Dust Explosion Protection using Flameless Venting

By

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Introduction

The risk of industrial explosions has been recognized for several hundred years. Many industries handle materials with the potential for a dust explosion and there are statutory requirements to take both preventative and protective measures to protect personnel and plant equipment. Explosion prevention techniques attempt to minimize or eliminate the occurrence of explosions, whereas explosion protection techniques control the effects of the explosion in such a way as to minimize or eliminate the damage that could occur due to an explosion. Explosion protection techniques include containment, venting, flameless venting, isolation and suppression.

For many years the most common and popular method of protection has been explosion venting. In its simplest form, a vent is an aperture in the top or side of a vessel to provide a means of pressure relief during an explosion. The technique of venting and vent system design was previously described in SHAPA Technical Bulletin No.10 “Sizing of explosion relief vents’ by Mike Ward (Fike UK, 2004).

In order to protect people close to a vented vessel located indoors and to prevent external dust deposits from becoming involved in a secondary dust explosion, the vent discharge must be directed outside the building with suitable ducting. This ducting has a substantial effect on the pressure experienced inside the vessel during the venting process and this must be allowed for in the vent area calculation. In some cases, the increase in pressure can be so great that an alternative protection method is required.

A new option – flameless venting – has recently been developed for dust explosions and is being actively marketed as an alternative to vent ducting. Another important application of this new technique is the retrofitting of existing installations. The Dangerous Substances and Explosive Atmosphere Regulations (DSEAR) require industry to critically review the explosion prevention/protection methods used with all equipment handling dangerous substances. It is not uncommon for powder manufacturers/processors, particularly in the traditional industries, to find that their current level/type of explosion protection does not satisfy the requirements of DSEAR and that additional protection is required to meet the Health and Safety Requirements.

1. Flameless Venting Devices

Flameless venting devices combine the techniques of explosion venting and flame arresting. Flameless venting devices typically comprise a vent panel, flanged housing, and a flame arrestor element. The general principle is that during the early stages of an explosion the explosion vent cover opens, burnt and un-burnt dust and flame enter the flame arrestor element. Flame propagation beyond the device is prevented by energy (heat) dissipation in the element, reducing the burning fuel below its ignition temperature (Barton, 2002). The dust is largely retained within the arrestor element and gases from the explosion are vented through the device into the external atmosphere around the device.

There are several types of flameless venting devices. They are passive devices that consist essentially of a cylinder closed at one end and open at the other. The surfaces are fabricated from various layers of high temperature stainless steel mesh. The device is bolted onto the explosion vent on the vessel with its open end overlapping the vent aperture.

Figure 1: Impression of layered high temperature stainless steel flamefilter

(wire gauze and gauze packs)

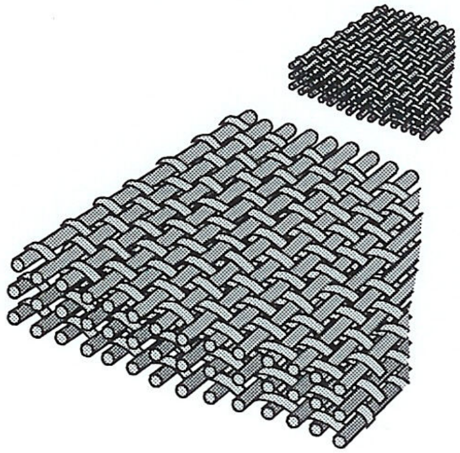
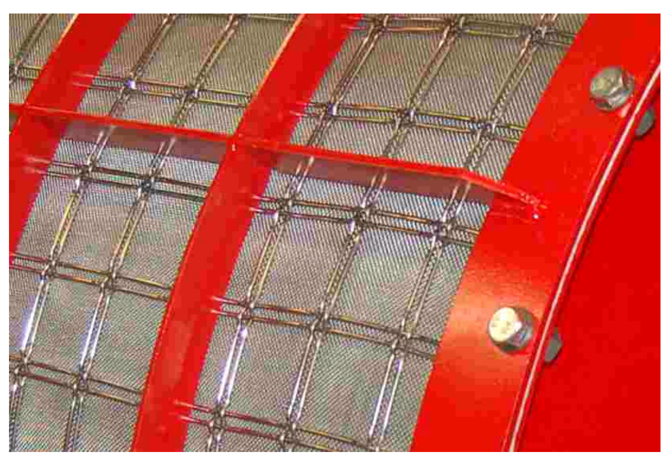


