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Standard Test Method for
Minimum Explosible Concentration of Combustible Dusts[1]

This standard is issued under the fixed designation E 1515; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This test method describes procedures for measuring the minimum concentration of a combustible dust (dispersed in air) that is capable of propagating a deflagration. The tests are made in laboratory chambers that have volumes of 20 L or larger.

1. Scope

1.1 This test method covers the determination of the minimum concentration of a dust-air mixture that will propagate a deflagration in a near-spherical closed vessel of 20 L or greater volume.

NOTE 1—The minimum explosible concentration (MEC) is also referred to as the lower explosibility limit (LEL) or lean flammability limit (LFL).

1.2 Data obtained from this test method provide a relative measure of the deflagration characteristics of dust clouds.

1.3 This test method should be used to measure and describe the properties of materials in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment that takes into account all of the factors that are pertinent to an assessment of the fire hazard of a particular end use.

1.4 The values stated in SI units are to be regarded as the 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.* Specific precautionary statements are given in Section 8.

2. Referenced Documents

2.1 *ASTM Standards:* [2]
D 3173 Test Method for Moisture in the Analysis Sample of Coal and Coke
D 3175 Test Method for Volatile Matter in the Analysis Sample of Coal and Coke
E 681 Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)
E 1226 Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *dust concentration, n*—the mass of dust divided by the internal volume of the test chamber.

3.1.2 *(dP/dt)*$_{ex}$, *n*—the maximum rate of pressure rise during the course of a single deflagration test.

3.1.3 *minimum explosible concentration (MEC), n*—the minimum concentration of a combustible dust cloud that is capable of propagating a deflagration through a well dispersed mixture of the dust and air under the specified conditions of test.

3.1.4 $P_{ignition}$, *n*—the absolute pressure at the time the ignitor is activated, see Fig. 1.

3.1.5 $\Delta P_{ignitor}$, *n*—the pressure rise in the chamber due to the ignitor by itself in air at atmospheric pressure

3.1.6 $P_{ex,a}$, *n*—the maximum explosion pressure (absolute) reached during the course of a single deflagration test (see Figs. 1 and 2).

