



Methanol Vapor Service and Flame Arresters

Application, Material Selection, Stabilized Burning, Inspection, and Maintenance Considerations

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Executive Summary

Methanol is a widely used flammable liquid whose vapors are commonly protected with flame arresters on storage tanks, process vents, and vapor piping. A flame arrester can be effective only when the device is correctly selected for the flame condition, vapor composition, operating pressure, piping configuration, material compatibility, and expected service environment.

The 2006 Bethune Point wastewater treatment plant explosion in Daytona Beach, Florida provides a critical industry lesson. Hot work ignited methanol vapor at the tank vent; the flame then passed through a severely corroded and obstructed aluminum flame arrester and ignited the tank vapor space. The U.S. Chemical Safety Board concluded that aluminum in methanol service, combined with a lack of inspection and maintenance, allowed the arrester to deteriorate until it no longer functioned.

A separate concern exists when a flame stabilizes on or near a flame arrester element. Stabilized burning can thermally overload an arrester even when the device is capable of stopping a short-duration deflagration. Published laboratory research also shows that hot stainless-steel surfaces can promote methanol conversion to formaldehyde under some high-temperature conditions. This observation does not establish that a commercial stainless-steel flame arrester will necessarily generate hazardous formaldehyde concentrations, but it is a legitimate technical consideration when prolonged high-temperature exposure is credible.

The available evidence does not support replacing a properly selected stainless-steel flame arrester with an aluminum unit as a solution to the potential stabilized-burning/formaldehyde concern. Instead, methanol flame protection should rely on a compatible, properly rated arrester; appropriate temperature monitoring and automatic action where stabilized burning is credible; and a documented inspection and maintenance program.

1. Purpose and Scope

This paper summarizes practical engineering considerations for the use of flame arresters in methanol vapor service. It is intended for storage tanks, vent systems, vapor piping, and related process equipment where an external or internal ignition could allow flame propagation into equipment containing a flammable methanol-air mixture.

The discussion combines lessons from the U.S. Chemical Safety and Hazard Investigation Board (CSB) investigation of the Bethune Point methanol tank explosion, current methanol-industry handling guidance, current manufacturer guidance for stabilized burning, and published research on high-temperature methanol reactions at stainless-steel surfaces. It is not a substitute for equipment certification, a process hazard analysis, applicable codes and standards, or approval by the authority having jurisdiction.

2. Methanol as a Flame-Arrester Application

Methanol has a low flash point and a wide flammable range in air, so normal storage and handling can create ignitable vapor-air mixtures when air is present. For flame-arrester selection, methanol is commonly treated as a Group D / IIA vapor. Published MESG data place methanol at approximately 0.92 mm, which is near the lower boundary of the IIA classification.

A flame arrester should not be selected from the chemical name alone. The required device depends on the actual flame-propagation scenario. Important distinctions include:

- End-of-line or free-vent service, where the ignition is outside the protected vessel or vent opening.
- In-line deflagration service, where flame propagates through connected piping at subsonic velocity.
- Detonation service, where a flame can accelerate through sufficient run-up distance and create supersonic flame propagation and shock loading.
- Short-time burning versus stabilized or endurance burning, where a flame can remain attached to the element and continuously heat it.

A device tested only for one of these conditions should not be assumed to provide protection for another. The arrester rating, gas group or MESG, operating pressure, pipe size, piping arrangement, allowable run-up distance, flow direction if applicable, and burn rating must match the installation.

3. The Bethune Point Methanol Tank Explosion — A Case Study

On January 11, 2006, workers at the City of Daytona Beach Bethune Point Wastewater Treatment Plant were using an oxy-acetylene torch to remove a damaged metal roof above a methanol storage tank. Sparks ignited methanol vapors discharging from the tank vent. The flame flashed through the vent flame arrester and ignited the methanol-air mixture inside the tank. The resulting explosion and fire killed two workers and critically injured a third.

The CSB identified inadequate hot-work control and hazard communication as root causes. It also identified the flame-arrester condition as an important contributing factor. The Protectoseal Model 864 arrester had aluminum plates and an aluminum housing. After roughly twelve years in methanol service, the interior was severely corroded, passages were clogged with aluminum-oxide scale, and portions of the flame plates were broken or missing. The CSB concluded that the arrester did not prevent the external fire from igniting the tank contents.

The significance of this incident extends beyond one product or one facility. It demonstrates three separate principles that apply broadly to methanol service:

- Material compatibility is a safety function. A flame arrester can lose its flame-quenching geometry through corrosion even if the original design was adequate.

- Inspection and maintenance are essential. The Bethune Point arrester had not been routinely inspected or cleaned, allowing progressive deterioration to remain undetected.
- A flame arrester is only one layer of protection. Ignition-source control, hot-work permitting, compatible piping, vent design, operating procedures, and emergency protection remain necessary.

Important distinction: the Bethune Point explosion was initiated by hot work, not by spontaneous failure of the flame arrester. The degraded arrester failed to perform its intended protective function once the external vapor fire occurred.

