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Dust Explosion Protection by Flameless Venting

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Despite a much greater awareness of dust explosion hazards, numerous accidents continue to happen throughout the world, resulting in casualties, property losses and business interruption. Prevention constitutes the first line of defense, and remains an essential part of risk mitigation for dust explosions; in addition, explosion protection techniques (such as containment, venting, isolation and suppression) also need to be implemented to deal with consequences and effects of explosion when they do occur. While conventional venting remains the most common and popular method of protection used, its implementation is not always straightforward, especially for indoor equipment. A new technology - flameless venting - has been developed for dust explosions, thanks to extensive large scale test programs. In comparison with conventional venting devices, the most notable benefits of using flameless venting devices are flame extinguishment and dust retention, resulting in blast, thermal radiation and noise minimization outside the protected equipment. Another distinct advantage is that it can be easily retrofitted to existing installations, without requiring significant changes to the process. In addition to describing the concept of flameless venting and its design, this article presents results of test programs, as well as current standardization activities related to flameless venting in Europe.

1. Introduction

Recent dust explosions have resulted in a much greater public awareness and, in turn, in a demand for improved safety performances by the regulator in many industrial countries. In the United States of America, the Occupational Safety and Health Administration (OSHA) issued a new Combustible Dust National Emphasis Program (NEP) in response of the Imperial Sugar dust explosion that occurred in 2008 (14 casualties, 36 injuries).

For many years, the most common and popular method of dust explosion protection has been venting. In its simplest form, a vent is an aperture in the top or side of a vessel that provides a means of pressure relief during an explosion. While conventional venting is quite efficient and recommended for most of the cases, its implementation can pose concerns when dealing with indoor equipment. Indeed, the vent discharge must be directed out of the building by suitable ducting, to protect people in the vicinity of the vented vessel, and also to prevent a secondary dust explosion fueled by dust deposits. However, the reduced explosion pressure inside the vented vessel will be much higher because of this ducting creates flow restriction during the venting process. Some applications may need long ducts, possibly elbows, which require a much larger vent. Sometimes, venting is no longer a viable solution, and other protection methods should be evaluated. Even when the vented vessel is installed outdoors, the hazards from overpressure, thermal radiation, release of material outside the vessel, as well as noise (Wirkner-Bott et al., 1992a; Wirkner-Bott et al., 1992b; Wirkner-Bott et al., 1993; Schumann et al., 1995; Crowhurst et al., 1995, Crowhurst and Colwell, 1995; Forcier and Zalosh, 2000, Holbrow et al., 2000; Taveau, 2010) have to be taken into account. The implications of dealing with these hazards may require large restricted areas (Bernard et al., 1998), which may not be desired for some applications.

A new technology of dust explosion protection has been developed (Going and Chatrathi, 2003) to overcome the above concerns. This technology, called flameless venting, has now been adopted in guidelines and described in technical papers by several authors (Barton, 2002; Zalosh, 2005; Grossel, 2012).

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2. Flameless Venting

A flameless venting device is a passive element that typically includes an explosion vent panel and a flame-quenching unit that is inside a flanged metal frame (Figures 1 and 2); the frame attaches the element to the process equipment, such as a dust collector (Snoeys, 2008; Snoeys and Going, 2010; Snoeys, 2012). The flame quenching unit's frame encloses layers of particle-retaining, high-temperature stainless steel mesh or carbon steel mesh. The flame-quenching unit may be cylindrical, rectangular, or square to fit the vent opening's shape. Other types of flame quenching units are given in Annex A of EN 16009 (2011).

Figure 1: Picture of Fike FlamQuench II^{TM} cylindrical flameless venting device