Figure 2 Detail of Fike FlamQuench II Square flame filter



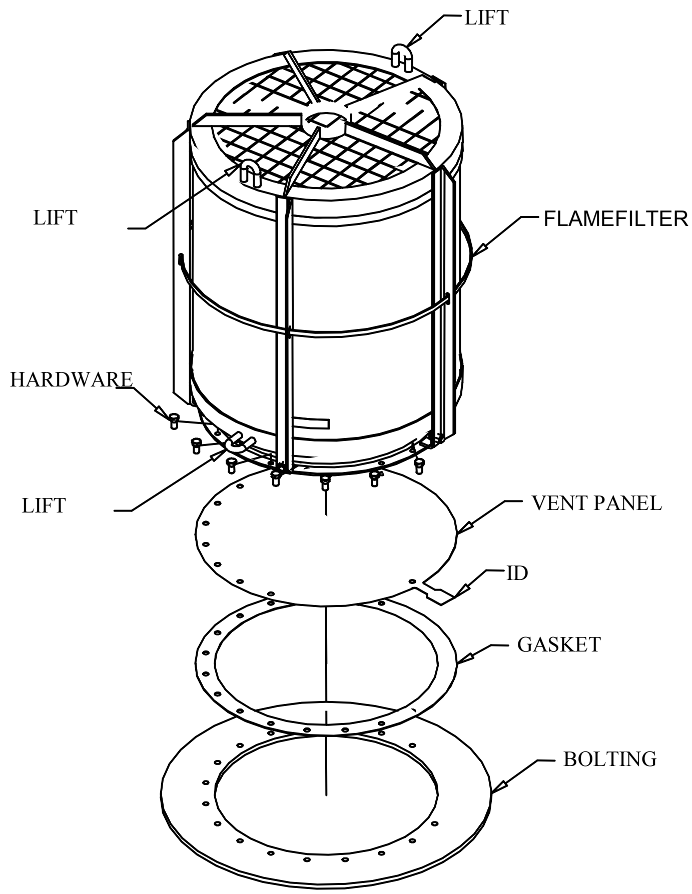


Figure 3: Exploded view of Fike FlamQuench II™ Flameless Venting Device

Figure 4 Representative view of FlamQuench II™ Flameless Venting Device:

In the event of a dust explosion inside the process vessel the explosion vent opens. As the explosion expands, flame, burnt and un-burnt dust will discharge through the open vent into the flameless vent cylinder. The dust will be retained in the cylinder and, because of heat absorption by the flamefilter; the flame from the explosion will be extinguished as it travels through the stainless mesh. Only the safe discharge of post-combustion gases from the explosion is allowed. Advantages of flameless venting are flame extinguishment, dust retention, elimination of the need for explosion vent ducts and minimization of the vent relief area requirements for indoor venting.

Figure 5: Vented explosion test with and without the Fike FlamQuench II device

Nowadays, a wide range of flameless vent products is offered to fit round or rectangular vent panels of different sizes. Devices have also been developed for specific applications such as bucket elevators (Fike EleQuench) and dust collectors (FlamQuench SQ).

Figure 6 EleQuench

Figure 7 FlamQuench II Square

2. Flameless Venting Testing and Certification

2.1 Testing

In 1992, a test program was undertaken by Dr. W.Bartknecht and A Vogl at FSA premises in Kappelrodeck, Germany to verify whether commercially available gas flame arrestors could be applied to stop propagation of industrial dust explosions. The flame arrestors tested were constructed from parallel windings of angled metal strips, thereby forming a large number of equally sized flame-arresting channels, typically of gap width 0.9mm and length 10mm. From the experiments, it was shown that a combination of two arrestors in series was required to prevent flame propagation.

