



Standard Test Method for Explosibility of Dust Clouds¹

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INTRODUCTION

Particulate solids of combustible materials present a significant risk of dust explosion if suspended in air and subjected to an ignition source. The methods of this standard can be used to determine if a dispersed dust cloud is “explosible” and, if so, to what degree it is explosible, that is, its “explosibility.” Knowledge that a dust may be explosible if dispersed as a dust cloud is important in the conduct of a process hazard safety review. Contained herein is an explosibility or go/no-go screening test procedure for the purpose of determining whether a dust sample is explosible.

If a dust is explosible, the explosibility parameters, maximum explosion pressure, P_{\max} ; maximum rate of pressure rise, $(dP/dt)_{\max}$; and explosibility index, K_{St} , are useful in the design of explosion prevention and control measures as described in national (NFPA) and international (ISO, CEN and others) explosion protection standards.

1. Scope

1.1 Purpose. The purpose of this test method is to provide standard test methods for characterizing the “explosibility” of dust clouds in two ways, first by determining if a dust is “explosible,” meaning a cloud of dust dispersed in air is capable of propagating a deflagration, which could cause a flash fire or explosion; or, if explosible, determining the degree of “explosibility,” meaning the potential explosion hazard of a dust cloud as characterized by the dust explosibility parameters, maximum explosion pressure, P_{\max} ; maximum rate of pressure rise, $(dP/dt)_{\max}$; and explosibility index, K_{St} .

1.2 Limitations. Results obtained by the application of the methods of this standard pertain only to certain combustion characteristics of dispersed dust clouds. No inference should be drawn from such results relating to the combustion characteristics of dusts in other forms or conditions (for example, ignition temperature or spark ignition energy of dust clouds, ignition properties of dust layers on hot surfaces, ignition of bulk dust in heated environments, etc.)

1.3 Use. It is intended that results obtained by application of this test be used as elements of an explosion risk assessment that takes into account other pertinent risk factors; and in the specification of explosion prevention systems (see, for example

NFPA 68, NFPA 69, and NFPA 654) when used in conjunction with approved or recognized design methods by those skilled in the art.

NOTE 1—Historically, the evaluation of the deflagration parameters of maximum pressure and maximum rate of pressure rise has been performed using a 1.2-L Hartmann Apparatus. Test Method E789, which describes this method, has been withdrawn. The use of data obtained from the test method in the design of explosion protection systems is not recommended.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

D3173 Test Method for Moisture in the Analysis Sample of Coal and Coke

D3175 Test Method for Volatile Matter in the Analysis Sample of Coal and Coke

E789 Test Method for Dust Explosions in a 1.2-Litre Closed Cylindrical Vessel (Withdrawn 2007)³

¹ This test method is under the jurisdiction of ASTM Committee E27 on Hazard Potential of Chemicals and is the direct responsibility of Subcommittee E27.05 on Explosibility and Ignitability of Dust Clouds.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

E1445 Terminology Relating to Hazard Potential of Chemicals

E1515 Test Method for Minimum Explosible Concentration of Combustible Dusts

2.2 NFPA Publication.⁴

NFPA 68 Standard on Explosion Protection By Deflagration Venting

NFPA 69 Standard on Explosion Prevention Systems

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

2.3 VDI Standard:

VDI-3673 Pressure Release of Dust Explosions⁵

2.4 ISO Standard:

ISO 6184/1 Explosion Protection Systems, Part 1, Determination of Explosion Indices of Combustible Dusts in Air⁶

3. Terminology

3.1 For determination of terms relating to hazard potential of chemicals see Terminology **E1445**.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 P_{ex} —the maximum pressure rise (above the pressure in the vessel at the time of ignition) produced during the course of a single deflagration test (see **Fig. 1**).

⁴ Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, <http://www.nfpa.org>.

⁵ Available from Beuth Verlag, D-1000 Berlin, Federal Republic of Germany or American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁶ Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch> or from Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

