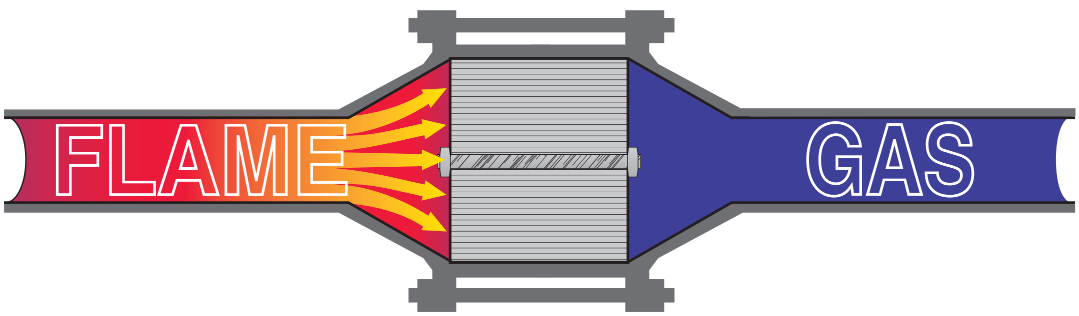
Training Module

Describe Flame Arrestor Operation and Maintenance



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- Training Module and Self-Check
- Blank Answer Sheet
- Knowledge Check and Answer Key

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Training Objectives

Upon completion of this training kit, you will be able to:

- Describe the purpose and importance of flame arrestors
- Describe flame propagation concepts
- Describe the principle of operation of flame arrestors
- Describe types of flame arrestors (end-of-line, in-line)
- Describe selection considerations for flame arrestors
- Describe procedures for installing, inspecting, and cleaning fire box flame arrestors
- Describe procedures for installing, inspecting, and cleaning in-line flame arrestors

NOTE

Refer to the glossary, located at the end of this module, for an explanation of terms.

1 Introduction

Industrial facilities are designed to be safe and to minimize the risk of fire or explosion. Many strategies are used to minimize the risk of fire or explosion: primary safety devices, such as isolation valves, hydraulic seals, oxygen analyzers, and gas analyzers provide the first line of defense. Flame arrestors provide backup protection in case primary safety devices fail. Flame arrestors can prevent a fire or explosion from propagating to other equipment inside or outside of a system.