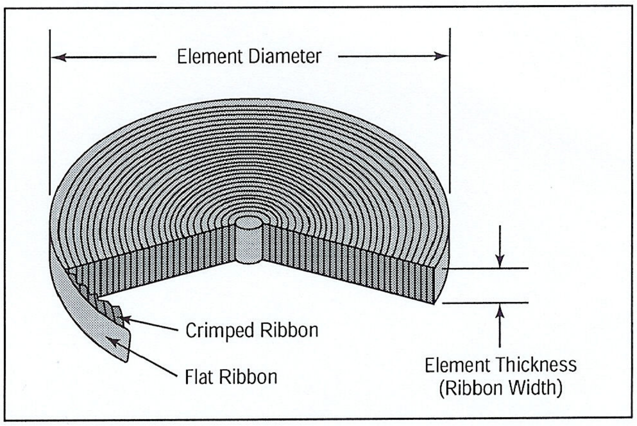


Figure 8 Flame arrestors from parallel windings of angled metal strips

As would be expected, the flame arrestor elements caused a restriction to flow and the effective relief area was diminished.

A much higher venting efficiency was achieved by using a cylindrical form, where both the top and sides of the structure are manufactured from particle retaining stainless steel mesh layers. The performance of this type of flameless venting devices to dust explosions was assessed in an experimental program carried out by Going and Chatrathi (Fike Corporation, 2003). Five devices with diameters of 8", 14", 20", 24" and 36" were used and were all manufactured by Fike (FlamQuench II). They were tested using explosion chambers having volumes of 0.5 m3, 2m3 and 4 m3. The test dusts were cornstarch, anthraquinone and Pittsburgh coal. It was found that the efficiency of venting was 70%-90% of that of a free vent with the variation related to P_{red}. This efficiency factor allows the calculation of the flameless venting device using conventional methods.

Large scale experimental tests have also been carried out to determine the performance and establish the efficiency of flameless venting devices when used with full scale industrial process equipment. This testing did show that important differences may exist between results obtained in vessels essentially free from obstructions (traditional test vessels) and industrial process equipment such as dust collectors and elevators, which have parts in them that may influence the venting process: filter bags, filter cartridges, baffle plates, buckets, and belts. Reduced efficiency of the venting device is a critical issue. Any reduction will result in an increase in the explosion pressure generated within the protected equipment. Should this exceed the design pressure of the vessel or equipment a rupture or mechanical failure is possible with the subsequent discharge of burning product, pressure and flame.

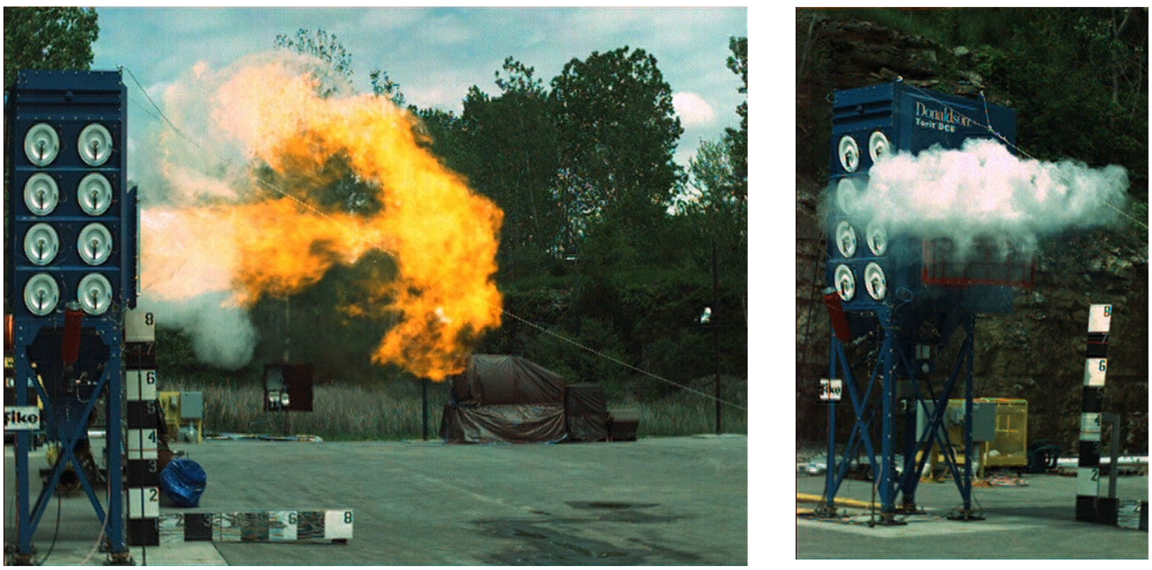


Figure 9 Test of explosion venting without and with a flameless venting device (printed with permission of Donaldson Filtration Solutions)

