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Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air¹

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1. Scope

1.1 This test method determines the minimum ignition energy of a dust cloud in air by a high voltage spark.

1.2 The Minimum Ignition Energy (MIE) of a dust-cloud is primarily used to assess the likelihood of ignition during processing and handling. The likelihood of ignition is used to evaluate the need for precautions such as explosion prevention systems. The MIE is determined as the electrical energy stored in a capacitor which, when released as a high voltage spark, is just sufficient to ignite the dust cloud at its most easily ignitable concentration in air. The laboratory test method described in this standard does not optimize all test variables that affect MIE. Smaller MIE values might be determined by increasing the number of repetitions or optimizing the spark discharge circuit for each dust tested.

1.3 In this test method, the test equipment is calibrated using a series of reference dusts whose MIE values lie within established limits. Once the test equipment is calibrated, the relative ignition sensitivity of other dusts can be found by comparing their MIE values with those of the reference dusts or with dusts whose ignition sensitivities are known from experience. **X1.1** of this test method includes guidance on the significance of minimum ignition energy with respect to electrostatic discharges.

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. Specific precautionary statements are given in Section 8.*

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. 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

E582 Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures

E789 Test Method for Dust Explosions in a 1.2-Litre Closed Cylindrical Vessel (Withdrawn 2007)³

E1226 Test Method for Explosibility of Dust Clouds

E1445 Terminology Relating to Hazard Potential of Chemicals

2.2 IEC Standards:⁴

1241-2-3, 1994 Electrical Apparatus for Use in the Presence of Combustible Dusts, Part 2: Test Method, Section 3: Method for Determining Minimum Ignition Energy of Dust-Air Mixtures

3. Terminology

3.1 *Definitions*—For additional definitions, see Terminology E1445.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *spark discharge, n*—transient discrete electric discharge, which takes place between two conductors, which are at different potentials. The discharge bridges the gap between the conductors in the form of a single ionization channel.

3.2.2 *minimum ignition energy (MIE), n*—electrical energy discharged from a capacitor, which is just sufficient to effect ignition of the most easily ignitable concentration of fuel in air under the specific test conditions.

3.2.3 *ignition delay time, n*—the time between the onset of dispersion of the dust sample into a cloud and the activation of the ignition source.

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.

⁴ Available from International Electrotechnical Commission (IEC), 3 rue de Varembe, Case postale 131, CH-1211, Geneva 20, Switzerland, <http://www.iec.ch>.

4. Summary of Test Method

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

4.2 Ignition trials of this dust-air mixture are then attempted, after a specific ignition delay time, by a spark discharge from a charged capacitor.

4.3 The stored energy discharged into the spark and the occurrence or nonoccurrence of flame are recorded.

4.4 The minimum ignition energy is sought by varying the dust concentration, the spark discharge energy and optionally the ignition delay time.

4.5 Ignition is determined by visual observation of a flame propagation away from the spark gap.

5. Significance and Use

5.1 This test method provides a procedure for performing laboratory tests to determine the minimum ignition energy of a dust cloud.

NOTE 1—For gases and vapors, see Test Method E582.

5.2 The data developed by this test method may be used to assess the spark ignitibility of a dust cloud. Additional guidance on the significance of minimum ignition energy is in X1.1.

5.3 The values obtained are specific to the sample tested, the method used and the test equipment used. The values are not to be considered intrinsic material constants.

5.4 The MIE of a dust as determined using this procedure can be compared with the MIE's of reference dusts (using the same procedure) to obtain the relative sensitivity of the dust to spark ignition. An understanding of the relative sensitivity to spark ignition can be used to minimize the probability of explosions due to spark ignition.

6. Interferences

6.1 Dust residue from previous tests may affect results. The chamber must be cleaned before a new product is tested.

6.2 Problems may arise due to electrical shortcircuits when using conductive materials.

7. Apparatus

7.1 *Test Apparatus*—Although a number of different test apparatuses are used in practice, they all have the following components in common: A test chamber, spark electrodes, and a spark generation circuit. Various configurations of the spark generation circuits are provided in the Appendix X1. The purpose of the test chamber is to produce a uniform, nonturbulent and known density dust cloud in air at the time of ignition. The clear plastic or glass Hartmann tube, typically 0.5 or 1.2 L, and the 20-L sphere apparatus have been found suitable for this test method. These vessels are described in Refs (1-4)⁵ and Test Methods E789 and E1226. These and

⁵ The boldface numbers in parentheses refer to the list of references at the end of this standard.

other suitable chambers can be used provided that the calibration requirements in 10.1 are met.