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

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[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.
Current edition approved ~~Dec.~~Oct. 1, ~~2003.~~2007. Published ~~January 2004. Originally~~approved ~~November 2007~~. Originally approved in 1993. Last previous edition approved in 2003 as E 1515 – 03a.
² Annual Book of ASTM Standards, Vol 05.05.
[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.
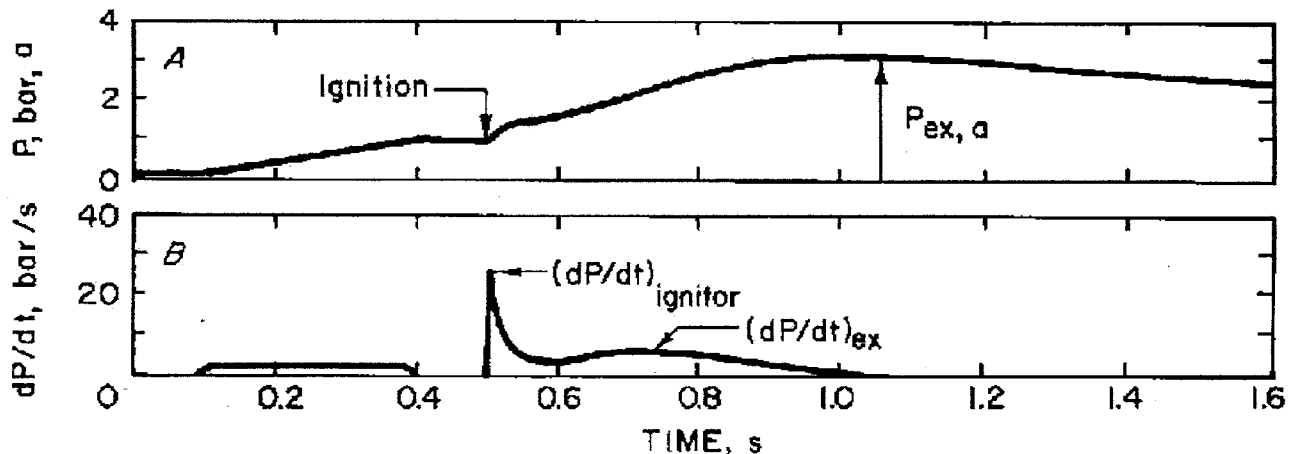
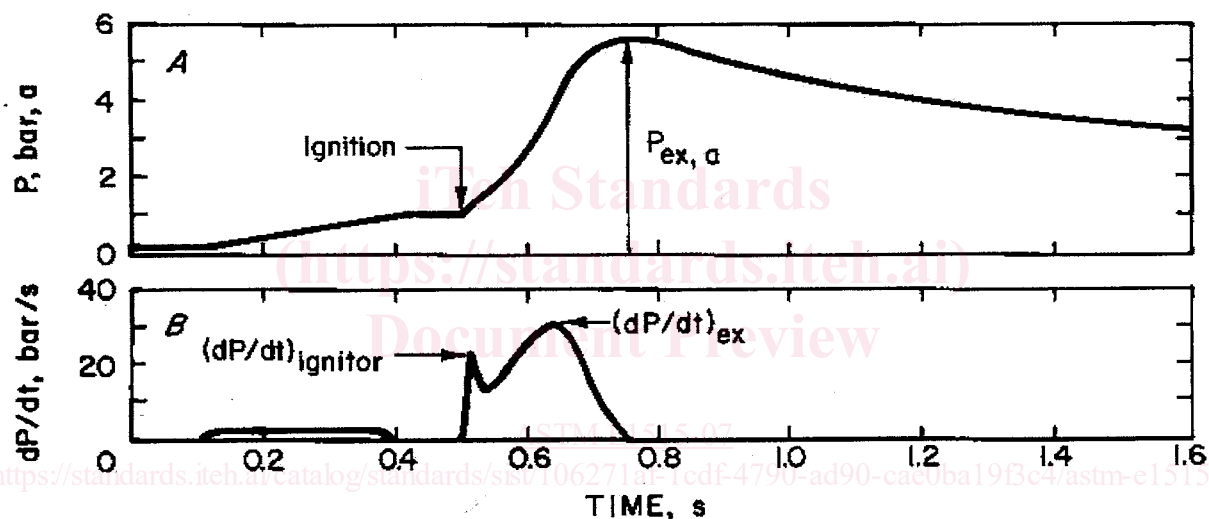FIG. 1 Typical Recorder Tracings for a Weak Dust Deflagration in a 20-L Chamber, using a 2500 J Ignitor

FIG. 2 Typical Recorder Tracings for a Moderate Dust Deflagration in a 20-L Chamber, using a 2500 J Ignitor

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. The test is normally made at atmospheric pressure.

4.2 Ignition of this dust-air mixture is then attempted after a specified delay time by an ignition source located near 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 relative deflagration parameters of dusts.

5.2 The MEC as measured by this test method provides a relative measure of the concentration of a dust cloud necessary for an explosion.

5.3 Since the MEC as measured by this test method may vary with the uniformity of the dust dispersion, energy of the ignitor, and propagation criteria, the MEC should be considered a relative rather than absolute measurement.

5.4 If too weak an ignition source is used, the measured MEC would be higher than the "true" value. This is an ignitability limit rather than a flammability limit, and the test could be described as" underdriven." Ideally, the ignition energy is increased until the measured MEC is independent of ignition energy. However, at some point the ignition energy may become too strong for the size of the test chamber, and the system becomes "overdriven." When the ignitor flame becomes too large relative to the chamber volume, a test could appear to result in an explosion, while it is actually just dust burning in the ignitor flame with no real propagation beyond the ignitor.

5.5 The recommended ignition source for measuring the MEC of dusts in 20-L chambers is a 2500 or 5000 J pyrotechnic

ignitor.[3]Measuring the MEC at both ignition energies will provide information on the possible overdriving of the system.[4] To evaluate the effect of possible overdriving in a 20-L chamber, comparison tests may also be made in a larger chamber, such as a 1 m³-chamber.

5.6 If a dust ignites with a 5000 J ignitor but not with a 2500 J ignitor in a 20-L chamber, this may be an overdriven system.[4]In this case, it is recommended that the dust be tested with a 10 000 J ignitor in a larger chamber, such as a 1 m³-chamber, to determine if it is actually explosible.

