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FIRE AND EXPLOSION PROTECTION

TESTING DUST FOR COMBUSTIBILITY AND EXPLOSIBILITY

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INTRODUCTION

The purpose of this paper is to provide some practical guidance for those confronted with the need to assess their safety requirements where combustible particulate solids (i.e. dusts) are being handled in bulk quantities. It is clear from all points of view that dust must be tested to determine the nature of the risk. What dust to test? What tests are needed? When would it be acceptable to use values obtained from published sources? These questions and more will be discussed in this paper. The intent is to provide advice that will allow the reader to make informed decisions leading to improved safety, while simultaneously minimizing cost. The first step in developing a sound basis of safety is to understand the nature of the materials being handled.

TESTING VS. EXISTING PUBLISHED DATA

For well-known commodities, published data is acceptable in many cases. Generally such data can be considered to be conservative provided that it is obtained from a reliable source such as can be found in NFPA documents. With that said, it would be a mistake to accept published data at face value. The prudent person will carefully compare the available data against the actual material being handled.

TABLE 1 - PUBLISHED DUST VALUES – NFPA 652 2019

Bulk Material	Pmax (bar)	Kst (barm/s)
Aluminum	12.4	415
Coal, Bituminous	9.2	129
Corn Starch - Coarse	7.9	186
Dextrin	8.8	106
Epoxy Resin	7.9	129
Iron Carbonyl	6.1	111
Lactose	7.7	81
Polypropylene	8.4	101
Rice	7.7	118
Sugar - Granulated	6.2	66
Sugar - Powdered	7.0	122
Sulfur	6.8	151
Wheat Flour	8.3	87
Wheat Grain	9.3	112
Wood Flour	10.5	205

For example, what is the moisture content by weight of the materials being compared? If they are not similar, then the usefulness of the data must be considered not pertinent to the situation. Test protocols typically specify that materials being tested have a moisture content of less than 5% by weight. Another characteristic useful when comparing materials is particle size distribution. Larger particles oxidize at a lower rate than smaller ones all else being equal, so a particle size distribution comparison is useful when using published data. In cases where the available published data is for a material that is significantly different from that which is being handled, even if the two materials are otherwise similar, can lead to trouble. A short case study illustrates what can go wrong.

A new cookie bakery was being planned. During the design phase of the project explosion protection was considered, but because there were no cookies being made, no actual ingredients were available for evaluation and test. Since the ingredients for cookies are all pretty well known and understood, published data was used for sizing of the explosion protection devices. It was agreed that once up and running, actual samples would be obtained and tests conducted to confirm that the data and assumptions made during design were valid. Of course, as happens, that follow up activity did not get done. One of the ingredients in cookies is sugar and sugar is quite friable. Meaning it easily breaks down into smaller and smaller particles during transport and handling.

The published sugar data used was for granular material, but the sugar fines being collected in a dust collector at the end of the process line were found to be much smaller particles overall.

TABLE 2 - DUST CLASSIFICATIONS

Dust Explosion Classification	Kst
ST-1	0 < and ≤ 200
ST-2	200 < and ≤ 300
ST-3	> 300

This difference has the practical effect of rendering the sugar fines much more easily ignited and much more quickly oxidized (i.e. low MIE and high Kst – explanation later in this paper). To make a long story short, there was an explosion, the protection system was undersized, and although no person was hurt, property loss and production interruption were both considerable.

Another less obvious disadvantage to using published data is that, as already stated, it can be quite conservative. Meaning the published values can frequently be higher, in many cases much higher, than the values for the actual materials being handled. In plain English, testing the actual dust can and often does lead to significant savings in design and build of vessels requiring explosion protection. This will be discussed in more detail later in this paper.

DUST TESTING

There are numerous tests that can be conducted to characterize the behavior and associated risk for combustible dusts. As difficult as it may be to believe, not even the experts always agree on the when and why of which dust tests may be required in any given situation. A full discussion of the whole subject is beyond the scope of this paper. Rather a brief overview of the most frequently performed tests will be covered here as well as the reasons why each of these tests may be necessary. Note well: Not every test is necessary or required every time or for every dust or every situation. Work with your chosen expert (it is a very good idea to use an expert for this) to determine what to test and what tests are needed.

WHAT TESTING IS AVAILABLE?

1. Dust Combustibility Test. AKA the OSHA Salt Lake City test or the Go/No-Go test. Now this test is part of ASTM E1226 (see below). This is a simple screening test to determine if the dust can behave in an explosible manner. It cannot be used for sizing, but it can minimize testing costs if the result is a No-Go. Note this test should be conducted as the first step when conducting dust explosibility in accordance with ASTM E-1226.

2. Dust Explosibility Test. In North America it is defined by ASTM E-1226, but a similar protocol exists for Europe (as an aside, test results from recognized labs in the EU are similar and can be used safely). This test is most often conducted using a 20 liter sphere, but can be conducted using a 1 m3 test vessel (more on this later) and provides values for Kst and Pmax. These values are essential for sizing explosion protection devices such as explosion vents or active suppression systems. This test is basic and should be conducted for all combustible dusts.

3. Lower Explosible Concentration (MEC). In North America it is defined by ASTM 1515, but a similar protocol exists for Europe (as an aside, test results from recognized labs in the EU are similar and can be used safely). For a dust to behave in an explosible manner it must be entrained in a dust cloud of sufficient concentration to have flame propagate through the mass of unburned material in a chain reaction. The test is useful in situations where dust concentration may be low and controllable. Examples might include certain types of dryers or conveyors.

