Protection against dust explosions in industrial plants handling carbon black

Technical Information TI 1230

orion ENGINEERED CARBONS

Focused. Innovative. Responsive.

1. Introduction

This information sheet is intended as an introductory guide to the explosion hazards of carbon black. More detailed information about dust explosion hazard is available in literature [1-3].

1.1 What is carbon black?

Carbon black has to be distinguished from carbon particles emitted from incomplete combustion of carbon-containing materials (called soot or black carbon), which are typically unwanted by-products. Carbon black is chemically and physically distinct from soot and black carbon, with most types containing greater than 97% elemental carbon arranged as aciniform (grape-like cluster) particulate [4].

1.2 Handling plants

Regarding this information, the term "handling" involves the storage, internal transport in any form, and processing of the carbon black in any fashion. These steps include emptying packaging, in-plant conveying, storage in containers and silos, and processing of carbon black with or into facilities equipment. If other substances are also present, then additional factors must be taken into consideration.

2. Explosion hazard for carbon black

Dust deflagration or explosion is a hazard when dealing with carbon black. A dust deflagration has the following requirements:

- A combustible dust (like carbon Black)
- Dispersion of the dust in air or other oxidant
- Sufficient concentration at or exceeding the minimum explosible concentration (MEC)
- Sufficiently powerful ignition source at or exceeding the minimum ignition energy (MIE)

If the deflagration is confined and produces a pressure sufficient to rupture the confining enclosure, the event is, by definition, an "explosion". Pelleted or granulated carbon black particles are too large for sufficient dispersion in air and are not capable of exploding. Nevertheless, even pelleted black still contains a certain portion of fines and/or dust which may increase by handling (conveying, processing, etc.).

2.1 Critical dust concentration

An important precondition for the explosibility of carbon black dust or powder dispersed in air is a concentration within its explosible range. At concentrations below the lower explosion limit (LEL), the carbon black quantity is too low to support an independent flame propagation. If the concentration is higher than the upper explosion limit (UEL), the quantity of oxygen is not sufficient. The UEL is on the order of kg/m^3 and for this reason hardly significant. The LEL for combustible dusts is better known as minimum explosible concentration (MEC).

The MEC is defined by certain test procedures [5-7] and is dependent on many factors, including particulate size distribution, moisture content, and particle shape. MEC values for carbon black dusts are typically > 50 g/m^3 and several orders of magnitude higher than allowed industrial hygiene limits which typically have threshold limits below 0.01 g/m^3 (e.g. United States, OSHA, PEL: 0.0035 g/m^3). Dust concentrations greater than 50 g/m^3 usually occur only inside equipment, provided that handling is properly performed and industrial hygiene instructions are obeyed [8].

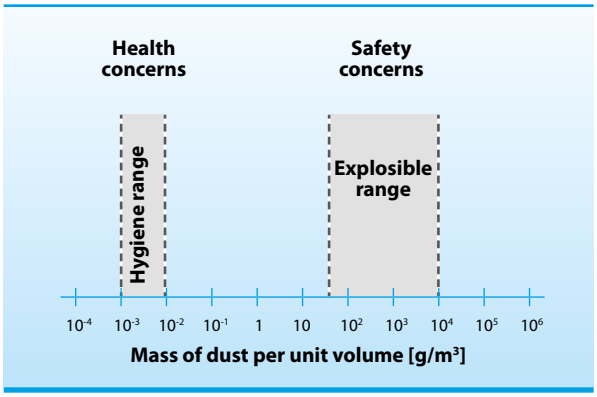

Figure 1: Dust concentration ranges [1]

2.2 Ignitibility

The ignitibility of a combustible dust is determined by the minimal ignition energy (MIE). It is defined (using standard test procedures [7, 9 and 10]) as the lowest spark energy with which a carbon black / air mixture under ideal conditions can still be ignited. It is also dependent on many factors, including particulate size distribution, moisture content, and temperature. MIE is critical in evaluating the probability for a dust explosion. While MIE for many explosible dusts (like epoxy resin, aluminum, sulphur, magnesium, sugar, polyethylene and wheat flour) is in the range of 1-100 mJ, MIE for carbon black dusts is typically above 1 kJ (=1,000,000 mJ). This excludes e.g. all types of electrostatic discharge as a potential ignition source for carbon black dust and grounding (potential equalization) will therefore eliminate all hazards caused by electrostatics.

But MIE can decrease drastically when carbon black is treated or mixed with other combustible substances. Mixtures of carbon black dust with flammable gases and vapors (so called hybrid mixtures) may modify the explosion risk substantially. Therefore, testing of the specific mixture is recommended to determine the explosibility parameters.

Smoldering carbon black can release carbon monoxide (CO), which can form explosible mixtures with air. Combined with carbon black, depending on the composition of this hybrid mixture, explosibility parameters may change. If carbon black dust were involved in an explosion it would contribute to the released energy.

3. Protective measures to prevent dust explosions

According to various international test methods [7, 11 and 12] carbon black is an explosible dust classified in hazard class St-1 (weak explosion) under these laboratory test conditions.