Figure 1—
Flame Arrestors

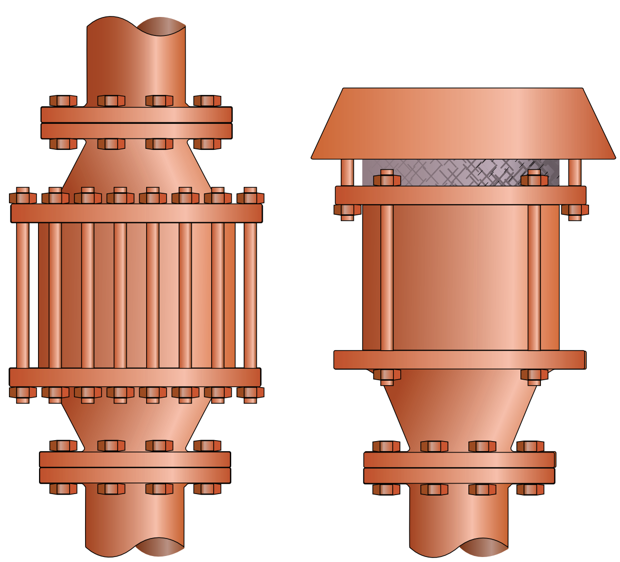
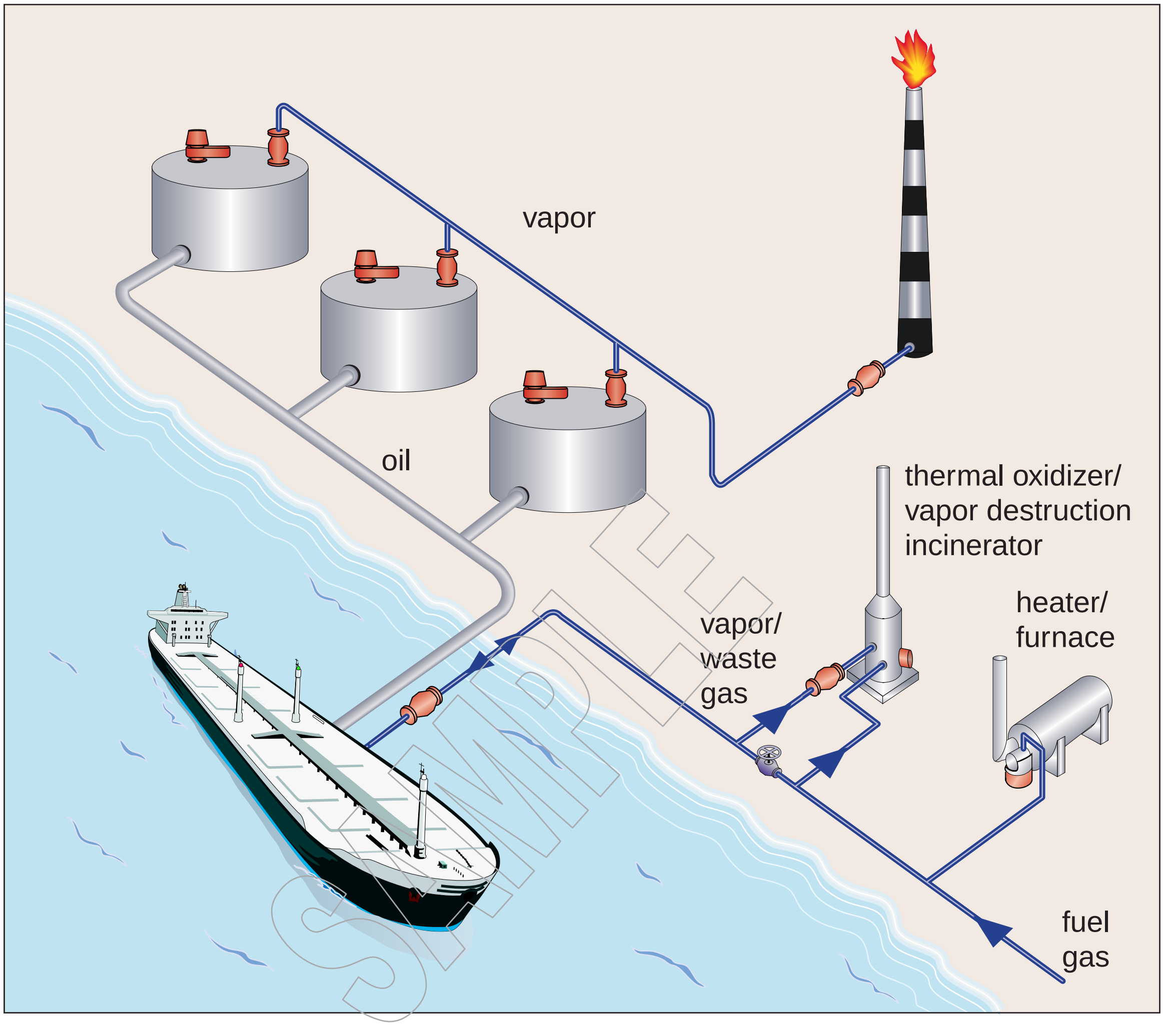
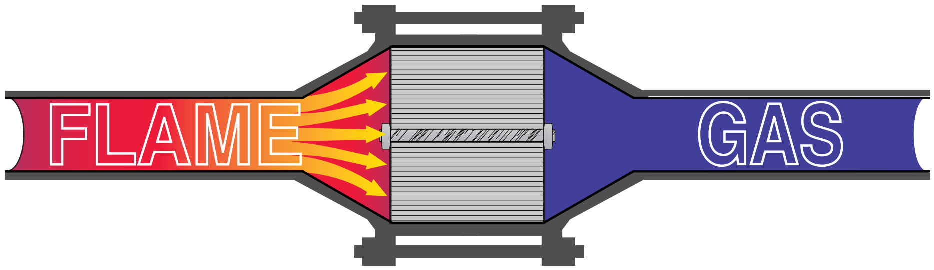


