Combustion Research Center
HOERBIGER Safety Solutions

CRC Combustion Hazard Test Services - DUSTS

1. Particle Sieve Analysis

This test determines the particle size distribution of the sample. Combustibility and reactivity of the material increases with decreasing particle size.

A dust sample is classified using U.S. Standard No. 40, 70, 100, and 200 sieve screens. Where the as-supplied dust does not contain a sufficient quantity of materials passing through a No. 200 screen, a test mixture is prepared consisting of the finest dust plus a sufficient quantity of the next finest dust to make up the amount required to conduct the tests. If required, and appropriate, the test material may be milled to reduce the size of particles to obtain fine dust for testing. The mixture ratio of dust fractions used in testing is indicated in the data table for the individual dust.

Sieve analysis employs standard sieve screens as specified in ASTM E11, Standard Specification for Wire Cloth and Sieves for Testing Purposes. The sieves screens commonly used in preparation of dusts for combustibility evaluations are given in the table below.

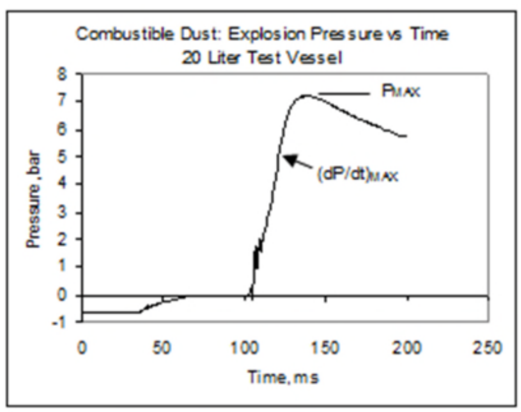
Sieve No.	Sieve Opening
40	425 μm
70	212 μm
100	150 μm
200	75 μm
230	63 μm
325	45 μm

2. Moisture Content

The higher the moisture content of a sample, the less explosive it is. The moisture content of the sample is determined prior to testing. Moisture content is determined by drying in an air-convection oven at 60°C to constant weight. Dusts containing more than 5% moisture are dried at 60°C unless otherwise requested by the customer.

3. Explosibility Parameters, P_{MAX} and K_{ST} (ASTM E1226)

This test is performed to determine whether a dust is combustible and indicates the degree of the explosion hazard. The Kst value derived from the test is used as a design parameter for your explosion protection system.
(Sample size required, 1000 g)



Combustible dusts suspended in air form highly flammable atmospheres. Explosion testing of dusts is carried out in a 20-liter spherical test vessel. The key explosion properties of dust clouds are the average maximum pressure (P_{MAX}) maximum rate of pressure rise(dP/dt_{MAX}) and the explosibility index K_{ST} which are all determined from multiple tests in three different series per ASTM E1226. A typical explosion pressure-time curve is in the chart.

4. Go/No Go Test for Determination of Dust Cloud Combustibility

The material is classified as combustible if the explosion pressure corrected for the effects of the igniter, is greater than 1.0 bar (14.5 psi). Where the observed explosion pressure rise is less than 1 bar at all test concentrations, the dust is classified as not combustible. In cases with ambiguous results further study may be required. The pressure-time profile developed during the deflagration is measured using two piezoelectric pressure transducers with the output signals automatically processed by the test control and data management system. An initial test is carried out using a 10 g dust sample, sufficient to create a dispersed dust cloud concentration of 500 g/m^3. Dusts not combustible at a concentration of 500 g/m^3 are tested at 1,000 g/m^3 or other higher concentration.

5. Classification of Combustible Dusts

This procedure is intended to meet the requirements of OSHA Directive No. CPL 03-00-008 (*Combustible Dust National Emphasis Program*, March 11, 2008) Annex E, Section 7.

Dust explosion tests are carried out at one or more dust cloud concentrations, typically in the range of 500 g/m^3 to 2000 g/m^3, to determine if the combustion characteristics meet the Explosion Severity (ES) criteria of a Class II combustible dust. Unless otherwise indicated, the tests are carried out on dusts that are dry (less than 5% moisture) and sieved through a No. 200 sieve screen (hole size of 74 µm).

The interpretation of Explosion Severity test results is as follows:

Test Result	Dust Classification
ES > 0.5	Class II combustible
ES < 0.4	Combustible but not Class II
0.4 < ES < 0.5	Indeterminate. Combustible but not Class II based on ES criterion alone.*
P_{MAX} < 1 bar	Not combustible

*Where 0.4 < ES < 0.5 OSHA recommends determination of ignition sensitivity (IS) to definitively determine whether a dust is Class II or not. Further testing is required to obtain this result.

Reference: https://www.osha.gov/OshDoc/Directive_pdf/CPL_03-00-008.pdf

6. Minimum Explosible Concentration – MEC (ASTM E1515)

This test is performed in a Kühner 20L Vessel and determines the minimum explosive concentration (MEC) of a dust cloud that may cause an explosion.
(Sample size required, 500 g)

Dust explosions are carried out at various dust cloud concentrations to establish the lowest concentration which will sustain flame propagation.

Tests are carried out in a Kühner 20-liter test vessel. Dust is pneumatically injected into the vessel (evacuated to -0.60 bar-g or -8.9 psig) from a reservoir pressurized with air to 20 bar-g (290 psig). Dust dispersion within the test vessel is achieved using a standard nozzle assembly. Ignition of the dust cloud is performed using a 2.5 or 5 kJ pyrotechnic igniter that is positioned in the center of the vessel. Ignition occurs 60 ms after the start of dust injection, and when the vessel pressure is at one atmosphere (0 bar-g or 0 psig).

The MEC is reported as the lowest concentration for which P_m > 1bar and where the next lower concentration is no more than 25% less than the MEC concentration.

