# Flame Arresters for Vents of Tanks Storing Petroleum Products

API RECOMMENDED PRACTICE 2210
THIRD EDITION, MAY 2000

REAFFIRMED, MARCH 2015

AMERICAN PETROLEUM INSTITUTE

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**Downstream Segment**

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# Flame Arresters for Vents of Tanks Storing Petroleum Products

## 1 Introduction

**1.1** In addition to connections for liquid entry and withdrawal, every atmospheric fixed-roof tank requires a vent that allows escape or entry of air and/or vapors to avoid development of pressure or vacuum conditions sufficient to damage the tank during liquid transfer or changes in ambient conditions. This publication discusses the benefits and detriments associated with the use of flame arresters on these vents.

**1.1.1** The provisions of this publication are intended for use when designing new facilities or when considering major expansions. It is not intended that the recommendations in this publication be applied retroactively to existing facilities. This publication also can be used as guidance when there is a need or desire to review existing facilities.

**1.2** NFPA 30, *Flammable and Combustible Liquids Code,* lists requirements for tank vents in which flammable and combustible liquids are stored. API Standard 2000, *Venting Atmospheric and Low-Pressure Storage Tanks,* and NFPA 30 cover the size and venting capacity to accommodate normal and emergency conditions of the tanks. Devices that are normally closed, except when operating under pressure or vacuum conditions, are often called pressure-vacuum valves. Such valves are normally required for flammable liquids (see NFPA 30). Additional information on vents and pressure-vacuum valves can be found in API Standard 620, *Design and Construction of Large, Welded Low-Pressure Storage Tanks,* and API Standard 650, *Welded Steel Tanks for Oil Storage*. Under certain circumstances, flame arresters listed by the Underwriters' Laboratories or approved by the Factory Mutual Engineering and Research Corporation are used in conjunction with, or in lieu of, a pressure-vacuum valve. The publications cited are considered standards for good practice, and may be incorporated in mandatory codes or ordinances in some jurisdictions.

**1.3** The most recent edition or revision of each of the following standards, codes, and publications are referenced in this Publication as useful sources of additional information supplementary to the text. Additional information may be available from the cited Internet World Wide Web sites.

| | |
|---|---|
| API | *www.api.org* |
| Std 620 | *Design and Construction of Large, Welded Low-Pressure Storage Tanks* |
| Std 650 | *Welded Steel Tanks for Oil Storage* |
| Std 2000 | *Venting Atmospheric and Low-Pressure Storage Tanks* |
| Publ 2028 | *Flame Arresters in Piping Systems* |
| RP12N | *Recommended Practice for the Operation, Maintenance and Testing of Firebox Flame Arresters* |
| AIChE[1] (CCPS) | *www.aiche.org/docs/ccps* |
| | *Guidelines for Engineering Design for Process Safety* |
| FM[2] | *www.factorymutual.com* |
| *Approval Guide* | *—A Guide to Equipment, Materials & Services Approved by Factory Mutual Research Corporation for Property Conservation* |
| *Class 6061* | *Flame Arresters for Vent Pipes of Storage Tanks* |
| NFPA[3] | *www.nfpa.org* |
| 30 | *Flammable & Combustible Liquids Code* |
| 69 | *Standard on Explosion Prevention Systems* |
| OSHA[4] | *www.osha.gov* |
| 1910.106 | *Subpart H—Hazardous Materials* |
| UL[5] | *www.ul.com* |
| | *Gas and Oil Equipment Directory* |
| 525 | *Flame Arresters* |

## 2 Scope

**2.1** This publication covers flame arresters on vents for above-ground steel petroleum tanks operating essentially at atmospheric pressure as defined in API Standard 650, *Welded Steel Tanks for Oil Storage.*

[1]American Institute of Chemical Engineers, Center for Chemical Process Safety, 345 East 47th Street, New York, New York 10017.

[2]Factory Mutual Insurance Company, 1151 Boston Providence Turnpike, P.O. Box 9102, Norwood, Massachusetts 02062.

[3]National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269.

[4]U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Ave. NW, Washington, D.C. 20210.

[5]Underwriters Laboratories, 333 Pfingsten Road, Northbrook, Illinois 60062.

**2.2** Specifically excluded from the scope of this publication are all in-line flame arresters such as *Flame Arresters in Piping Systems* which are addressed in API Publication 2028 or flame arresters for marine vapor control systems (which have requirements regulated by the Federal Government, Title 33 *CFR* Part 154). *Operation, Maintenance and Testing of Firebox Flame Arresters* is the subject of API Recommended Practice RP12N. API Publication 2028 discusses the influence of flame speed on flame arrester performance for deflagrations (subsonic flame speed) and detonations (flame propagation at speeds greater than the speed of sound). Tank vent flame arresters are not intended for protection against detonation.