5.7 The values obtained by this test method are specific to the sample tested (particularly the particle size distribution) and the method used and are not to be considered intrinsic material constants.

6. Interferences

6.1 Unburned dust or combustion products remaining in the chamber or disperser from a previous test may affect results. The chamber and disperser should both be cleaned thoroughly before each test is made.

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 between 1.3:1 and 0.7:1) in shape.

7.2 The vessel should be designed and fabricated in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII.[5] A maximum allowable working pressure (MAWP) of at least 15 bar is recommended.

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

7.4 Optical dust probes, such as those described in Footnotes[6,7] 7 and 8, may be used to monitor the uniformity of the dust dispersion.

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

7.6 An example of a chamber and specific procedures that have been found suitable are shown in Appendix X1.

NOTE 2—Another 20 L chamber design is described in Appendix X1 of Test Method E 1226.

8. Safety Precautions

8.1 Prior to handling a dust, 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 If chemical ignitors are used as an ignitor source, safety in handling and use is a primary consideration. Premature 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 preparation. Federal, state, and local regulations for the procurement, use, and storage of chemical ignitors must be followed.

8.4 All testing should initially be conducted with small quantities of sample to prevent overpressurization due to high energy material.

8.5 Explosive, highly reactive, or easily decomposed materials should not be tested unless they have been characterized by prior testing. Procedures such as the use of barricades, hoods, and personal protective equipment should be used as judgment indicates.

9. Sampling, Test Specimens, and Test Units

9.1 It is not practical to specify a single method of sampling dust for test purposes because the character of the material and

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[3] Annual Book of ASTM Standards, Vol 14.02.

[3] The pyrotechnic ignitors are available commercially from Cesana Corp., PO Box 182, Verona, NY 13478, or from Fr. Sobbe, GmbH, Beylingstrasse 59, Postfach 140128, D-4600 Dortmund-Derne, Germany.

[4] The pyrotechnic ignitors are available commercially from Cesana Corp., PO Box 182, Verona, NY 13478, or from Fr. Sobbe, GmbH, Beylingstrasse 59, Postfach 140128, D-4600 Dortmund-Derne, Germany.

[4] Cashdollar, K. L., and Chatrathi, K., "Minimum Explosible Dust Concentrations Measured in 20-L and 1-m³ Chambers," *Combustion Science and Technology,* Vol. 87, pp. 157–171, 1993.

[5] Cashdollar, K. L., and Chatrathi, K., "Minimum Explosible Dust Concentrations Measured in 20-L and 1-m³ Chambers," *Combustion Science and Technology,* Vol. 87, pp. 157–171, 1993.

[5] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[6] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[6] Cashdollar, K. L., Liebman, I., and Conti, R. S., "Three Bureau of Mines Dust Probes," RI 8542, U.S. Bureau of Mines, 1981.

[7] Cashdollar, K. L., Liebman, I., and Conti, R. S., "Three Bureau of Mines Dust Probes," RI 8542, U.S. Bureau of Mines, 1981.

[7] Conti, R. S., Cashdollar, K. L., and Liebman, I., "Improved Optical Dust Probe for Monitoring Dust Explosions," *Review of Scientific Instruments,* Vol 53, 1982, pp. 311–313.

its available form affect selection of the sampling procedure. Generally accepted sampling procedures should be used as described in MNL 32.[8]

9.2 Tests may be run on an as-received sample. However, due to the possible accumulation of fines at some location in a processing system, it is recommended that the test sample be at least 95 % minus 200 mesh (75 µm).

9.3 To achieve this particle fineness (≥95 % minus 200 mesh), the sample may be ground or pulverized or it may be sieved.

NOTE 2—The 3—The operator should consider the thermal stability and the friction and impact sensitivity of the dust during any grinding or pulverizing. In sieving the material, the operator must verify that there is no selective separation of components in a dust that is not a pure substance.

9.4 Dust samples that are much finer than 200 mesh (75 µm) may have even lower MEC values.

NOTE 3—It 4—It may be desirable in some cases to conduct dust deflagration tests on materials as sampled from a process because process dust streams may contain a wide range of particle sizes or have a well-defined specific moisture content. Materials consisting of a mixture of chemicals may be selectively separated on sieves and certain fibrous materials that may not pass through a relatively coarse screen may produce dust deflagrations. When a material is tested in the as-received state, it should be recognized that the test results may not represent the most severe dust deflagration possible. Any process change resulting in a higher fraction of fines than normal or drier product than normal may increase the explosion severity.