Figure 10 Donaldson filter protected by Fike FlamQuench II Square flameless venting device

2.2 Certification

The technique of flameless venting of dust explosions is described in NFPA68-2007, VDI-3673; EN 14797. In the absence of an official performance standard, compliance with NFPA 68 and the ATEX100a has been demonstrated by large scale testing. Approval shall be sought from a notified body which will issue an EC-Type Examination Certificate. Typically this certificate includes the following:

1) Statement that confirms the certificate is an EC_Type Examination Certificate.
2) Equipment and protection systems intended for use in potentially explosive atmospheres Directive 94/9/CE.
3) Certificate number.
4) Protection apparatus or system identification.
5) Manufacturer and address.
6) The protection system or equipment are described in an annex to the certificate
7) Statement that the device achieves Essential Health and Safety Requirements by conformity with appropriate standard i.e. EN 1127-1 (1997) and VDI 3673 part 1 (1995).
8) Reference to the report in which the tests are described.
9) A statement that if the sign “X” is placed after the certificate number, it indicates that the protective system is subject to special conditions for safe use mentioned in the annex of the certificate.
10) Marking applied to the device.

Also, FM Global created a set of similar performance tests, and an FM listing can be obtained. FM describes a special test condition in which fibrous dust is used in an attempt to reproduce accidental blocking of the flamefilter. In addition, FM provides recommendation on maximum volume that can be protected by one single device of a certain size and on the pressure build up in a room.

2.2.1 EN Standard

A standard for flameless venting devices is being developed as part of the CEN Technical Committee 305. CEN TC 305 - Work Group 3 covers devices and systems for explosion prevention and protection when explosive atmospheres containing flammable dust are a hazard. The aim is to develop a standard that describes the basic requirements for the design and application of flameless explosion venting devices and will consider explosions of flammable dust-air mixtures only. The standard will cover:

- Testing/demonstrating the efficiency of the flameless vent in comparison to unrestricted (open) venting, allowing sizing according to EN14491 Dust explosion venting protective systems. This standard briefly refers to flameless venting and notes that the area immediately surrounding the vent can experience overpressure and radiant energy. Venting indoors has an effect on the building that houses the protected equipment due to the increased pressurization of the surrounding volume. Expected overpressures need to be assessed in relation to the building strength and building venting may need to be considered.

- Testing/demonstrating that the device is effective at dust retention and prevention of flame release.

- Testing/demonstrating the influence of fibrous dust, other product related effects or any material from the device itself (heat shield fragments, insulating material) which may hinder the venting action and thereby influence the venting efficiency.

- Determination of the application range in diameter, fuel type and maximum vessel volume to be protected.

- Determination of safety distances for personnel with respect to noise and residual pressure.

- Determination of the increase in pressure inside rooms where flameless explosion venting devices may vent.

- Special applications of flameless venting devices including elevators, diverters, etc.

- Installation and maintenance requirements.

- Marking.

2.2.2. NFPA 68 Standard for venting of deflagrations

This standard is produced by the National Fire Protection Association in the USA. It is applicable to the design, location, installation, maintenance, and use of equipment that vents deflagrations from enclosures to minimize structural and mechanical damage. Dust explosion (or deflagration) protection using flameless venting devices are addressed:

- Flameless venting devices - called flame-arresting vent systems and particulate retention vent systems - are described in the standard. Limitations and safety considerations are discussed and it points out that that consideration should be given to the proximity of personnel, volume of the room, possibility of combustible mixtures exterior to the equipment and possible toxic emissions.