7.2 *Spark Generation Circuit*—The Appendix describes some suitable forms of circuits, all of which shall have the following characteristics:

7.2.1 *Electrode Material*, such as tungsten, stainless steel, brass, or graphite.

7.2.2 *Electrode Diameter and Shape*, 2 ± 1 mm. For circuits in which high voltage is maintained across the spark gap prior to spark breakdown, a significant fraction of the energy stored in the capacitor may drain away as corona discharges from sharp electrode tips prior to the spark discharge. This is increasingly important at low stored energies. Electrodes with rounded tips can be used to reduce corona effects that can occur with pointed electrodes, which may give incorrect values of spark energy. If pointed electrodes are used, corona effects should be considered carefully.

7.2.3 *Electrode Gap*—The optimum spacing is typically of the order of 6 mm. For certain materials at low ignition energy values, however, the gap spacing may need to be reduced in order to initiate the spark. Under these circumstances, the spark gap can be reduced and the tests carried out with the largest gap possible, but the gap should not be less than 2 mm.

NOTE 2—The capacitance of the electrodes and associated high voltage cables between the storage capacitor and the electrodes should be as low as possible. It should be noted that cable capacitance may be of the order 40pF/m depending on its construction, which represents significant additional stored energy at low storage capacitance and high voltage. The stray capacitance of these components must be measured to determine if it needs to be taken into account when calculating the stored circuit energy.

NOTE 3—Insulation resistance between electrodes should be sufficiently high to prevent leakage currents prior to discharge. Typically, a minimum resistance between the electrodes of $10^{12} \Omega$ is required for a minimum ignition energy of 1 mJ, and $10^{10} \Omega$ for a minimum ignition energy of 100 mJ. Insulation resistance may decrease over time due to contamination of the surface with carbon and other materials. The resistance may be directly measured across the electrodes. Alternatively, a decrease may be inferred by the inability to hold constant voltage on the isolated storage capacitor for the timescale of a test.

NOTE 4—Almost all electrostatic discharges in plant installations are capacitive with negligible inductance. It has been found that for equal stored energies many dusts can be ignited more easily when a resistor or an inductance is placed in the discharge circuit to create longer duration sparks. Ideally, the MIE should correspond to circuits whose discharge duration has been optimized for the dust in question using, for example, an inductance.

8. Safety Precautions

8.1 Prior to handling a test 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. MIE-tests should be conducted in a ventilated hood or other area having adequate ventilation.

8.2 Before initiating a test, check and secure the apparatus, fittings and gaskets to prevent leakage.

8.3 All enclosures containing electrical equipment must be connected to a common ground.

8.4 The test method should not be used with recognized explosives, such as gunpowder or dynamite; pyrophoric substances; or, substances or mixtures of substances, which may under some circumstances behave in a similar manner without considering the special hazards. Where any doubt exists about the existence of a hazard due to explosive properties, expert advice should be sought.

8.5 Because the apparatus consists of a circuit with high voltage components, adequate safeguards must be employed to prevent electrical shock to personnel.

8.6 The operator should work from a protected location, such as from outside a closed fume hood, in case of vessel or electrical failure.

8.7 Care should be taken not to clean acrylic Hartmann tubes with incompatible solvents, which can lead to embrittlement and cracking.

9. Sampling

9.1 It is not practical to specify a single method of sampling dust for test purposes because the character of the material and its available form affect selection of the sampling procedure.

9.2 Minimum ignition energy decreases with decreasing particle size (see Fig. 1). Although tests may be run on an “as-received” sample, explosible dust clouds often consist largely of sub-200 mesh dust, which accumulates in suspension when coarser bulk powder is handled. Therefore, it is recommended that the test sample be at least 95 % minus 200 mesh (75 μm). In general, the sample tested should be at least as fine as the dust at the location being considered, which, in some cases, may require testing of sub-325 mesh or even finer dust.