Figure 2—Flame Arrestor Applications



Flame arrestors are fire safety devices which allow air or flammable gases to pass, but prevent the propagation of flames through the device. Flame arrestors are passive safety devices; they have no moving parts and do not require a source of energy to function.

Figure 3— Flame Arrestor Concept



Industries using flame arrestors include oil and gas processing and refining, pharmaceutical, pulp and paper, waste and sewage treatment, mining, and marine transportation. Within these industries, arrestors are often used on air intakes on fired heaters, incinerators, and boilers; fuel inlet piping to fire boxes; flare systems; tank vents; and vapor recovery lines.

This training module describes how flame arrestors work, types of flame arrestors, and factors to consider when selecting, installing, and maintaining flame arrestors. The last two sections of this module describe specific types of flame arrestors: end-of-line flame arrestors and in-line flame arrestors. For each type, the module describes the conditions that reduce flame arrestor effectiveness, some considerations for correct installation, and how to inspect and service the arrestors to ensure effective operation.

2 Flame Propagation Concepts

Combustion is defined as the process of burning. Chemically, combustion is the process of oxidization in which an oxidizing agent, often oxygen, rapidly combines with a fuel, giving off heat and usually light. The behavior of a flame front (the leading surface of a flame) formed by combustion is dependent on a large number of variables including:

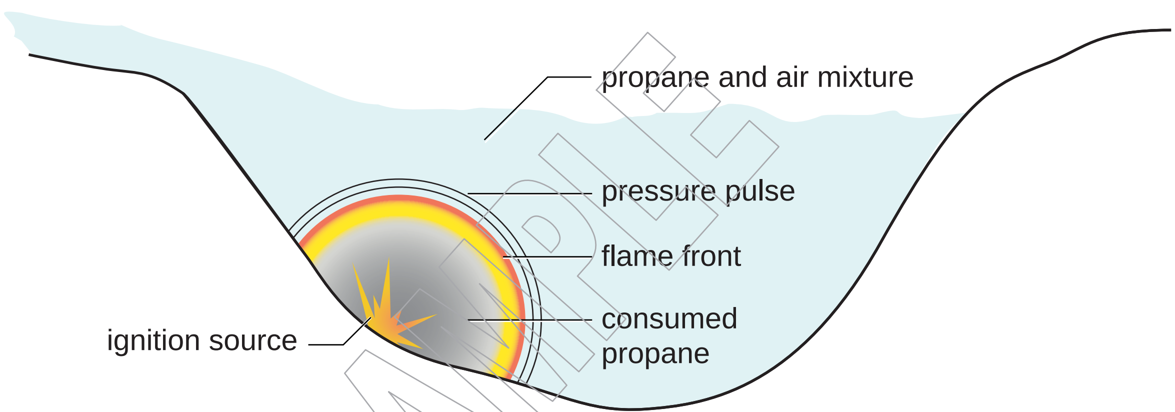
- rate of chemical reaction (type of fuel)
- fuel-air mixture
- pressure
- temperature of the fuel
- turbulence

The flame front's behavior is also very different in an unconfined space (i.e., the atmosphere) than in the confined space of a pipe or vessel.

2.1 Flame Propagation in an Unconfined Space

Consider a release of propane to the atmosphere. Propane, being heavier than air, migrates and collects in low-lying areas such as trenches and valleys. If the concentration of the propane increases to above 2.1% by volume (its lower explosive limit) and if there is a source of heat, the propane will ignite.

