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Dust collector explosions: A quantitative hazard evaluation method

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A R T I C L E I N F O

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A B S T R A C T

A methodology is presented to evaluate the explosion hazard of typical bag and cartridge dust collectors. The evaluation accounts for the expected development of suspended dust concentrations greater than the dust MEC during the normal pulsing of the bags or cartridges to remove part of the attached dust. Equations are presented to calculate these concentrations and also the associated partial volume explosion pressures resulting from the ignition of these dust clouds. Five quantitative examples are presented. The methodology also includes considerations of potential upset condition full volume explosions associated with the detachment of about half the dust on the bags or cartridges. A flow chart is offered to implement this hazard evaluation method for special situations in which the need for dust explosion protection may not be obvious.

1. Introduction

According to many dust explosion incident compilations, more dust explosion incidents have occurred in dust collectors than any other type of equipment (CSB, 2006; Going and Lombardo, 2007; Zalosh et al., 2005). Although the basic phenomena and typical explosion scenarios pertinent to the dust collector explosion hazard are well known, apparently there has not yet been a quantitative hazard evaluation methodology published.

NFPA 654 (2013) and other combustible dust standards require explosion protection for dust collectors when an explosion hazard exists in the collector. Paragraph 6.1.7 of NFPA 654 (2013) states that an explosion hazard exists "where both of the following conditions are possible:

(1) Combustible dust is present in sufficient quantity to cause enclosure rupture if suspended and ignited.
(2) A means of suspending the dust is present."

In order to implement the NFPA 654 (2013) explosion hazard criteria, it is necessary to estimate the amount of combustible dust in a collector during normal operation, and calculate the explosion pressure expected if all that dust were suspended and ignited. It is also necessary to evaluate various means of suspending the dust in the collector during both normal and abnormal operation.

The following section provides equations and test data to estimate how much dust can be expected to be attached to the filtration media in a collector during normal operation, and how that amount is influenced by the collector operating parameters. It also provides a methodology for estimating the amount and concentrations of dust dispersed during filter pulsing. Section 3 of the paper uses the amounts and concentrations of dispersed dust in the collector to estimate partial volume explosion pressures, and compares those pressures to typical strengths of collectors.

The fourth section of the paper describes possible scenarios in which significantly more than the normal amount of dust is dispersed within the collector such that an ignition would be more likely to produce a full volume dust explosion. The fifth section of the paper combines the results of the first four sections to present a quantitative dust explosion hazard evaluation method for filtration dust collectors.

2. Dust accumulations and dust clouds in filtration collectors

2.1. Dust collector design and operation

The most commonly used dust collector is the baghouse illustrated in Fig. 1. Dust laden air flows into the baghouse where it encounters a number of vertical filter bags suspended below a tube sheet that separates the clean air from the dirty air. The porous filter bags capture the dust on their exterior surfaces while the air flows into the bags and then up through the clean air plenum above the tube sheet. An exhaust fan, not shown in Fig. 1, located in the clean

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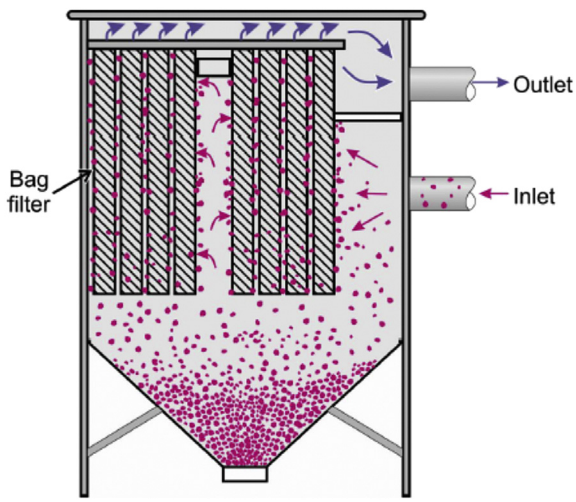

Fig. 1. Baghouse schematic diagram. From NIOSH RI 9689 (2012).

air duct pulls the air through the dust collection ducting and baghouse.

Another widely used type of filter collector is the cartridge collector illustrated in Fig. 2. Here the filter cartridges are usually horizontal and the dust laden air flows down and over the cartridges such that the dust is deposited on the cartridges while the dust free air flows through the cartridges on its way to the clean air outlet. As indicated in Figs. 1 and 2, dust that is not captured by the bags or cartridges falls into a hopper at the bottom of the collector.

The accumulated dust on the external surfaces of the bags and cartridges forms a filter cake shown in the normal operation diagram in Fig. 3. Periodically, a portion of the filter cake is blown off the bags or cartridges by a pulse of compressed air directed into the bag or cartridge interior as shown in the filter cleaning operation diagram in Fig. 3. The compressed air pulse temporarily interrupts and reverses the normal air flow direction into the bag/cartridge.