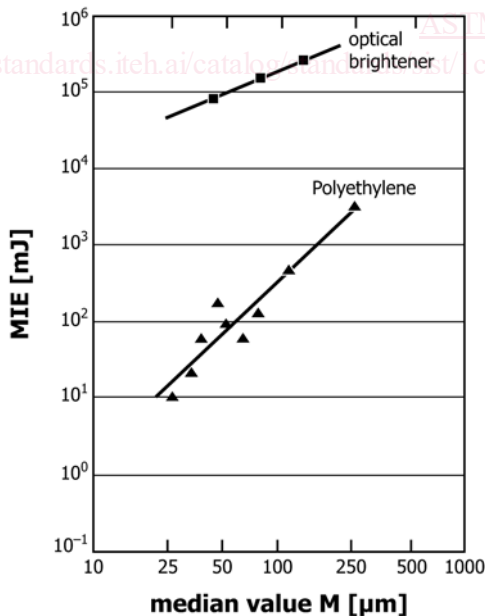


FIG. 1 Correlation of Median Particle Size and MIE (5)

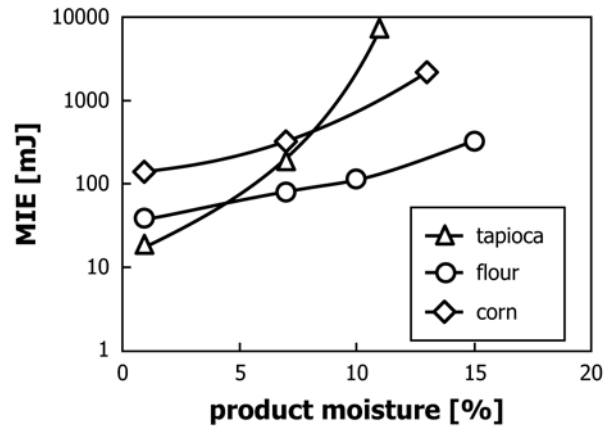


FIG. 2 Influence of the Humidity (Water Content) of Combustible Dusts (5)

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

NOTE 5—The operator should consider the thermal stability of the dust during grinding or pulverizing.

NOTE 6—In some cases, it may be desirable to conduct dust deflagration tests on material 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. When a material is tested in the as-received state, it should be recognized that the test results may not represent the most severe ignition hazards possible. Any process change resulting in a higher fraction of fines or drier product may result in a lower MIE for the product.

NOTE 7—The possible reduction of the particle size due to attrition by the dust dispersion system of the test apparatus should be considered.

NOTE 8—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. Materials consisting of a mixture of chemicals may be separated selectively on sieves and certain fibrous materials, which may not pass through a relatively coarse screen may produce dust deflagrations.

9.4 Minimum ignition energy for some dusts increases with increased moisture content (see Fig. 2). Dusts should be tested either in the dry state or approximating the moisture content under the handling conditions of interest. “Dry” samples should be transported to the test laboratory in sealed containers under dry air or nitrogen, and then stored in a desiccator. Desiccants, such as phosphorus pentoxide, may be more effective than silica gel in removing residual moisture.

NOTE 9—There is no single method for determining the moisture content or for drying a sample. Sample drying equally is complex due to the presence of volatiles, lack of or varying porosity (see Test Methods D3173 and D3175), 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 Calibration tests should be carried out on at least three different reference dusts. The results shall be within the following ranges (measured without inductance):

| | |
|-------------------------------|--------------------|
| Irganox 1010: ⁶ | MIE = 1 to 6 mJ |
| Anthraquinone: | MIE = 1 to 11 mJ |
| Lycopodium: ⁷ | MIE = 10 to 30 mJ |
| Pittsburgh coal: ⁸ | MIE = 30 to 140 mJ |

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

11. Procedure

11.1 Test Description:

11.1.1 Inspect equipment to be sure it is cleaned thoroughly and in good operational condition.

11.1.2 The combustible dust to be tested is dispersed in air at laboratory ambient test conditions in the test-apparatus, and the dust cloud is subjected to a spark discharge from a charged capacitor.

11.1.3 Ensure that the oxygen content of the dispersion air is $20.9 \pm 0.5\%$. Higher or lower oxygen content may affect the MIE result.

11.1.4 The energy discharged from the capacitor is calculated from the following formula:

$$W = 0.5 C(V_i^2 - V_f^2) \quad (1)$$

where:

- W = the discharged energy in joules [J],
- C = the total capacitance of the discharge circuit in farads [F], and
- V_i and V_f = the initial and final voltages of the charged capacitor in volts [V] as measured using an electrostatic voltmeter or equivalent very high impedance device.

