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Dust Classification Testing and Explosibility of Combustible Dusts: What is the Difference?

Dust classification by explosion severity (OSHA Class II) testing and explosibility of combustible dusts (P_{max} and K_{st}) are two different tests performed at the CRC, yet both of these tests utilize the Kuhner 20 Liter vessel, follow a similar protocol, and generate the same type of data, P_{ex} and R_{ex}. If that's the case, why, you may ask, can only one of these tests be used to determine the dust deflagration index (K_{st} value)? After reading this bulletin you will be able to answer this question with a better understanding of these two tests including how they are performed, the differences in the results obtained from each, and the impact these results have on deflagration protection measures that are being considered.

Know Your Variables

Let's start with a basic review of the variables involved in the testing. The ASTM E1226 definitions of the five variables discussed in both test protocol results are reproduced below.

P_{ex} - The maximum explosion pressure reached during the course of a single deflagration test.[1]

P_{max} – The maximum pressure reached during the course of a deflagration for the optimum concentration of the dust tested.[1]

$(dP/dT)_{ex}$ – R_{ex}, The maximum rate of pressure rise during the course of a single deflagration test.[1]

$(dP/dT)_{max}$ – R_{max}, The maximum rate of pressure rise during the course of a deflagration for the optimum concentration of the dust tested.[1]

K_{st} – dust deflagration index, maximum (dP/dT) measured at the optimum dust concentration normalized to a $1.0 m^3$ volume.[1]

As can be seen from the definitions, K_{st} values must be obtained using the optimum deflagration conditions that can occur with a dust. That means a series of tests over a large range of concentrations must be conducted to determine what dust concentration is optimum for a deflagration. Once the optimum dust concentration is determined the P_{max} and R_{max} values can be found. The K_{st} can then be calculated using this R_{max} value, which essentially represents the R_{ex} at the optimum deflagration concentration for the dust being tested.

Reviewing the Test Protocols

Dust Classification by Explosion Severity

The test protocols are nearly identical when it comes to conducting the actual tests. Both tests start with a sieve analysis and determination of moisture content to ensure the sample has less than 5% water content. The samples for both tests are then dispersed in the Kuhner vessel at varying concentrations to determine explosibility. Here the two test protocols deviate from each other. The dust classification testing requires that up to three tests are conducted using dust concentrations of 500 g/m^3, 1000 g/m^3, and 2000 g/m^3.[2] Each of these tests produces a P_{ex} and a R_{ex} value which are

Figure 1: 20 L vessel used in dust deflagration testing.

then used to determine the explosion severity (ES) for each test. The ES is calculated using the following equation:

$$ES = \frac{(P_{ex} \cdot R_{ex})_{SampleTested}}{(P_{ex} \cdot R_{ex})_{PittsburgCoal}}$$

Therefore dust classification only examines data on a test by test basis in order to determine the area classification as far as electrical equipment is concerned. If any one of the three tests produces an ES greater than 0.5 the dust sample is considered a Class II combustible based on the criteria provided in Table 1.

Table 1: Dust Classification Criteria[3]

ES Value	Classification
< 0.4	Not Class II Combustible
0.4 < ES < 0.5	Indeterminate - Evaluate Ignition Sensitivity
> 0.5	Class II Combustible

The P_{ex} and the R_{ex} are determined from graphical outputs of the test, as seen in Figure 2 below. Note how there is only data for one test shown in each graph.

Explosibility of Dusts, K_{st}

Determining the explosibility of a dust requires three series of tests to be completed resulting in a total of at least 11 individual tests and often more. Each test series requires the sample dust to be tested at several concentrations, typically (but not always):

Series 1: 500, 750, 1000, 1250 and 1500 g/m^3

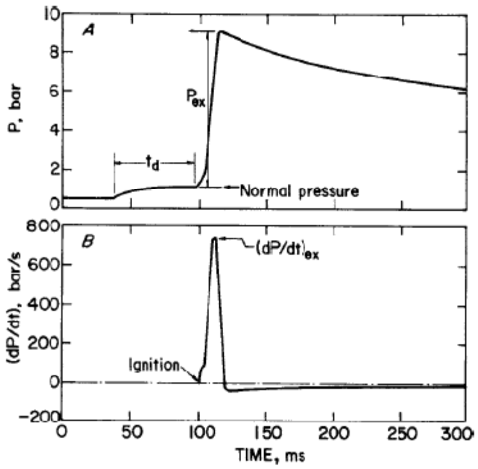

Figure 2: Typical graph showing P_{ex} and dP/dT_{ex} for a dust deflagration.[1]
(Reproduced from ASTM E1226)