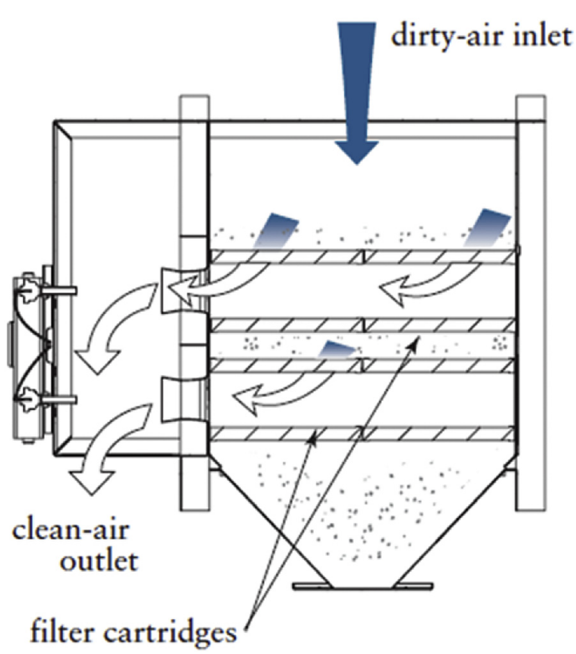

Fig. 2. Typical cartridge collector diagram showing normal operation. From Donaldson.

2.2. Dust loads on bags and cartridges

The dust filter cake load density (collected dust mass per unit bag surface area) and corresponding filter cake height depend on the inlet dust concentration, the filter media characteristics, the air pressure drop across the filter during dust collection, and the time interval or differential pressure that triggers air pulse reverse flow to initiate dust partial detachment from the bags. As an example, the filter cake height reported in (Saleem et al., 2011) for an inlet dust concentration of about 7 g/m^3 varied from 0.1 mm to 0.5 mm as the air pressure drop across the bags varied from 420 Pa to 1225 Pa (1.7–4.9 inches of water). Slightly lower heights in the range 0.075–0.4 mm were measured at inlet concentrations of 4.5–4.8 g/m^3. More detailed measurements accounting for patches of filter cakes on the filters and a wide variation of pressures showed a distribution of cake heights with an upper bound of about 1 mm at high differential pressures of about 1500 Pa (6 in water). Even larger heights up to 3 mm have been measured with much larger dust inlet concentrations of about 200 g/m^3 (Chen and Hsiau, 2009).

The relationship between filter cake load density, m″, and filter cake height, h, is

$$m'' = \rho_b h = \rho_p (1-\varepsilon) h \tag{1}$$

where ρ_b is the compacted bulk density of the filter cake just before pulsing, ρ_p is the dust particle density, and ε is the filter cake porosity. Filter cake porosities depend on the dust properties and the pressure drop (or corresponding air velocity) across the filter bag/cartridge. Chen and Hsiau, 2009 found ε to be in the range 0.65–0.71 for fly ash, whereas Sliva et al. (1999) report lower porosities in the range 0.28–0.33 for a fine cohesive powder. Dust particle densities for a variety of combustible dusts are listed in Table 1, and the corresponding filter cake load densities are shown for a porosity of 0.55 and 0.70, and filter cake depths of 0.08 mm and 0.50 mm, i.e. the range cited above for inlet concentrations of 4.5 g/m^3 to 7 g/m^3.

The total dust load, M, in a filter media dust collector can be calculated using the following equation.

$$M = m'' A_{bag} N_{bag} \tag{2}$$

where A_{bag} is the bag surface area, and N_{bag} is the number of bags in the collector. Pleated cartridges can have significantly larger effective surface areas than fabric bags of the same projected surface area. Table 2 shows some examples of bag areas, numbers of bags, and dirty side volume of five different small to medium size baghouse and cartridge dust collectors. Using a relatively light filter cake dust load density of 200 g/m^2 (lower than all but one of the m″ values in Table 1), the total quantities of filter cake dust, M, in these five dust collectors would vary from 30 kg to 371 kg. If the significantly higher dust loadings shown in Table 1 for the higher particle density materials were used in Equation (2), correspondingly larger amounts of filter cake dust would result.

2.3. Mass and concentration of dispersed dust during pulsing

Suspended dust concentrations in filter collectors vary in time and space as the entering dust flows around the various bags/cartridges and as groups of bags/cartridges (usually in rows) are sequentially pulsed. The highest concentrations usually occur near the bags/cartridges closest to the dirty air inlet particularly when those bags/cartridges are pulsed. Simon et al. (2010) have shown the highest concentrations occur around the first pulsed row of bags during each pulsing cycle, and that those bags subsequently