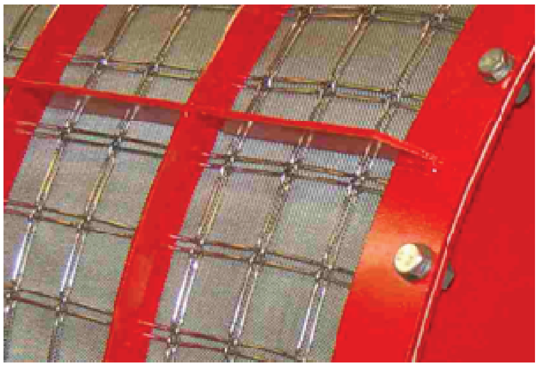

Figure 2: Detail of Fike FlamQuench II^{TM} square flameless venting device

During the early stages of an explosion inside the process equipment, the explosion vent panel opens. As the explosion expands, flame, burnt and unburnt dust discharge through the open vent into the flame-quenching element. Most of the dust is retained inside the element, and the energy (heat) dissipates as it travels through and is absorbed by the steel mesh inside the element. This reduces the burning fuel's temperature below the fuel's ignition temperature, extinguishing the flame and preventing flame propagation beyond the device. Only a small amount of dust passes through the flame-quenching element, and post-combustion gases from the explosion are safely vented through the device into the external atmosphere around it (Figure 3).

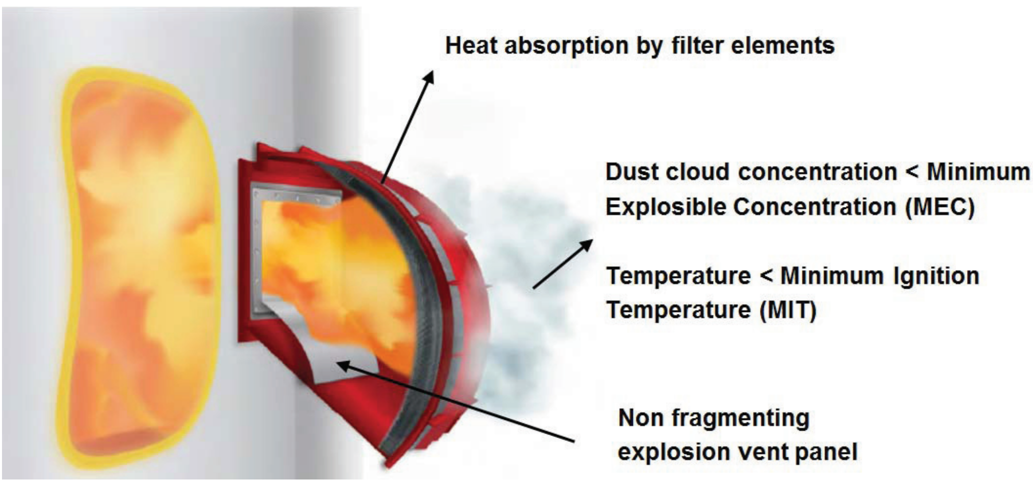

Figure 3: Working principle of flameless venting

The flameless venting device not only extinguishes the flame and retains dust, but completely eliminates the need for explosion vent ducting and minimizes the vent relief area required for indoor explosion venting. Flameless venting devices are designed to suit particular storage and process equipment such as silos, bins, hoppers, dryers, mixers, dust collectors, cyclones, but also transport equipment such as belt conveyors, screw conveyors, and bucket elevators (Figure 4).

Figure 4: Fike FlamQuench IITM flameless venting device on a hopper (cylindrical), on a bucket elevator and on a filter installation (square)

3. Flameless Venting Testing

The first information about testing flameless venting devices for dust explosion is given by Eckhoff (2003). Unfortunately, information available to the public is scarce.

In 1992, a test program was undertaken by Dr. W. Bartknecht and A. Vogl at Forschungsgesellschaft für angewandte Systemsicherheit und Arbeitsmedizin (FSA) premises in Kappelrodeck, Germany, to verify whether commercially available gas flame arrestors could be applied to stop propagation of industrial dust explosions. 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 has been achieved by using a cylindrical form, where both the top and sides of the structure are manufactured from multiple flame arresting stainless steel mesh layers and fine mesh particle retention screens.
The performance of this type of flameless venting devices to dust explosions was assessed in an experimental program carried out by Fike (Going and Chatrathi, 2003).

Tests were conducted in three explosion chambers of 0.5 m^3, 2 m^3 and 4 m^3, with four materials (propane, cornstarch, anthraquinone and Pittsburg coal) having K_{st} up to 300 bar.m/s, five sizes of flameless venting devices (DN 200 to DN 900), two styles of explosion vents (Fike explosion vent models CV and CV-S) and at two static burst pressures (0.1 and 0.2 barg).