11.1.5 It is necessary to take account of the following possible influences on the test:

11.1.5.1 Dust-air mixture dynamics/turbulence (a function of ignition delay time and dispersing pressure, etc.).

11.1.5.2 Dust concentration,

11.1.5.3 Voltage to which the capacitor is charged,

11.1.5.4 Capacitance of the discharge circuit capacitor,

11.1.5.5 Inductance of the discharge circuit,

11.1.5.6 Ohmic resistance of the discharge circuit, and

11.1.5.7 Materials and dimensions of the electrodes and the gap between the electrodes.

11.1.6 The final MIE result is reported for a dust cloud of optimum dust concentration for ignition and having the lowest turbulence level experimentally attainable. The optimum dust concentration cannot be obtained in one step; therefore, an iteration procedure is required. Examples include the following:

11.1.6.1 Start with a value of a spark energy that reliably will cause ignition of a given concentration in air of the dust

⁶ Irganox 1010: Tetrakis-[Methylene(3,5-di-(tert)-butyl-4-hydroxyhydrocinamate)]methane, available source: Ciba Specialty Chemicals.

⁷ Lycopodium Clavatum: Lycopodium is a natural plant spore having a narrow size distribution with 100 % minus 200 mesh and a mass median diameter of $\sim 28 \mu\text{m}$.

⁸ The Pittsburgh coal has $\sim 80\%$ minus 200 mesh, a mass median diameter of $\sim 45 \mu\text{m}$, and 36 % volatility.

being tested. Then, the spark energy is reduced in steps, for example, factor of ~ 3 , at the given dust concentration until the dust cloud no longer ignites in any of ten tests at a given energy. Repeat the procedure at different dust concentrations until the lowest minimum ignition energy value is found (see Fig. 3).

11.1.6.2 Start as in 11.1.6.1 using a dust loading that is estimated to give $250\text{--}500 \text{ g/m}^3$ and determine “go/no go” spark energies. Once a “limit” point is found for a particular concentration, repeat the procedure for higher and lower dust concentrations until a roughly parabolic curve is obtained for ignition energy versus dust concentration (see Fig. 4). Depending on the scatter evident in the curve, conduct ten repeat tests at the most ignitable dust concentration.

NOTE 10—Figs. 3 and 4 show both methods using Lycopodium as an example. Fig. 3 shows “go/no go” using the factor-of-3 method 11.1.6.1 and Fig. 4 shows the single curve comprising “go/no go” points (method 11.1.6.2).

11.1.6.3 The ignition delay time also may be varied step by step until the minimum value of the ignition energy is found.

11.1.7 These general procedures are applicable for all suitable circuits. The detailed procedures specific to each circuit are listed in the corresponding appendix.

11.1.8 The minimum ignition energy, MIE, lies between the highest energy, W_1 , at which ignition fails to occur in ten successive attempts to ignite the dust-air mixture, and the lowest energy, W_2 , at which ignition occurs once at least within ten successive attempts:

$$W_1 < \text{MIE} < W_2 \quad (2)$$

The ratio of the energy steps should be ≤ 3.3 , for example, 1 mJ, 3 mJ, 10 mJ, etc.)

11.1.8.1 In the method described in 11.1.6.2, the MIE normally is determined from the minimum of the spark energy versus concentration curve after the curve has been smoothed. If additional repeat tests are made at the most sensitive

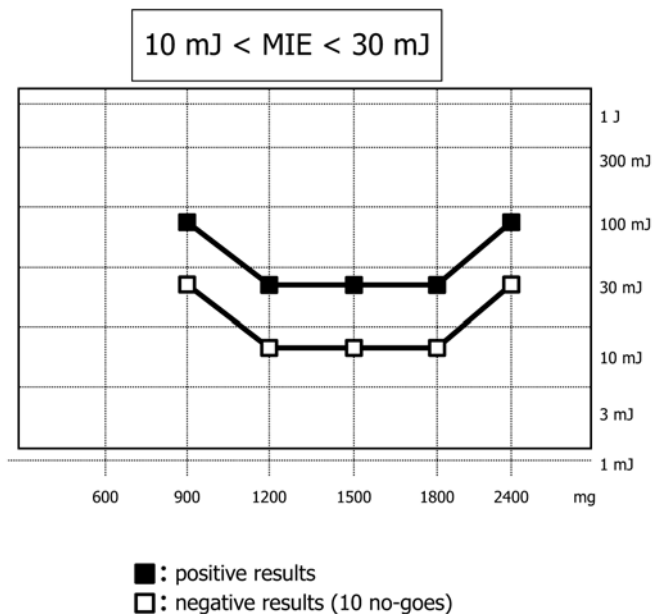


FIG. 3 MIE Test Results (10 mJ < MIE < 30 mJ)