Dust explosion class	K_{ST} [bar m/s]	Characteristic
St 0	0	No explosion
St 1	>0 and ≤ 200	Weak explosion
St 2	> 200 and ≤ 300	Strong explosion
St 3	> 300	Very strong explosion

Table 1: Dust explosion classes

Despite this classification, maximum pressures generated in a carbon black dust explosion can still be strong enough to rupture equipment and / or can cause burn injuries. Typical flame temperatures generated from a dust explosion, even of slow burning St 1 classified dusts, are in excess of 2000 °C (3630 °F) and pressure can easily exceed 6 bar (90 psig).

Where ignitable carbon black dust / air mixtures are handled, equipment has to be classified according to hazardous area classifications [13-16]. Ignition sources that exceed the MIE of carbon black have to be strictly avoided.

As a fugitive dust, carbon black is prone to secondary dust explosions (the blast waves of a smaller primary explosion create a carbon black dust cloud which is then ignited by the primary explosion). This secondary explosion can either be devastating or may cause further (cascading) dust explosions.

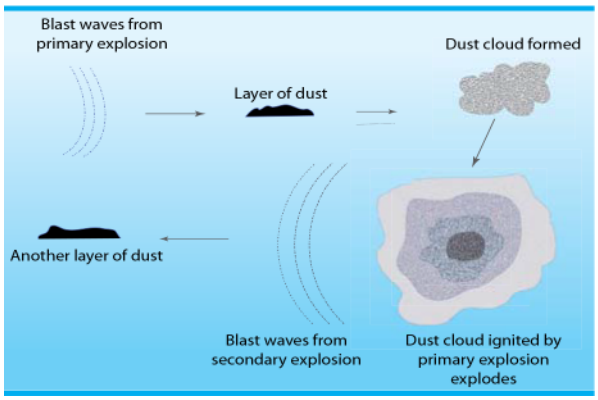

Figure 2: Primary and Secondary Dust Explosions [17]

Good engineering practices, good housekeeping practices, and effective dust removal systems are necessary to minimize carbon black emissions and resultant build-up on horizontal and some vertical surfaces. Fugitive carbon black emissions should be minimized and housekeeping activities performed periodically [18].

References:

[1] Dust Explosions in the Process Industries, 3rd edition, R.K. Eckhoff, Elsevier, 2003

[2] Dust Explosions: Course, Prevention, and Protection, W. Bartknecht, Springer-Verlag, 1989

[3] Dust Explosion Prevention and Protection, J. Barton (IChemE), Butterworth-Heinemann, 2002

[4] Carbon black vs. black carbon and other airborne materials containing elemental carbon: Physical and chemical distinctions, C. Long, M. Nascarella, P. Valberg, Environmental Pollution Vol. 181, Oct. 2013, pp. 271-286

[5] ASTM E 1515, Standard Test Method for Minimum Explosible Concentration of Combustible Dusts

[6] EN 14034-3, Determination of explosion characteristics of dust clouds - Part 3, Determination of the lower explosion limit LEL of dust clouds

[7] VDI 2263-1, Test methods for the determination of the safety characteristics of dusts

[8] Orion Engineered Carbons, Technical Information 1451, Handling of carbon black

[9] ASTM E 2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air

[10] EN 13821, Determination of minimum ignition energy of dust/air mixtures

[11] ASTM E 1226, Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts

[12] EN 14034, Determination of explosion characteristics of dust clouds

[13] NFPA 499, Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

[14] EN 60079-10-2, Explosive atmospheres, Part 10-2 Classification of areas, Combustible dust atmospheres.

[15] Directive 1999/92/EC (ATEX 137) on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres, Annex 1

[16] NFPA 70, National Electrical Code

[17] Abbasi T., Abbasi S.A. (2007). Dust explosions - Cases, causes, consequences and control. Journal of Hazardous Materials, 140, 7-44

[18] NFPA 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids

ENGINEERED CARBONS

Focused. Innovative. Responsive.

The Americas

Orion Engineered Carbons LLC
1700 City Plaza Drive, Suite 300
Spring, TX 77389
USA
Phone +1 832 445 3300

AMERICAS@orioncarbons.com

Europe/ Middle East/ Africa

Orion Engineered Carbons GmbH
Frankfurter Straße 60 - 68
65760 Eschborn
Germany
Phone +49 6196 771 929 100

EMEA@orioncarbons.com

Asia Pacific

Orion Engineered Carbons (China) Investment Co., Ltd.
Room 2301, 2302, 2307, BM InterContinental Business Center
100 Yutong Road, Jing'an District, Shanghai 20007
P. R. China
Phone +86 21 6107 0966

APAC@orioncarbons.com

Incorporated in Luxemburg

Orion Engineered Carbons S.A., 6, Route de Trèves, 2633 Senningerberg, Luxembourg, Phone +352 270 48 06 0

www.orioncarbons.com

OEC-TI 1230-10/2022