and the ability of the arrester element to quench the flame.

In practical terms, normal operating pressure verifies the mechanical pressure rating of the device; IOP defines the flame-arrester performance challenge condition.