## 3 Background

**3.1** In the early history of the petroleum industry, when storage tanks were constructed of wood or wrought iron with wooden roofs, there were spectacular losses from tank fires. Lightning or other ignition sources that ignited vapors in (or escaping from) the tank usually caused the tank fires. The permeability and combustible nature of wooden roofs contributed to the start and magnitude of the fires.

**3.2** The losses caused by fires and the evaporation of crude oil and gasoline in wooden-roof tanks contributed to the development and use of riveted steel-roof tanks. The tightness of the riveted steel-roof tanks led to the need for controlled tank venting. The use of a valve that remains tightly closed during periods when the tank internal pressure is within specified limits but that promptly opens when pressure or vacuum exceeds those limits can prevent tank damage and reduce fire losses. This valve, initially known as a breather valve, is now more commonly known as a conservation vent or a pressure-vacuum (PV) valve.

**3.3** As steel-roof tanks began to replace wooden ones, it was noted that lightning-caused fires continued to occur in tanks with wooden roofs, but tanks with steel roofs were virtually immune to lightning-caused fires. Based on this experience, steel-roof tanks were selected for the storage of volatile stocks. Such tanks were usually equipped with pressure-vacuum valves as a measure to reduce evaporation loss. A 1925 API committee report documented the fact that the combination of a tight steel roof and a pressure-vacuum valve gave virtually complete protection against lightning-caused fires; the use of this combination in the ensuing years has confirmed this report.

## 4 Flame Arresters

**4.1** The term *flame arrester* describes a device or form of construction that will allow free passage of a gas or gaseous mixture but will interrupt or prevent the passage of flame. It prevents the transmission of flame through a flammable gas/air mixture by quenching the flame on the high surface area provided by an array of small passages through which the flame must pass. The emerging gases are cooled enough to prevent ignition on the protected side. Effective and reliable arresting devices are designed for many specific situations. The metal screen in the coal miners' Davy safety lamp and the tiny passages in the sintered metal powder device in a combustible gas indicator are examples of flame-arresting devices.

**4.2** Arresters have been made incorporating wire screens, small metal tubes, drilled holes, or passages between interleaved corrugated and flat sheets of metal for use on tanks storing gasoline and similar flammable liquids. Such devices have been tested and listed as acceptable by the Underwriters Laboratories or approved by the Factory Mutual Insurance Company. The listing is based on tests made with mixtures of hydrocarbon vapor and air of maximum explosiveness, with prescribed limitations on the manner of installation. For example, a pipe extension on the atmospheric side of the arrester that is longer than the extension used in the test invalidates the listing (see Underwriters' Laboratories *Gas and Oil Equipment Directory* and the *Factory Mutual Approval Guide)*. For other vapors or gases and for installations that do not conform to the arrangement described in the listing, there is no assurance that the arrester will be effective.

**4.3** Problems in the application and maintenance of tank flame arresters occur from a number of causes such as:

1. The tank vapor must pass through the arrester's narrow passages causing a friction loss that may reduce the flow capacity below that of an open pipe or a vent pipe with a pressure-vacuum valve of comparable size. Thus, the pressure drop must be considered when a flame arrester is selected.

2. Narrow passages can clog with dust, scale, polymers or airborne debris. A rigorous maintenance program is necessary to avoid vent plugging and the possibility of pressure or vacuum-related damage to the tank roof.

3. The water bottoms of certain petroleum tanks produce high-humidity in the vapor space. Ice can accumulate and clog the arrester in freezing weather and jeopardize the tank. External environmental icing conditions can also cause arrester plugging. To remedy an icing situation, the arrester must be heated or removed. Since removal would nullify the protection for which the arrester was installed, heat tracing may be required.

4. The need for periodic inspecting and cleaning afford opportunities for errors in reassembly, possibly making the arrester incapable of stopping flame.

5. A listed flame arrester is not reliable indefinitely, even in perfect conditions. Although the mixture of hydrocar-

bon vapor and air employed in the Underwriters' Laboratories tests is the mixture most likely to flash through a narrow passage, evidence exists that a richer mixture could burn at the inlet of the flame arrester and produce heat damage which may render the device incapable of preventing flame propagation. UL 525 includes an *Endurance Burn Test* and a *Continuous Flame Test* to test flashback potential. Arresters categorized as Type I are tested using the *Endurance Burn Test* which requires a fire to burn from the flame arrester's exit for at least two hours after which time flashback should not occur. Type II arresters are designed to resist flashback in the UL 525 *Continuous Flame Test* which requires a flame to burn from the exit of the flame arrester during ten minute intervals for at least one hour.