9.5 The moisture content of the test sample should not exceed 5 % in order to avoid test results of a given dust being noticeably influenced.

NOTE 4—There 5—There is no single method for determining the moisture content or for drying a sample. ASTM lists many methods for moisture determination in the *Annual Book of ASTM Standards*. Sample drying is equally complex due to the presence of volatiles, lack of or varying porosity (see Test Methods D 3173 and D 3175), and sensitivity of the sample to heat. Therefore, each must be dried in a manner that will not modify or destroy the integrity of the sample. Hygroscopic materials must be desiccated.

10. Calibration and Standardization

10.1 Because a number of factors (uniformity of dispersion, ignition energy, sample age, etc.) can affect the test results, any test vessel design other than that listed in Appendix X1 must be standardized using dust samples whose minimum explosible concentrations are known. A minimum of five dust samples over a range of MEC values is required. The MEC for each dust must agree to within ±10 % or 5 g/m^3, whichever is larger. The comparison must be made using the same dust, ignitor energy, and chamber volume.

10.2 Representative MEC data in grams per cubic metre (g/m^3) for five dusts samples are listed as follows:

	Bureau of Mines 20-L Chamber[A]		Fike 1 m^3 Chamber[B]
	2500 J	5000 J	10 000 J
Bituminous coal, Pocahontas seam	120	85	...
Bituminous coal, Pittsburgh seam	80	60	80
Lycopodium	45	30	42
Gilsonite	35	30	36
Polyethylene	32	28	...

[A]20-L Chamber at Pittsburgh, PA. See Appendix X1 and Cashdollar, K. L. and Hertzberg, M. "20-L Explosibility Test Chamber for Dusts and Gases," *Rev. Sci. Instrum.*, Vol 56, 1985, pp. 596–602.
[B]1-m^3 Chamber at Blue Springs, MO. See Cashdollar, K. L. and Chatrathi, K., "Minimum Explosible Concentrations in 20-L and 1-m^3 Chambers," *Combust. Sci. Tech.*, Vol. 87, 1993, pp. 157–171.

The Pocahontas seam bituminous coal has ~75 % minus 200 mesh, a mass median diameter of ~52 µm, and 17 % volatility. The Pittsburgh seam bituminous coal has ~80 % minus 200 mesh, a mass median diameter of ~48 µm, and 36 % volatility. The lycopodium is a natural plant spore having a narrow size distribution with 100 % minus 200 mesh and a mass median diameter of ~28 µm. The gilsonite has ~91 % minus 200 mesh, a mass median diameter of ~28 µm, and 84 % volatility. The polyethylene has ~98 % minus 200 mesh, a mass median diameter of ~29 µm, and 100 % volatility.

10.3 In addition to the initial calibration and standardization procedure, at least one reference dust sample should be retested periodically to verify that the dispersion and other characteristics of the chamber have not changed.

11. Procedure

11.1 These general procedures are applicable for all suitable chambers. The detailed procedures specific to each chamber are listed in Appendix X1.

11.2 Inspect equipment to be sure it is thoroughly clean and in good operational condition.

NOTE 5—A 6—A high frequency of tests could increase the operating temperature in some chambers. Tests should not be run at chamber temperatures more than 20°C above ambient as this may affect the measured MEC value.

11.3 Ensure that the oxygen content of the dispersion air is 20.9 ± 0.5 %. Higher or lower oxygen contents will affect the MEC value.

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[6]Conti, R. S., Cashdollar, K. L., and Liebman, I., "Improved Optical Dust Probe for Monitoring Dust Explosions," *Review of Scientific Instruments,* Vol 53, 1982, pp. 311–313.
[8]MNL 32, Manual on testing Sieving Methods, is available from ASTM Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

11.4 Place a weighed amount of dust in the disperser according to detailed instructions in Appendix X1.

11.5 Place ignition source in the chamber. The recommended ignition source for measuring the MEC in 20-L chambers is a 2500 or 5000 J pyrotechnic ignitor (see 5.4-5.6).

11.6 Seal chamber; all valves must be closed.

11.7 Partially evacuate chamber so that, after addition of dispersing air, the desired normal chamber pressure of 1 bar absolute will be reached prior to initiation of the deflagration test.