4. Minimum Ignition Energy (MIE). In North America it is defined by ASTM E-2019, but a similar protocol exists for Europe (as an aside, test results from recognized labs in the EU are similar and can be used safely). Some dusts are more easily ignited than others. This test determines how much static discharge energy is required to ignite a dust cloud. Certain dusts are easily ignited and some are hard to ignite. Both extremes are important to know for handled materials. There are situations where safe handling requires that personnel working with handled materials need to be grounded to prevent static discharge ignition from their own bodies. At the other extreme there are materials that are so difficult to ignite that they can be safely processed with no fear from static.

5. Related to MIE are tests for the bulk resistivity and the static relaxation rate for materials. These characteristics are very important to know where materials with low MIE (~ <30 mJ) are being handled.
6. Minimum Auto Ignition Temperature (MAIT) for a layer ASTM E2021, and for a cloud E1491. These tests are important to conduct where materials are handled at elevated temperatures, such as in a dryer.

WHAT DUST TO TEST?

1. This question starts with picking the location in the process for collecting the dust sample for test. Ideally the sample would be from a location where the finest fraction of the dust is collected. A dust collector at or near the end of the process would be a likely possibility.
2. The test protocols typically specify that the sample be dry (i.e.<5% moisture by weight). This is done to ensure that near worst case materials are tested. But what if moisture is controlled in the process to a different value? In that situation maybe consideration should be given to testing the materials as near to actual process conditions as practical. As an aside, it is a little known fact that most dust explosions occur in the cold, dry winter months. When in doubt dry the material before testing.
3. This raises a related question. Should the dust be tested "as received" or should it be dried and reduced/classified to test only fines? Again the protocols encourage the effort to capture worst case. In cases where variables such as particle size and moisture content are carefully monitored and controlled, perhaps testing materials "as received" is the best option, otherwise it would be prudent to take the more conservative approach and follow the protocols.
4. The next consideration, is the dust being handled comprised of only one material, or is it a mixture of several? Mixtures pose several challenges. For one thing, mixtures often contain a multitude of components. For example, it is common for multiple vitamins to have a bill of material of at least 25 different ingredients. It is not practical to test everything. In general the component ingredients that comprise the bulk of the total mix by weight or by volume will be representative of the combustibility characteristics of the total mix. So in the multiple vitamin example, the top 5 or 6 components represent the largest percentage of the mix and it is these that should be tested at a minimum.
5. Dusts that can change character or degrade pose a special challenge both in sample collection and packaging and shipping. Metal dusts offer an excellent case in point. Metal dusts oxidize quite readily and must be packed in air-tight vacuum containers and shipped the fastest way possible. Keep in mind that not all dust samples can be air freighted.

THE CONTROVERSY CONCERNING TEST VALIDITY

Recently there has been a challenge mounted where certain materials have tested positive, but the results are disputed. Papers have been written and heated discussions have frayed nerves, but the controversy remains unresolved. A bit of background is necessary to frame the dispute. As mentioned, there is a test apparatus that is a 20 liter and another that is a 1 cubic meter vessel. The 20 liter sphere was specifically developed to be a lab practical test apparatus that could provide a result that is reasonably similar to (i.e. +/- 10%) to the result which would be achieved in the one cubic meter vessel. So the one cubic meter vessel is the benchmark vessel. To achieve an acceptable level of accuracy in a 20 liter sphere there are certain details of the test set-up that can be adjusted as necessary to hit the target. A comprehensive methodology and peer review have been set up to ensure accuracy. In any event in certain cases involving materials that perhaps are very hard to ignite, the 20 liter sphere has yielded a positive result, but retest in the one cubic meter vessel has not provided confirmation.

This raises questions: Why? What does this mean? Can results obtained using a 20 liter sphere be relied upon?

The why and the wherefore of it seem to rest on the notion that depending on the test setup, the 20 liter sphere can be “overdriven” by too much ignition energy. So the unwary pay for another very expensive test in the larger one cubic meter vessel and come up negative. So what do we know from that? Well we know that under one set of conditions the material tested positive and under another set of conditions the material did not test positive. Regulatory bodies typically take the position that a positive result is just that and the fact that a different result using a different test set-up did not confirm it, is neither here nor there. As far as OSHA is concerned a Kst = 1 bar*m/s demarks a combustible dust. Moreover, the 20 liter sphere is ubiquitous in North America and has been for decades. Challenging 20 liter sphere data is difficult. However, more recent studies have suggested that 20 liter sphere data may also not be accurate for metal dusts. Comparable tests between a 20 liter sphere and a one cubic meter sphere showed that the same metal dusts actually increased in Kst when tested in the larger test apparatus. More studies are being done to explain this phenomenon as metal dusts seem to behave differently during testing compared to organic materials.

IN SUMMATION

The first step in the process of developing a sound basis for safety for combustible dusts is to develop a scientific and comprehensive understanding of the materials being handled. Every dust is unique and every explosion involving them is unique. The more you know the better your chances of averting unacceptable loss. For well know commodities such as most agricultural dusts, published data from reliable source should be sufficiently conservative. Note that it might cost more in the end than having data from the actual process. It is also necessary to make sure that the published data used is representative of material that is similar to that being handled. When in doubt, have the material tested. There are a variety of tests that are available to quantify the characteristics of the dust. Not every test is required in every situation. A thorough understanding of the process is required to determine which tests are needed. Although some of the test methodology has been challenged, the fact is that those who have used the data and acted appropriately have improved their safety and in so far as is known have sustained no losses.

ABOUT CV TECHNOLOGY

Headquartered in Jupiter, Florida, CV Technology is a global leader in explosion mitigation solutions for processes handling combustible dusts. CV Technology is a manufacturer of explosion mitigation products including explosion vents, flameless vents, mechanical isolation valves, and chemical suppression equipment. CV Technology also offers combustible dust audits and dust testing services.

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