6. Flame arrester maintenance requires safe access to avoid placing personnel at risk and to facilitate efficiency.

**4.4** The above limitations are recognized in NFPA 30 (see paragraph 2–3.5.7) and in the paragraphs introducing the products in the Underwriters' Laboratory *Gas and Oil Equipment Directory* and the *Factory Mutual Approval Guide*.

## 5 Pressure-Vacuum Valves As a Substitute For Flame Arresters

**5.1** NFPA 30 and OSHA 1910.106(b)(2)(iv)(f) recognize that a pressure-vacuum valve is an acceptable alternative to a flame arrester under certain circumstances. This recognition is based on tests started in 1920, supplemented by many years of experience.

**5.2** Even in mixtures of maximum flammability, flame cannot pass back through an opening if the efflux velocity exceeds a critical value. Tests by the Bureau of Mines and others made with mixtures of gasoline components and air flowing through openings typical of tank vents have demonstrated that this critical velocity is approximately 10 feet per second. In a valve set to close when the upstream pressure falls below approximately $^3/_4$ inch of water, the velocity of flow across the pallet-seat area exceeds twice this critical velocity. The flame propagation cannot overcome the gas flow to pass from the low-pressure to the high-pressure side. In these tests, flame was snuffed out when the valve closed as the upstream pressure was deliberately reduced to test and confirm this condition. Chapter 13 of the AIChE CCPS book, *Guidelines for Engineering Design for Process Safety,* discusses flame arresters and cites test work done which substantiates velocity flame stopping.

**5.3** Tests have also shown that under some circumstances a long-burning flame at the valve outlet could damage the valve sufficiently to interfere with its closing. Under such circumstances, flashback may occur when the flow rate falls below the critical velocity, if a flammable mixture exists inside the tank.

## 6 Summary

**6.1** The desire to protect a tank vent from flashback is based on the *theoretical* potential for a simultaneous occurrence of an ignition source in the vicinity of the vent and the release from the vent of a mixture capable of transmitting flame.

**6.2** Ignition sources such as open flames usually are, and certainly can be, excluded from the vicinity of tank vents. Falling embers, unless actually flaming, are not an ignition source for petroleum vapors. Lightning is a potential ignition source, as demonstrated by the occasional ignition of vent stacks that release vapor continuously. However, such stacks are usually taller and thus a much more attractive target for lightning than a tank vent.

**6.3** The availability of a mixture capable of producing flashback must be considered. Stocks stored at temperatures below their flash points do not produce ignitable mixtures in the vapor space. Crude oil and gasoline generally produce mixtures too rich to transmit flame. Expelled vapor, if ignited, will burn as a torch until its flow ceases, at which time the fire will go out. If a tank containing crude oil, gasoline or similar hydrocarbon materials with volatile fractions were to breathe in a substantial volume of air, it is possible that the diluted mixture within the vapor space in the tank could fall within the flammable range. Such a condition. however, is likely to be brief. There are, of course, a few stocks that produce a mixture within the flammable range under normal atmospheric conditions. These stocks are the exceptions and may warrant special consideration.

**6.4** The conditions under which a tank can exhale must be examined. Whether because of filling or ambient condition change, this exhaling period is unlikely to exist more than half the time.

**6.5** Flashback through an open tank vent can only result from the coincidental occurrence of two unlikely events—efflux of a flammable mixture and the presence of an ignition source (such as lightning) at the right time and place. The records support the belief that the probability of this coincidence is very low.

**6.6** Most companies have accepted the premise that a tight steel roof and a pressure-vacuum valve provide appropriate protection and that any potential additional protection afforded by flame arresters does not warrant their installation in addition to a pressure-vacuum valve. API Standard 2000 (4.4.1.2) and NFPA 30 (paragraph 2–3.5.6) state that a flame arrester is not considered necessary for use in conjunction with a pressure-vacuum valve where the tank is normally closed except when venting. This is consistent with OSHA requirements in 1910.106(b)(2)(iv)(f).

## 7 Conclusion

A systematic evaluation based on engineering analysis and tests, supported by experience, show that there is no technical or experiential basis for requiring that an outdoor aboveground petroleum tank provided with a pressure-vacuum valve must also be equipped with a flame arrester.

For practical safety considerations the use of flame arresters for these vents is discouraged to avoid tank damage resulting from the introduction of a new failure mode, unless the user is able to institute the flame arrester maintenance necessary to ensure that the required venting capacity is maintained.

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