11.8 Actuate the timing circuit to conduct the test.

NOTE 7—The 8—The dust sample is automatically dispersed through a dispersion system in the chamber. The deflagration is then initiated when a defined ignition delay time has elapsed. This effective ignition delay time, t_d, is the length of time between the first pressure rise due to dust dispersion and the moment normal pressure has been reached in the chamber and ignition is activated (see Fig. 1). The length of this time defines the degree of turbulence and in some cases the concentration of the dust dispersed in the chamber at the moment of ignition.

11.9 Record pressure time curve on a suitable piece of equipment, such as a high speed chart recorder, storage oscilloscope, or computer-based data acquisition system. Obtain the explosion data, $P_{ignition}$, $P_{ex,a}$, and dP/dt_{ex}, according to Figs. 1 and 2.

11.10 After the test, open a valve to vent pressure from the chamber. Open the chamber, remove residue, and thoroughly clean the chamber and dispersion system.

11.11 It is recommended that an initial concentration of 100 g/m^3 be tested. If the initial concentration produces a deflagration, decrease the concentration until no deflagration occurs (see Fig. 3). If the initial concentration does not produce a deflagration, increase the concentration in steps of 100 g/m^3 until a deflagration is obtained.

11.12 For the final determination of the MEC, the concentration increments should be no greater than 25 % of the MEC. It is necessary that at least two tests be made at each concentration near the MEC.

11.13 Plot the explosibility data from individual tests versus dust concentration as shown in Fig. 3.

12. Calculation

12.1 The dust concentration is the mass of dust divided by the volume of the test chamber.

12.2 Determine pressures and rates of pressure rise from pressure-time records. Figs. 1 and 2 are typical records from which these values are obtained. $P_{ignition}$ is the absolute pressure in the chamber at the time of ignition. The value of $P_{ex,a}$ for a test at a given concentration is the highest deflagration pressure (absolute) as shown in Fig. 1(a) and 2(a). The value of dP/dt_{ex} for a given test is the maximum slope of the pressure trace (see Fig. 2(a)) or the highest value on the rate of pressure rise trace (see Fig. 2(b)).

12.3 If a low dP/dt is obtained (see Fig. 1(b)), a weak deflagration may have occurred. Under these conditions, it is important that the dP/dt measurement is not taken from the ignition source but from the dust-air mixture itself. In order for a test to be considered a deflagration, there must be a measureable dP/dt, beyond the effects of the ignitor.
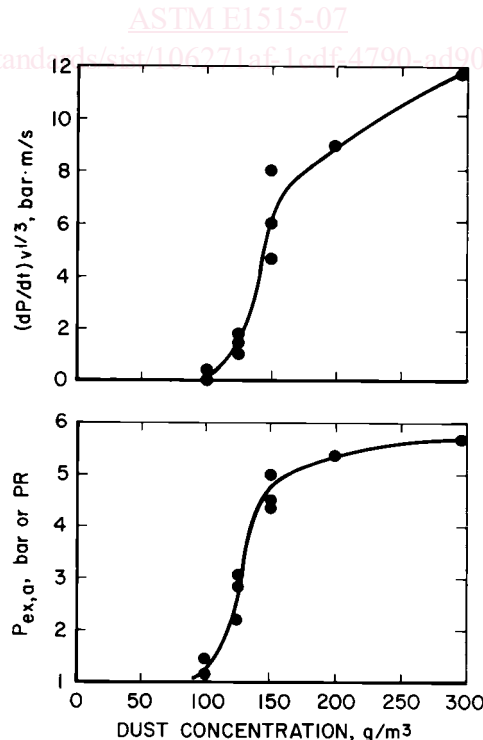

FIG. 3 Explosibility Test Data as a Function of Concentration for
a Typical Dust in a 20-L Chamber, using a 2500 J Ignitor

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NOTE 8—The 9—The rate of pressure rise can be size-normalized by multiplying by the cube root of the chamber volume, giving $(dP/dt)_{ex}\,V^{1/3}$.

12.4 The pressure ratio is: $PR = (P_{ex,a} - \Delta P_{ignitor})/P_{ignition}$.

12.5 The PR (or $P_{ex,a} - \Delta P_{ignitor}$) data and $(dP/dt_{ex})V^{1/3}$ (or dP/dt_{ex}) data are then plotted as a function of concentration as shown in Fig. 3.