In all the tests carried out, flame never emerged from the FlamQuench II^{TM} flameless venting device. This has been verified using three methods: one method was the examination of videotapes of the experiments, a second method was the placement of cotton rags soaked with gasoline on the exterior surface, whereas a third method involved placing a 3 mm layer of cornstarch dust on the top of the unit. Photographs of tests conducted by Fike, without and with flameless venting device, are provided in Figure 5.

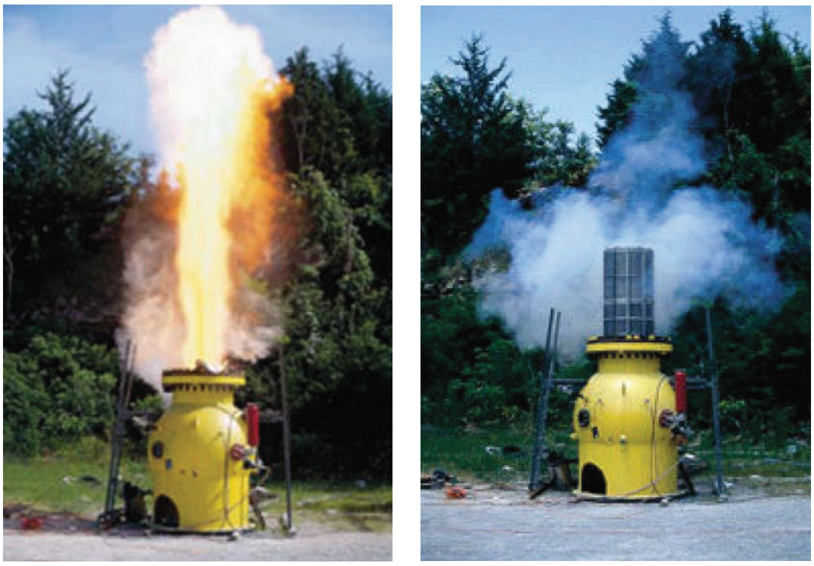

Figure 5: Vented explosion test without and with Fike FlamQuench IITM flameless venting device

It was found that the efficiency of venting using FlamQuench II^{TM} flameless venting device was above 80% (Figure 6). This efficiency factor then allows the calculation of required vent area when using a flameless venting device.

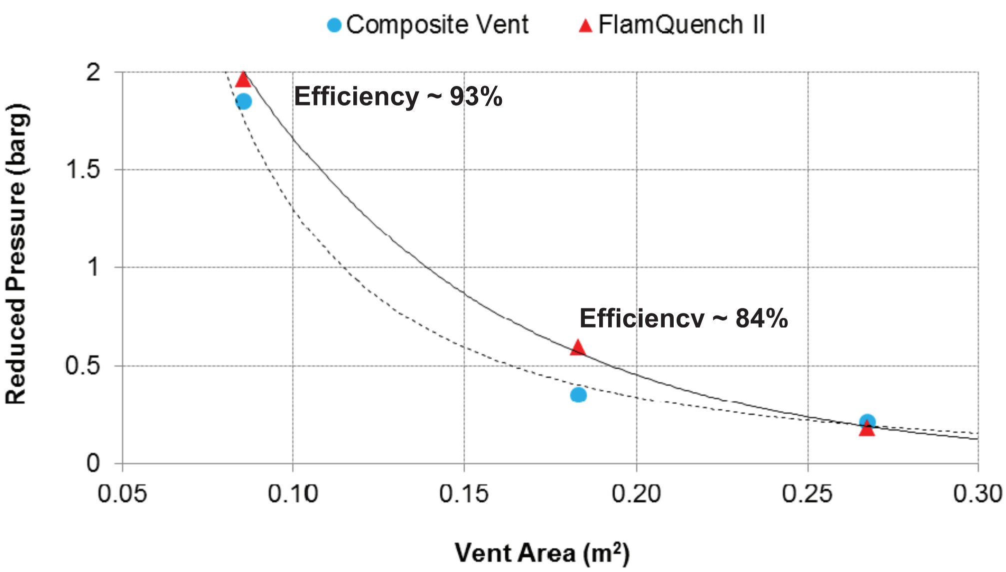

Figure 6: Efficiency results on 2 m3 test vessel - Kst,max = 197 bar.m/s and Pstat = 0.1 barg (Fike)