Series 2: Concentrations resulting in the maximum values of P_{ex} and R_{ex} determined in Series 1 and the next higher and lower concentration by adding and subtracting 250 g/m^3.
Series 3: Repeat of Series 2.[1]

Once data from all 11 (or more) tests has been collected, values of P_{max} and R_{max} can be determined by averaging the highest single values for P_{ex} and R_{ex} respectively from each of the 3 test series. The R_{max} is used to determine the K_{st} in the following formula:

$$K_{st} = R_{max} \cdot V^{\frac{1}{3}}$$

In the formula above, V is the volume of the vessel used during the tests.

Based on the method of determining the P_{max} and R_{max}, these two values cannot be obtained through the dust classification testing and therefore neither can the K_{st} value. Figure 3 shows the compilation of data from explosibility testing in order to determine the P_{max} and R_{max} values. Note how multiple data sets are displayed in comparison to the single data set in the dust classification testing. A clear optimum concentration with corresponding P_{max} and R_{max} can be established from the data presented in Figure 3. This was not the case for data presented in Figure 2 for the dust classification testing, as it only examined one test at a time and not enough tests are completed in the procedure to determine a clear optimum concentration.

What does it mean for Explosion Protection?

When preparing to design an explosion protection system the dust combustion characteristics required are the K_{st} and P_{max} values per NFPA 654: Standard for the prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, NFPA 68: Vent Sizing, and NFPA 69: Suppression and Isolation Systems. As discussed throughout this bulletin, these values cannot be obtained through the OSHA Class II dust classification testing. The dust classification test simply determines if the dust is a Class II combustible dust or not. Additional data is required to obtain statistically valid values of P_{max} and K_{st}.

The dust classification testing results focus on the explosion severity for individual tests while the explosibility of a combustible dust test, or more commonly referred to as the K_{st}, examines a much larger data set to determine the

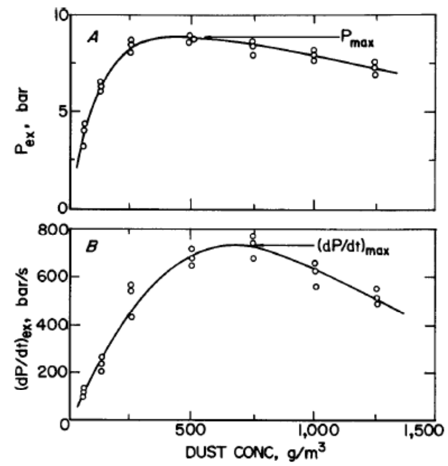

Figure 3: P_{ex} and dP/dT_{ex} data as a function of dust concentration for determining the optimum deflagration concentration and equivalent P_{max} and R_{max}.[1]
(Reproduced from ASTM E1226)

optimum deflagration concentration and its maximum pressure and maximum rate of pressure rise. The dust classification testing reports whether the ES is greater than 0.5 on any 1 of up to three tests performed. The K_{st} testing reports an average of the highest single P_{ex} and R_{ex} values from each of the three test series, which are then termed P_{max} and R_{max}, and represent conditions for the optimum dust concentration. It is this optimum dust concentration R_{max} value that must be used to determine the K_{st}, not any one R_{ex} value obtained from a single deflagration test.

It is important to note that even though the dust may have an ES less than 0.4 and be considered combustible but not Class II an explosion protection system may still be warranted by NFPA 654 requirements. The K_{st} value must be examined along with the P_{max} value. The K_{st} provides data on how reactive the dust material is while the P_{max} value tells you how destructive an explosion could be. So, if a test results in a low K_{st} and a high P_{max}, although the explosion may take more effort to initiate, the explosion should it occur could still be extremely destructive. Having an explosion protection system in place would help to mitigate the overall damage. With all that said, are you adequately protected?

References

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