Figure 4—Unconfined Flame Propagation



Upon ignition, the flame moves outward (propagates) toward the unburned gas. The expanding flame front forms a narrow layer between the unburned gas and the consumed gas. A pressure pulse forms in front of the flame. Both chemical and mechanical energy contribute to forming the pressure pulse:

- **Chemical energy**—the heat from the flame elevates the temperature and pressure of the gas in front of the flame
- **Mechanical energy**—the consumed gas expands outward because its temperature and pressure have increased

The pressure pulse dissipates as the flame expands in the unconfined space. Usually the velocity of the flame front in an unconfined space is subsonic (less than the speed of sound). A flame traveling at subsonic velocity is called deflagration. Deflagration is a chemical reaction in which there is a vigorous release of heat accompanied by flames and sometimes sparks.

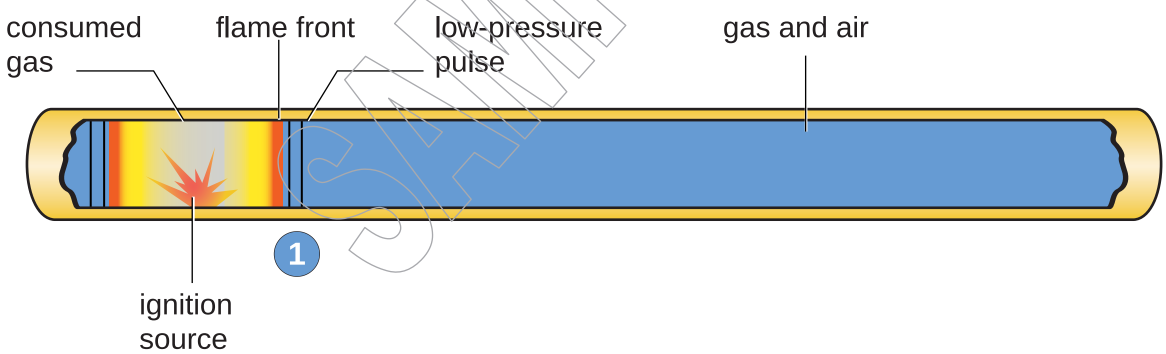
2.2 Flame Propagation in a Confined Space

Flame propagation in a confined space behaves very differently than in an unconfined space. In a confined space, the heat and pressure generated from the flame remains confined. The temperature and pressure of the pressure pulse in front of the flame increases, causing an increased rate of the chemical reaction and acceleration of the flame front.

Flame propagation behavior in a confined space is complex and not fully understood. To introduce basic flame propagation concepts associated with flame arrestors, a simplified explanation follows.

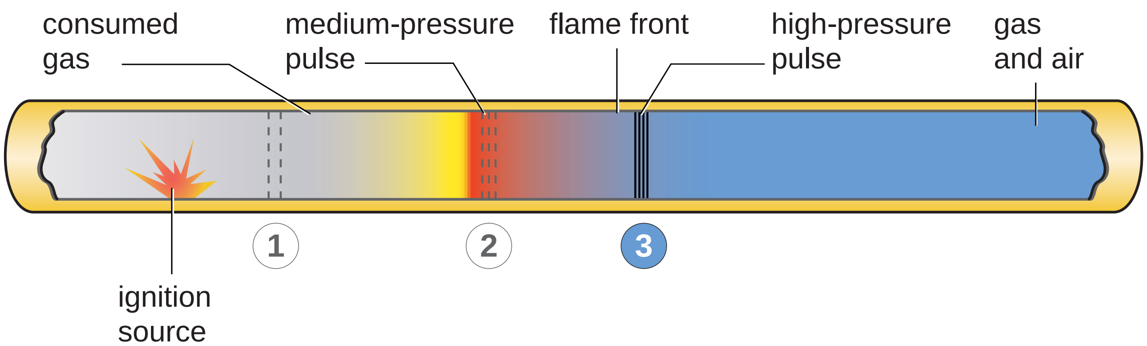
To understand the sequence of events that occurs when a flame propagates in a confined space, consider a combustible fuel mixture in a long pipe. In the following illustrations, each event is identified by a number in a circle.