Recent tests performed by Health and Safety Laboratory (Holbrow, 2006; Holbrow, 2011; Holbrow, 2012) in the United Kingdom involved a 2 m^3 vessel equipped with a Fike flameless venting device.
The objective of these tests was to study volume and fuel limitations. Wheat flour, corn flour and wood dusts were tested. Figure 7 shows the results of a vented explosion for the same vessel equipped with a traditional venting device (on the left) and a flameless venting device (on the right). While an external flame of several meters was observed for the first case, *"the flame was completely eliminated by the introduction of a flameless venting device with only smoke, dust and water vapour emitted from the device."*

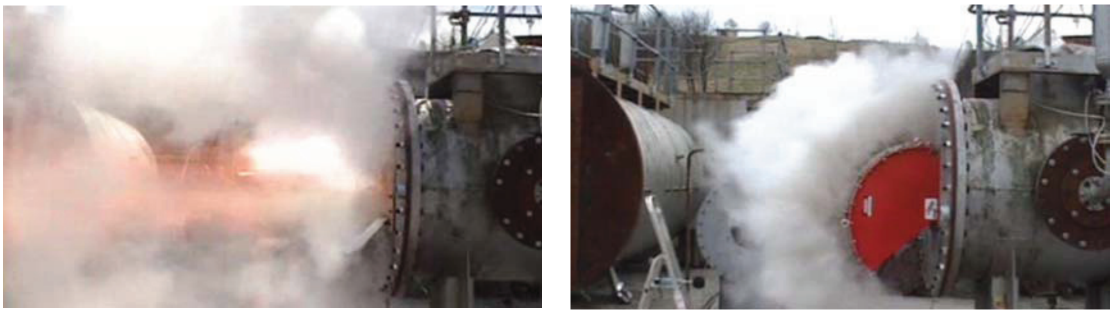

Figure 7: Vented explosion test performed by HSL with a flameless venting device

4. Current Standardization Activities related to Flameless Venting

The technique of flameless venting is described in both American standard NFPA 68 "Standard on explosion protection by deflagration venting" (2007, currently under revision) and European standard EN 16009 "Flameless explosion venting devices" (2011).
Published in 2011, European standard EN 16009 has been prepared by a group of experts gathered in Working Group 3 of CEN Technical Committee 305 "Devices and systems for explosion prevention and protection" and is exclusively dedicated to flameless venting. This detailed document specifies the requirements for flameless explosion venting devices, in terms of design, inspection, testing, marking, documentation and packaging.
It particularly provides test requirements for manufacturers and lists elements to be included in the test report, such as:
- Product characteristics (nature of the sample - sample pre-treatment - characteristics data for particle size distribution and moisture content - type of fuel and all relevant safety characteristics).
- Characteristics of the test rig (dimensional sketch of the test rig - enclosure volume, aspect ratio, surface area - dust-dispersion system - explosion characteristics of the fuel (sample) in the test enclosures - ignition delay time).
- Characteristics of the flameless explosion venting device (type and construction including, but not limited to material specification, physical dimensions and parameters relevant for production quality control - static activation pressure of the venting device).
- Results (venting efficiency - $P_{red,max}$ - surface temperature and external pressure - result of flame transmission test - observations on external effects).

5. Conclusions

For many years, the most common and popular method of dust explosion protection has been venting. While conventional venting is quite efficient and recommended for most of the cases, its implementation is not always straightforward, especially for indoor equipment.
A new technology has been developed for dust explosions, thanks to extensive large scale test programs. This technology, called flameless venting, has now been adopted in guidelines and described in technical papers by several authors in the industry.
In comparison with conventional venting devices, the most notable benefits of using flameless venting devices are flame extinguishment and dust retention, resulting in blast, thermal radiation and noise minimization outside the protected equipment. Another distinct advantage is that it can be easily retrofitted to existing installations, without requiring significant changes to the process.

When considering flameless venting, one has to consider the following:
- The overall efficiency of the flameless venting device shall be determined by testing in order to calculate the required vent relief area.
- Special attention must be paid to dusts that have the potential to block the flame quenching element (coarse or fibrous dusts).
- Even though flameless venting devices greatly limit overpressures outside the protected equipment, it should be verified whether the building can withstand these pressure effects.

It is therefore recommended to work closely with an explosion protection manufacturer who can provide the appropriate recommendations and suitable equipment for the considered application.

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