4. Material Selection for Methanol Service

4.1 Aluminum alloys

The Bethune Point evidence and methanol-industry guidance make aluminum alloys a poor default choice for methanol flame-arrester components. The Methanol Institute warns that methanol can corrode aluminum alloys and, in its current Safe Handling Manual, states that aluminum and titanium alloys should not be used in methanol or methanol-vapor service without a rigorous mechanical-integrity program.

For flame-arrester service, the practical lesson is stronger than a general materials-compatibility warning. Corrosion that changes the dimensions, continuity, or cleanliness of a flame cell directly changes the device's ability to quench flame. Material degradation therefore cannot be treated only as a service-life or leakage issue; it can eliminate the primary safety function of the arrester.

4.2 Stainless steel

Stainless steel is widely used for flame-arrester elements because of its corrosion resistance, mechanical strength, and high-temperature capability relative to aluminum. For ordinary methanol vapor service, stainless steel is generally the more defensible starting material when the manufacturer has qualified the material and device for the application.

Stainless steel should not, however, be viewed as immune to all methanol-related concerns. Under sufficiently high-temperature conditions, stainless-steel surfaces can participate in surface reactions involving methanol. This becomes relevant primarily when a flame stabilizes on the element and holds the surface at elevated temperature for an extended period.

5. Stabilized Burning Is a Separate Failure Mode

A flame arrester may successfully stop a short-duration flame front and still be unsafe under stabilized burning. During a transient deflagration, the element absorbs heat long enough to reduce the flame temperature below the ignition threshold on the protected side. During stabilized burning, heat is continuously deposited at or near the flame cell. If heat input exceeds the element's ability to dissipate that heat, the element temperature rises until quenching capability is reduced, the structure deforms, or flame transmission occurs.

Current Enardo EN-7 manufacturer instructions provide a useful example of this distinction. Those devices are rated for short-time burning, with tBT not exceeding one minute under the stated test conditions. Where stabilized burning is possible, the manufacturer requires temperature sensing and corrective measures that eliminate the stabilized burn within one-half of the rated short-time

burn period — 30 seconds for that particular product. This is a product-specific requirement, not a universal 30-second rule for all flame arresters.

Accordingly, any application in which flame stabilization is credible should be reviewed for:

- The manufacturer's short-time or endurance-burn rating.
- Temperature-sensor location and response time.
- Automatic shutdown, isolation, inerting, flow interruption, or other extinguishing action.
- The maximum time permitted before the protective action must be completed.
- Post-event inspection or replacement requirements after abnormal temperature or flame exposure.

6. Stainless Steel and Possible Formaldehyde Formation

Methanol can be converted to formaldehyde by oxidation or dehydrogenation reactions. Industrial formaldehyde production deliberately uses catalytic metal-oxide systems for this purpose. More recently, laboratory research has shown that stainless-steel reactor surfaces can produce measurable formaldehyde from methanol at elevated temperatures. In a 2022 ACS Catalysis study, formaldehyde yields from an empty stainless-steel reactor were higher than those from a comparable quartz reactor under the tested high-temperature conditions, and the authors attributed the effect to transition-metal sites associated with the steel surface.

This research supports the technical plausibility of surface-assisted methanol conversion on hot stainless steel. It does not, by itself, prove that a stainless-steel flame-arrester element in methanol service will generate enough formaldehyde to alter the explosion behavior of the vapor stream. Flame-arrester geometry, residence time, oxygen concentration, element temperature, methanol concentration, pressure, heat flux, oxide condition, and flow rate are all different from a laboratory catalytic reactor.

The appropriate engineering treatment is therefore caution rather than assumption. If a process can produce prolonged stabilized burning or sustained high element temperature, formaldehyde and other reaction products should be considered as possible secondary species until the application has been evaluated or tested.



7. Why Vapor Composition Matters

Methanol itself has a published MESG of about 0.92 mm and is commonly classified as IIA / Group D. Formaldehyde has a substantially smaller published MESG, approximately 0.57 mm, corresponding to IIB behavior. This difference is important because flame-arrester performance is fundamentally tied to the flame-quenching characteristics of the actual combustible mixture.

The possible formation of formaldehyde does not mean that every methanol installation must automatically be treated as an IIB formaldehyde application. The concentration of any reaction product matters, mixtures can behave differently from pure components, and the only reliable basis for a changed gas-group requirement may be mixture data or representative testing. The key point is that a device selected solely from the incoming chemical name may be non-conservative if the process itself can materially change the combustible vapor composition before or at the arrester.

8. Inspection and Maintenance

The Bethune Point investigation is a direct warning against treating a flame arrester as a passive, maintenance-free fitting. Flame cells depend on narrow, controlled passages. Corrosion, deposits, polymerized material, debris, insect nesting, mechanical damage, or improper reassembly can reduce flow area, increase pressure drop, change heat transfer, or create openings through which flame can pass.