Figure 5—Confined Flame Propagation: Low-Speed/Low-Pressure Deflagration



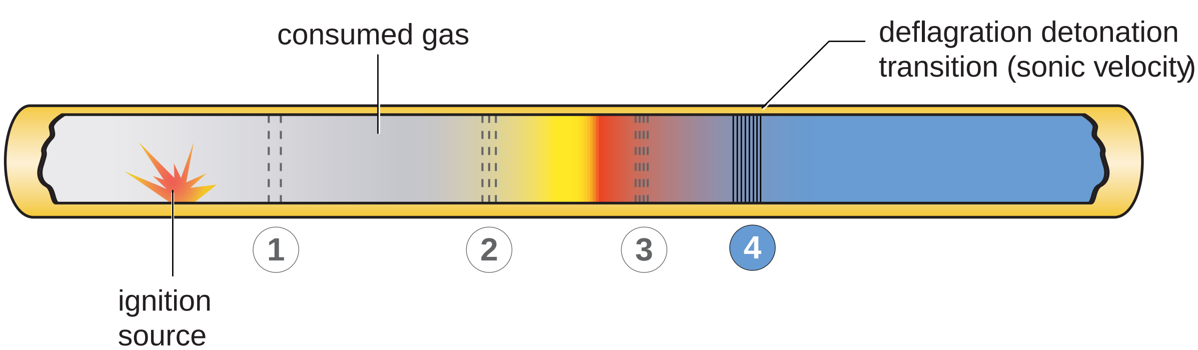
① If the fuel is ignited, the flame travels in opposite directions. A pressure pulse forms in front of the flame because of the heat from the flame and the expansion of the consumed gas. Close to the source of ignition, the flame condition is a low-speed/low-pressure deflagration as indicated by ① in figure 5.

Figure 6—Confined Flame Propagation: Accelerating Flame Front



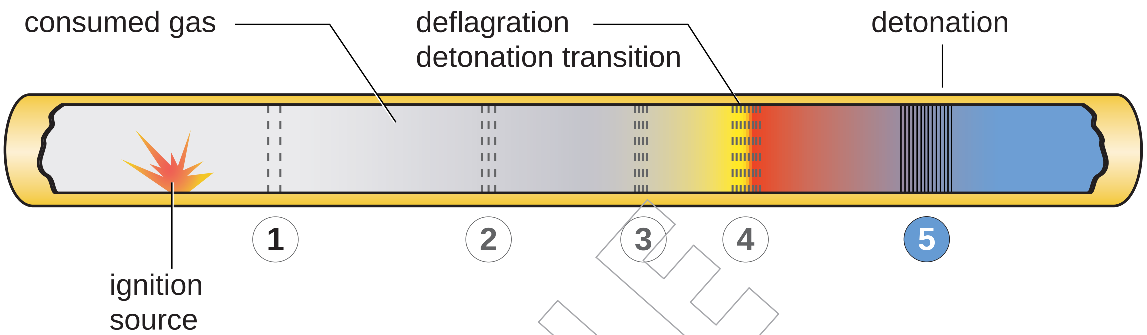
②③ In a confined space, the inability of the energy to dissipate intensifies the flame—more energy is being released per unit volume due to the increased pressure (compression) of the pressure pulse. The elevated pressure and temperature of the pressure pulse cause the rate of chemical reaction to increase. The increased rate of chemical reaction, in turn, causes an increase in pressure and temperature of the pressure pulse in front of the flame. This process results in the flame front accelerating along the pipe. As the flame front continues to travel along the pipe, the temperature and pressure of the pressure pulse continue to increase—low-speed/low-pressure deflagration evolves to medium-speed/medium-pressure deflagration ② and then to high-speed/high-pressure deflagration ③.

Figure 7—Confined Flame Propagation: Reaching Sonic Velocity



④ When the flame reaches sonic velocity, the flame comes in contact with the pressure pulse. The energy of combustion causes a shockwave of highly compressed gas to travel at supersonic speed along the pipe. This stage of flame propagation is considered the point of transition from deflagration to detonation (DDT) ④.