12.6 The minimum explosible concentration (MEC) is defined as the lowest concentration for which $PR \geq 2.0$. The MEC is usually rounded to the nearest 5 g/m^3 or 10 %, whichever is larger. For the example shown in Fig. 3, the MEC would be 120 g/m^3.

NOTE 9—For 10—For most dusts, the rich explosibility limit is at a concentration of greater than several thousand grams per cubic metre.[9] Therefore, it is usually not practical to try to measure the rich limit for dusts. This is in contrast to the normal rich limits of gases as measured by Test Method E 681.[8]

12.7 An alternative to the procedures in 12.5 and 12.6 is to plot the pressure rise ($P_{ex,a} - P_{ignition} - \Delta P_{ignitor}$) as a function of concentration. In this case, the MEC is the lowest concentration for which ($P_{ex,a} - P_{ignition} - \Delta P_{ignitor}) \geq 1$ bar, gauge.

12.8 The values of $\Delta P_{ignitor}$ and $(dP/dt)_{ignitor}$ for the ignition source by itself must be established in the apparatus.

13. Report

13.1 Report the following information:

13.1.1 Complete identification of the materials tested; including type of dust, source, code numbers, forms, and previous history,

13.1.2 Particle size distribution of the sample as received and as tested,

13.1.3 Moisture or volatile content, or both, of the as-received and as-tested material, if applicable,

13.1.4 Minimum explosible concentration,

13.1.5 Test pressure, that is, pressure at time of ignition,

13.1.6 Type and energy of the ignition source, and

13.1.7 Test chamber used and any deviation from the normal procedure.

13.2 If the dust does not ignite (according to the criterion in 12.6 and 12.7) at any of the dust concentrations tested, report this fact and the range of dust concentrations tested.

14. Precision and Bias

14.1 *Precision*—Measurement of the MEC of a dust should be repeatable to within ±10 % for a particular ignitor.

14.2 *Bias*—Because the values obtained are relative measures of deflagration characteristics, no statement on bias can be made.

15. Keywords

15.1 dust explosion; minimum explosible concentration

APPENDIX

(Nonmandatory Information)

X1. BUREAU OF MINES 20-L CHAMBER

X1.1 General Description

X1.1.1 Figs. X1.1 and X1.2 are vertical and horizontal cross section drawings of the Bureau of Mines 20-L explosibility test chamber. Further details on the chamber and its operation may be found in Footnotes 5[4] and 10.[9]

X1.1.2 The chamber is made of Type 304 stainless steel and has a pressure rating of 21 bar. It has a volume of 20 L and a wall thickness of 13 mm. The hinged top is secured with six 19-mm-diameter steel bolts that are not shown on the drawings.

X1.1.3 One or two optical dust probes (see Footnotes 7 and 8) are used to monitor the uniformity of the dust dispersion. The optical probes measure the transmission over a 38-mm path length through the dust cloud. Thin jets of air keep the windows of the probes clean.

X1.1.4 The absolute pressure is measured with a strain gage pressure transducer.

X1.1.5 The data from the various instruments are collected by a high speed personal computer-based data acquisition system. It can sample data from 16 channels at a maximum rate of 9 kHz if all channels are used or at faster rates if fewer channels are used.

X1.1.6 The dispersion air comes from a 16-L reservoir (see Fig. X1.3) that is connected by tubing to the chamber. A solenoid valve and a swing check valve are in the air line.

X1.1.7 The standard ignitors are electrically activated, pyrotechnic ignitors with energies of 1000, 2500, or 5000 J. These ignitors contain a mixture of 40 % zirconium, 30 % barium nitrate, and 30 % barium peroxide. See also Figs. X1.4 and X1.5.

X1.2 Test Procedures

X1.2.1 Calculate and weigh the amount of dust necessary to give the desired dust cloud concentration in the 20-L chamber.

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[9] MNL 32, Manual on testing Sieving Methods, is available from ASTM Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

[9] Cashdollar, K. L., and Hertzberg, M., "20-L Explosibility Test Chamber for Dusts and Gases," *Review of Scientific Instruments,* Vol 56, 1985, pp. 596–602.