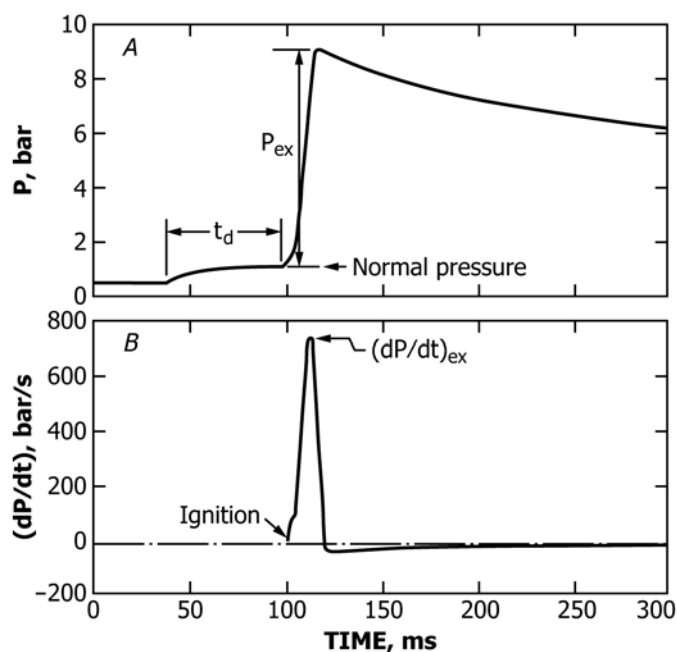


FIG. 1 Typical Recorder Tracings of Absolute Pressure, P , and Rate of Pressure Rise, dP/dt , for a Dust Deflagration in a 20-L Chamber

3.2.2 P_m —maximum pressure rise produced during the course of a single deflagration test that is corrected for the effects of ignitor pressure and cooling in the 20-L vessel (see Sections **X1.8** and **X1.9**).

3.2.3 $P_{ex,a}$ —the maximum absolute pressure produced during the course of a single deflagration test, $n - P_{ex,a} = P_{ex} + P_{ignition}$.

3.2.4 P_{max} —the maximum pressure rise (above pressure in the vessel at the time of ignition) reached during the course of a deflagration for the optimum concentration of the dust tested. P_{max} is determined by a series of tests over a large range of concentrations (see **Fig. 2**). It is reported in bar.

3.2.5 $P_{ignition}$ —the absolute pressure in the vessel at the time of ignition.

3.2.6 $\Delta P_{ignition}$ —the pressure rise above $P_{ignition}$ caused by activation of the ignitor(s) with no dust present in the chamber.

3.2.7 $(dP/dt)_{ex}$ —the maximum rate of pressure rise during the course of a single deflagration test (see **Fig. 1**).

3.2.8 $(dP/dt)_{max}$ —maximum value for the rate of pressure increase per unit time reached during the course of a deflagration for the optimum concentration of the dust tested. It is determined by a series of tests over a large range of concentrations (see **Fig. 2**). It is reported in bar/s.

NOTE 2—Recorder tracings of pressure (absolute) and rate of pressure rise for a typical dust deflagration in a 20-L chamber are shown in **Fig. 1**. The maximum values, P_{max} and $(dP/dt)_{max}$ for a dust are determined by testing over a large range of concentrations as shown in **Fig. 2**.

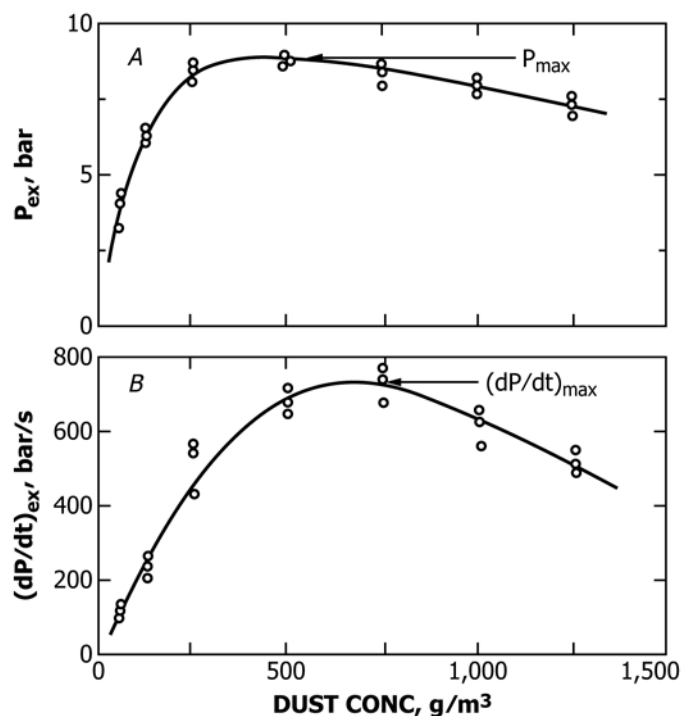


FIG. 2 P_{max} and $(dP/dt)_{max}$ as a Function of Concentration for a Typical Dust in a 20-L Chamber

3.2.9 *deflagration index*, K_{St} —maximum dP/dt normalized to a 1.0-m³ volume. It is measured at the optimum dust concentration. K_{St} is defined in accordance with the following cubic relationship:

$$K_{St} = (dP/dt)_{\max} V^{1/3} \quad (1)$$

where:

- P = pressure, bar,
- t = time, s,
- V = volume, m³, and
- K_{St} = bar m/s.