- It is stated that gases are cooled, no flame emerges and near-field blast effects (overpressure) are greatly reduced outside the system.

- The guide points out that the user should work closely with the manufacturer to ensure that these parameters are addressed.

- When venting within a building even with complete retention of flame and particles, the immediate surrounding area around the vent can experience overpressure and radiant energy. The expected overpressure must be considered in relation to the strength of the building and building venting should be considered to limit overpressures.

3. Flameless Venting system design

Explosion venting system designers must take recently developed design standards into consideration in order to ensure that the calculated relief area and selected venting devices are compliant with legislative requirements or standards. EN standard EN14491 and NFPA 68 provide detailed guidance on the process of vent area calculation and vent system design, refer to SHAPA Technical Bulletin No.10 “Sizing of explosion relief vents’ by Mike Ward (Fike UK, 2004) for more information.

When installing a flamefilter downstream of the explosion vent panel, the overall efficiency shall be taken into account. This overall efficiency factor results from large scale testing and shall be used to compensate for the restriction to flow which will diminish the effective relief area.

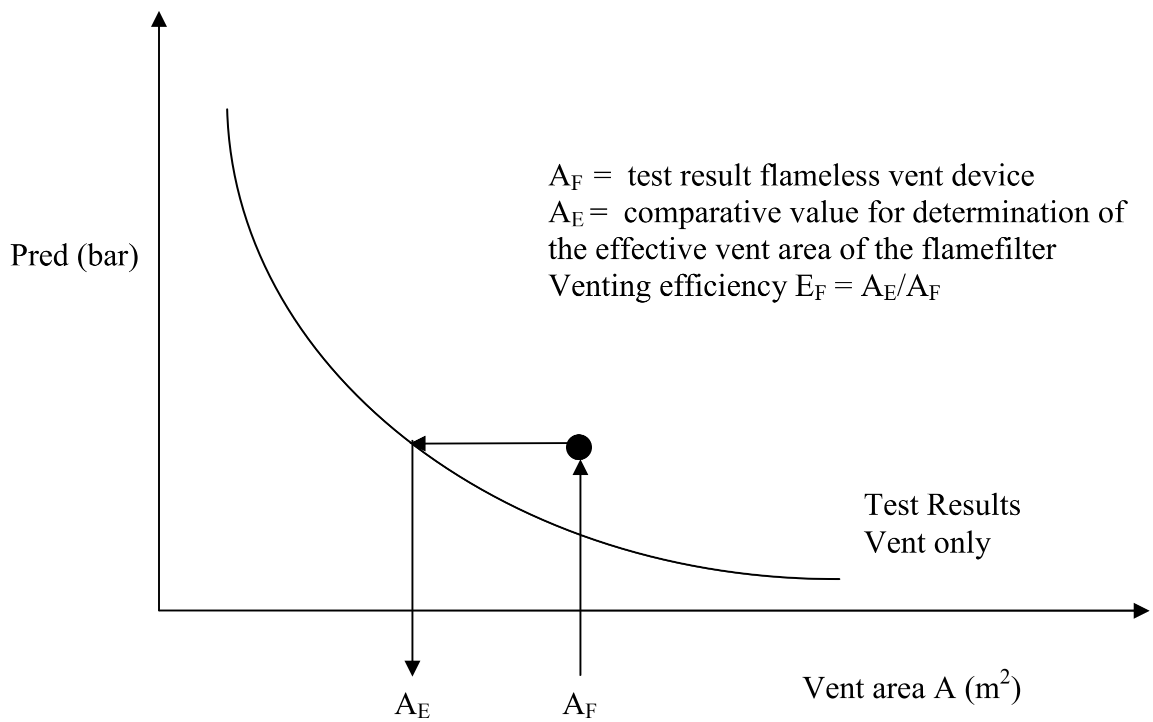


Figure 11 Flameless venting efficiency

This correction factor shall be applied to the vent area as calculated by venting standards to produce the required increase in vent area.

Two examples are given below:

Example 1

Given:

- A dust collector, installed indoor, is be protected by flameless explosion venting.
- The dust is a non-fibrous Starch with Kst 150 bar.m/s.