A methanol-service maintenance program should, at a minimum:

- Follow the inspection and cleaning interval specified by the manufacturer, adjusted for actual service severity.
- Verify that flame-cell passages remain clean, dimensionally intact, and free of corrosion or missing material.
- Inspect housings, fasteners, gaskets, and instrumentation ports for corrosion, leakage, or mechanical damage.
- Record pressure-drop changes where practical, because an unexplained increase can indicate fouling or blockage.
- Inspect the arrester after any known flashback, abnormal temperature excursion, stabilized-burn event, or process upset.
- Use manufacturer-approved cleaning and reassembly procedures; do not mechanically alter flame-cell geometry.
- Maintain records showing inspection date, condition found, cleaning performed, parts replaced, and next scheduled inspection.

9. Recommended Engineering Basis for Methanol Flame-Arrester Applications

Engineering step	Application requirement
1. Define the vapor	Identify methanol concentration, air/inert content, contaminants, and any credible reaction products. Use the actual worst-case vapor basis rather than the chemical name alone.
2. Define the flame condition	Determine whether the credible event is end-of-line flame, in-line deflagration, high-pressure deflagration, detonation, short-time burning, or stabilized burning.
3. Match the device rating	Use an arrester tested/certified for the applicable gas group or MESG, operating pressure, pipe size, configuration, and flame condition.
4. Verify material compatibility	Select element and housing materials suitable for long-term methanol vapor service. Avoid generic substitution to aluminum as a solution to high-temperature chemistry concerns.
5. Address stabilized burning	Where credible, use manufacturer-specified temperature sensing and automatic extinguishing, shutdown, isolation, or inerting within the rated burn time.

Engineering step	Application requirement
6. Control ignition sources	Maintain hot-work controls, hazardous-area electrical practices, grounding/bonding, and other ignition-prevention measures. A flame arrester is not a substitute for ignition control.
7. Maintain the arrester	Establish documented inspection, cleaning, and post-event inspection procedures based on the manufacturer and actual service.
8. Reassess process changes	Re-evaluate the arrester whenever vapor composition, operating pressure, vent routing, pipe length, equipment, or process chemistry changes.

10. Conclusions

- Methanol service is a valid and common flame-arrester application, but successful protection depends on matching the device to the actual vapor and flame-propagation scenario.
- The Bethune Point explosion demonstrates that an aluminum flame arrester can deteriorate severely in methanol service and that failure to inspect and maintain the device can allow loss of flame-stopping capability.
- Aluminum should not be treated as a generic substitute for stainless steel in methanol flame-arrester service. Material compatibility and mechanical integrity must be established for the specific product and service.
- Stabilized burning is an independent thermal hazard. A device that stops a transient flame can still fail if a flame remains attached to the element beyond its rated burn capability.
- Published research makes high-temperature, stainless-steel-assisted methanol conversion to formaldehyde technically plausible. The relevance to a particular flame arrester depends on actual temperature, residence time, composition, and geometry and should not be assumed without evaluation.
- Where stabilized burning is credible, temperature detection should initiate an automatic protective action within the manufacturer's rated time. Alarm-only monitoring may be inadequate.
- Inspection and maintenance are part of the flame-arrester safety function, not optional housekeeping.

Key engineering takeaway

For methanol service, the safest general approach is a compatible, properly rated flame arrester; a design basis that considers the actual vapor and credible flame condition; automatic protection against stabilized burning where required; and disciplined inspection and maintenance throughout the equipment life.

References

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2. **Methanol Institute / MI — The Global Methanol Alliance.** Methanol Safe Handling Manual, 5th Edition. Material compatibility and storage-safety guidance for methanol service. [Source](#)
3. **Emerson / Enardo.** EN-7 Series Flame Arrestor Instruction Manual, D103583X012, March 2026. Guidance on short-time burning, temperature sensors, and corrective action for stabilized burning. [Source](#)
4. **Paunović, V.; Hemberger, P.; Bodi, A.; Hauert, R.; van Bokhoven, J. A.** “Impact of Nonzeolite-Catalyzed Formation of Formaldehyde on the Methanol-to-Hydrocarbons Conversion,” ACS Catalysis, 2022, 12(21), 13426–13434. [Source](#)
5. **Lafyatis, D. S.; Creten, G.; Froment, G. F.** “TAP Reactor Study of the Partial Oxidation of Methanol to Formaldehyde Using an Industrial Fe-Cr-Mo Oxide Catalyst,” Applied Catalysis A: General, 1994, 120(1), 85–103. [Source](#)
6. **Published MSG data and gas-group classification references.** Methanol MSG approximately 0.92 mm; formaldehyde MSG approximately 0.57 mm. Gas-group application should follow the governing standard and actual mixture basis for the installation. [Source](#)

Publication note: This technical paper is intended for educational and engineering discussion. Final flame-arrester selection, certification, installation, inspection, and shutdown logic must be confirmed for the actual service by the equipment manufacturer, process designer, applicable code requirements, and the authority having jurisdiction.

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