3.2.10 *explosible*—a material with a Pressure Ratio equal or greater than 2.0 in any test when tested using the Explosibility or Go/No-go Screening Test described in Section 13.

NOTE 3—An explosible dust when dispersed in air is capable of propagating a deflagration, which could cause a flash fire or explosion depending on the level of confinement.

3.2.11 *ignition delay time*, t_d —experimental parameter defined as the time interval between the initiation of the dust dispersion procedure (the time at which the dispersion air starts to enter the chamber) in an experimental apparatus and the activation of the ignition source (see Fig. 1). The ignition delay time characterizes the turbulence level prevailing at ignition under the defined test conditions.

3.2.12 *pressure ratio (PR)*, n — $PR = (P_{ex,a} - \Delta P_{ignitor}) / P_{ignition}$

NOTE 4—When testing in the Siwek 20-L vessel (see Appendix X1) PR may be calculated using the corrected explosion pressure, $n - PR = (P_m + P_{ignition}) / P_{ignition}$.

4. Summary of Test Method

4.1 A dust cloud is formed in a closed combustion chamber by an introduction of the material with air.

4.2 Ignition of this dust-air mixture is then attempted after a specified delay time by an ignition source located at the center of the chamber.

4.3 The pressure time curve is recorded on a suitable piece of equipment.

5. Significance and Use

5.1 This test method provides a procedure for performing laboratory tests to evaluate deflagration parameters of dusts.

5.2 The data developed by this test method may be used for the purpose of sizing deflagration vents in conjunction with the nomographs and equations published in NFPA 68, ISO 6184/1, or VDI 3673.

5.3 The values obtained by this testing technique are specific to the sample tested and the method used and are not to be considered intrinsic material constants.

5.4 For dusts with low K_{St} -values, discrepancies have been observed between tests in 20-L and 1-m³ chambers. A strong ignitor may overdrive a 20-L chamber, as discussed in Test Method E1515 and Refs (1-3).⁷

⁷ The boldface numbers in parentheses refer to a list of references at the end of this standard.

NOTE 5—Ref (2) concluded that dusts with K_{St} -values below 45 bar m/s when measured in a 20-L chamber with a 10 000-J ignitor, may not be explosible when tested in a 1-m³ chamber with a 10 000-J ignitor. Ref (2) and unpublished testing has also shown that in some cases the K_{St} -values measured in the 20-L chamber can be lower than those measured in the 1-m³ chamber. Refs (1) and (3) found that for some dusts, it was necessary to use lower ignition energy in the 20-L chamber in order to match MEC or MIC test data in a 1-m³ chamber. If a dust has measurable (nonzero) P_{max} - and K_{St} -values with a 5000 or 10 000-J ignitor when tested in a 20-L chamber but no measurable P_{max} - and K_{St} -values with tests conducted using an ignition source less than or equal to 2500 J, it may be helpful to test the material in a larger chamber such as a 1-m³ chamber using at least a 10 000-J ignition source to further characterize the material's explosibility in dust cloud form.

6. Interferences

6.1 In certain industrial situations where extreme levels of turbulence may be encountered, such as the rapid introduction of expanding gases resulting from combustion in connected piping or operations where hybrid mixtures (combustible dusts and combustible gases or vapors) are encountered, the use of the deflagration indices based on this test method for the sizing of deflagration vents may not be possible.

7. Apparatus

7.1 The equipment consists of a closed steel combustion chamber with an internal volume of at least 20 L, spherical or cylindrical (with a length to diameter ratio of approximately 1:1) in shape.

7.2 The apparatus must be capable of dispersing a fairly uniform dust cloud of the material.

7.3 The pressure transducer and recording equipment must have a combined response rate greater than the maximum measured rates of pressure rise.

7.4 An example of a chamber and specific procedures that have been found suitable are shown in Appendix X1. This chamber has been calibrated as described in Section 10.

7.5 Examples of other test chambers that have not yet been calibrated are listed in Appendix X2.

8. Safety Precautions

8.1 Prior to handling a dust material, the toxicity of the sample and its combustion products must be considered. This information is generally obtained from the manufacturer or supplier. Appropriate safety precautions must be taken if the material has toxic or irritating characteristics. Tests using this apparatus should be conducted in a ventilated hood or other area having adequate ventilation.

8.2 Before initiating a test, a physical check of all gaskets and fittings should be made to prevent leakage.

8.3 All enclosures containing electrical equipment should be connected to a common ground. Shielded cables should be used.

8.4 If chemical ignitors are used as an ignition source, safety in handling and use is a primary consideration. Ignition by electrostatic discharge must be considered a possibility. When handling these ignitors, eye protection must be worn at all times. A grounded, conductive tabletop is recommended for