Solution

- The calculated vent area as per EN14491 is 0.28 m^2.
- From representative testing, a flameless vent efficiency of 60% is obtained for the combination vent + flamefilter
- The resulting required flameless vent area: A=0.28 m2/(60/100) = 0.47 m^2
- A vent and Fike FlamQuench (Type SQ) with area greater than 0.47 m^2 is selected. A 566 x 900 mm Sani-V vent with a 566 x 900 mm FlamQuench Square provides an effective area of 0.51 m2, exceeding the required 0.47 m^2.

Special attention is required for fibrous dust since these may show a increased tendency to clog the flame filter. If the intended use includes a fibrous dust (e.g. wood fibers, flock) contact the manufacturer for further guidance. The technique of flameless venting of dust explosions has not been approved for metal dust, contact the manufacturer for documented performance in case of doubt.

Example 2

Given:

- Based on the following parameter, the calculated vent area is 1.0 ft^2 (144 in^2).
  - Volume = 50 ft3
  - L/D = 1
  - Pstat = 1.45 psi, Pred = 4.5 psi
  - Kst = 120, Pmax = 7 bar
- The dust is fibrous.
- The enclosure is indoors and requires ducting or a Fike FlamQuench II.
- The venting application requires FM Approval

Solution A: FlamQuench

- From representative testing an efficiency of 54.2% was obtained for 8-20 inch FlamQuench II, for FM application with fibrous dust.
- The resulting flameless vent area is: $A=1.0\ ft^2 /(54.2/100) = 1.85\ ft^2$ ($165\ in^2$)
- One (1) 20" FlamQuench II and one (1) 20" vent are selected for the application. The supplied vent area is $1 \times 2.02 = 2.02\ ft^2$, exceeding the calculated area of $1.14\ ft^2$.
- No construction or wall penetration is required.

Solution B: Vent Duct of 10 feet,

- Using NFPA 68, the vent duct effect would require an area of $2.54\ ft^2$ or a 24" round vent
- A vent duct would need to be designed, constructed and installed
- A wall penetration would be required
- A safe discharge area must exist

Effects of flame and pressure shall be evaluated. Even with complete retention of flame and particulates, the immediate area surrounding the vent can experience overpressure and radiant energy. Venting indoors has an effect on the building that houses the protected equipment and personnel present due to increased pressurization of the surrounding volume. Expected overpressure should be compared to the building design and building venting should be considered to limit overpressures. A practical approach is to use a volume ratio between protected equipment and building. Typical values are 1/9 for reinforced or vented buildings, 1/15 for not specifically reinforced buildings. Other approaches, more or less conservative are allowed if supported by representative large scale testing.
Example:

A protected storage bin of volume $5\ m^3$ would require a room volume of $45\ m^3$ (reinforced or vented building)

4. Examples

Since the market introduction of flameless venting, a wide variety of process equipment in different process industries is protected by flameless venting devices of different shape and construction. Because the technique is passive, as opposed to active suppression systems, and the devices are essentially free from inspection and maintenance, the field of application is still expanding. Today, flameless venting is applied to dust collectors, bucker elevators, conveyors, dryers, cyclones in a wide range of industries such as food, pet food, pharmaceutical, energy, wood, paper & pulp etc..

Figure 12 EleQuench on a bucket elevator

Figure 13 FlamQuench II Square on a filter installation

5. Conclusion

Explosion venting system designers must take recently developed design standards into consideration in order to ensure that the calculated relief area and selected venting devices are compliant with legislative requirements. This will include the location of the venting device on the enclosure and its effect on the calculated vent area. Equally important is the location of the enclosure; indoors or outdoors. Since indoor venting is not permitted, the designer has to select between vent ducting and flameless venting. Flameless venting is a viable alternative to ducting and sometimes is the only alternative. Flameless venting must consider venting efficiency and incorporate it in the overall design. The venting efficiency factors of the venting and flameless venting devices are manufacturer product specific, can be application specific and should be used in accordance with the manufacturers' recommendations only.

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4. NFPA 68 Standard on Explosion Protection by Deflagration Venting -2007 edition

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6. European Standard prEN 14797 Explosion Venting Devices

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