Figure 8—Confined Flame Propagation: Detonation



⑤ As the shockwave travels along the pipe it usually detonates continuously. A detonation is defined as a flame front traveling at supersonic velocity.

Detonations are self-igniting. The high compression of the shockwave heats the gas above the ignition temperature of the gas. Detonations are violent because the shockwave contains a large mass of compressed gas that ignites all at once, releasing a large amount of energy.

The detonation will continue to travel along the pipe as long as the conditions in the pipe remain the same ⑤.

The distance at which the various stages of deflagration and detonation occur depends on a variety of factors, including the type of fuel or mixture of fuels that is in the confined space. For a specific fuel and set of conditions, the distance that each event occurs from the point of ignition depends on the diameter of the pipe—the larger the pipe diameter, the longer the distance from the point of ignition for each event to occur. For example, in a 150 mm (6 in.) pipe, a propane and air mixture at atmospheric pressure and 20°C (68°F) will detonate at a location in the pipe between 10 and 15 m (33 and 50 ft) from the point of ignition. The distance from the source of ignition at which the detonation would occur would double if the pipe diameter doubled to 300 mm (12 in.).

3 Principles of Flame Arrestor Operation

For combustion to occur and be sustained, three elements must be present: oxygen, fuel, and a source of ignition (a source of high temperature).

If any one of the three elements is missing, combustion cannot take place. Flame arrestors eliminate heat, one of the three elements. All flame arrestors function by dispersing and cooling the flame front to a temperature below the ignition temperature of the flammable gas in the system.

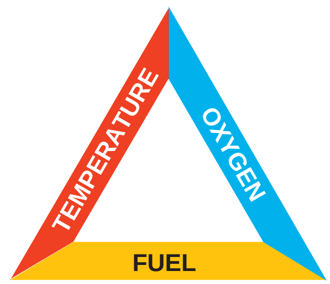


Figure 9—Fire Triangle

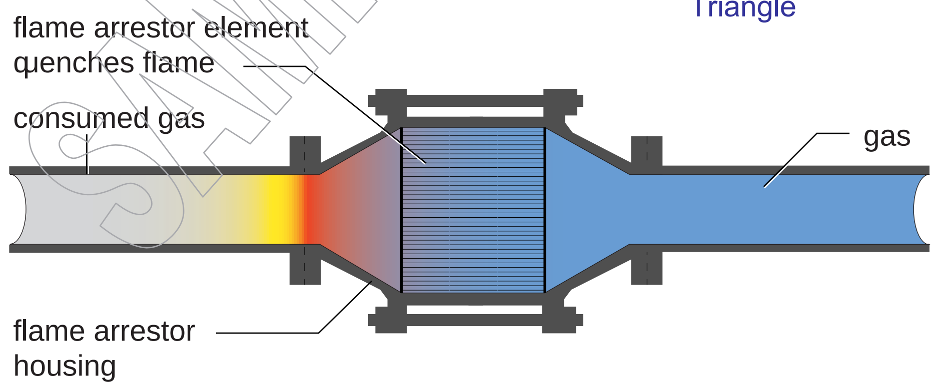


Figure 10—Flame Arrestor Operation

To effectively quench the flames, arrestors must rapidly transfer the heat from the flame to the arrestor and sustain the heat transfer over a long period of time (e.g., two hours). Arrestors accomplish these goals in three ways:

1) **Heat conducting material**—The arrestor element which absorbs the heat is made of a material, such as metal or metal-ceramic media that readily conducts heat.

2) **Large surface area**—The element exposes the flame to a large heat-conducting surface area so that a large quantity of the heat is rapidly transferred from the flame to the element. A large surface area is achieved by using spiral-wound crimped ribbon or metal-ceramic beads to form flame cells.

End of Sample

A full licensed copy of this kit includes:
• Training Module and Self-Check
• Knowledge Check and Answer Key
• Blank Answer Sheet