7. Limiting Oxygen Concentration to Support Combustion, LOC (ASTM E2931)

This test is performed in a Kühner 20L Vessel and determines the limiting oxygen concentration (LOC) at which a particular dust is combustible. LOC is needed if inerting is used as a basis of safety for explosion protection. (Sample size required, 500 g)

Dust cloud deflagrations are carried out at a fixed dust cloud concentration, near the minimum explosible concentration (MEC) and at successively reduced oxygen concentrations. It has been found that the lowest value of LOC is obtained at low dust cloud densities. The oxygen concentration in the test vessel is adjusted by replacing the quantity of air with nitrogen or another inert gas. The test determines the maximum deflagration pressure (P_{MAX}) which is compared with the pressure at ignition (P_{IGN}) for each condition. The defining criterion for a deflagration is $P_{MAX} - P_{IGN} \geq 1.0$ bar. Tests are conducted at progressively lower oxygen concentrations until the deflagration criterion cannot be achieved in at least two identical tests. The LOC value is determined to the nearest whole percentage of oxygen.

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The LOC value reported is the average of the lowest oxygen concentration that meets the deflagration criterion and the highest oxygen concentration that does not meet the criterion in the air-inert gas system employed.

8. Minimum Ignition Energy - MIE (ASTM E2019)

This test determines the minimum ignition energy (MIE) or the lowest electrostatic spark energy capable of igniting a dust cloud. A dust having a very low MIE requires special attention to process conditions to avoid ignition. MIE values less than 100mJ indicate a potential for ignition from static discharges from personnel. MIE values less than 25mJ indicate a potential for ignition from static discharges from the movement and bulk handling of powders. If the MIE value is less than 25mJ, resistivity testing is important to determine the ability of the material itself to generate electrostatic charges.
(Sample size required, 500 g)

Testing is performed in a Kühner MIKE3 Apparatus. The minimum energy sufficient to ignite the dust under investigation is determined. This ignition energy is then successively reduced while varying the dust concentration and the ignition delay time (turbulence) in a series of tests until no ignition takes place in at least 10 successive experiments. The MIE lies between the lowest energy value (E2) at which ignition occurred, and the energy value (E1) at which no ignition occurred in at least 10 successive experiments.

The energy range thus determined is called the MIE of a combustible dust in air. However, for purposes of simplification often only the lower limit value (E1) is specified as the MIE.

$E1 < MIE < E2$

To assess the ignition hazard for dust/air mixtures due to operational spark discharges, especially electrostatic discharges, the MIE must be determined with a purely capacitive spark discharge (without inductance) by the method described above.

The electric spark ignition energy is computed as the average of lowest igniting and highest non-igniting stored energy values.

9. Dust Cloud Ignition Temperature - T_C (ASTM E1491)

This test determines the sensitivity of a dust cloud to a hot environment (T_C).
(Sample size required, 100 g)

Tests are conducted in vertical tube furnace containing a system of dispersing small quantities of dust into the top of the furnace which has a bore of 3.8 cm and a length of 30.5 cm. The furnace temperature is measured using a type N thermocouple positioned 1.6 mm from the heated wall.

Tests are conducted by dispersing a fixed amount of dust into the top of the furnace that has been pre-heated to a specified temperature and the dust is heated as it cascades down the furnace tube. Ignition is deemed to have occurred if a flame appears at the bottom outlet of the furnace. A series of tests is conducted at successively reduced temperatures until a temperature is reached at which ignition fails to occur in five successive tests. Tests are conducted at temperature intervals such that the difference between the lowest igniting temperature and the highest non-igniting temperature is no more than 20°C.

The minimum dust cloud ignition temperature reported is the average of the lowest test temperature at which ignition was observed and the highest test temperature at which ignition was not observed. The reported minimum dust cloud ignition temperature is rounded down to the nearest 10°C.

10. Hot Surface Layer Ignition Temperature – T_S (ASTM E2021)

This test determines the sensitivity of a dust to hot surfaces. It measures the minimum temperature at which a dust layer will ignite.
(Sample size required, 500 g)

Tests to determine the Hot Surface Ignition Temperature of a Dust Layer are performed using a commercial hot plate. The dust layer is confined within a metal ring which sits on top of the hot plate.

A series of tests is conducted in which the desired test temperature is set on the temperature controller and the hot plate is heated. When the temperature is reached, the ring is filled with the sample dust, and the surface of the layer is leveled within a two minute time period. Ignition is deemed to have occurred if within the 120 minute period the sample temperature rises to 50°C or more above the plate temperature, or a red glow or flame is seen. The test is terminated if the layer melts or reaches a maximum temperature without igniting and starts cooling down. If no ignition occurs the test is repeated at a higher temperature. Note that ignition of some materials can occur after longer induction periods at temperatures lower than those reported herein. The test series is discontinued if the dust layer does not ignite at a set temperature of 390°C.

The hot surface ignition temperature of a dust layer is reported as the lowest temperature that causes ignition in less than 60 minutes.

11. Dust Layer Ignition Temperature - T_L (Bureau of Mines RI5624)

This test determines the minimum temperature at which a dust layer in a hot environment will ignite.
(Sample size required, 100 g)

Tests to determine the minimum ignition temperature of a layer of dust are conducted in a system consisting of a vertical tube furnace which has a bore of 3.6 cm and a length of 22.9 cm. The dust sample is placed in a wire mesh basket which holds the test sample. The basket measures 2.54 cm in diameter and 1.27 cm deep. The tip of a small type K thermocouple is positioned in the center of the sample. Air is injected into the bottom of the furnace cavity at a rate of 1.3 standard liters per minute which assures there is adequate oxygen to support combustion. The furnace temperature is measured using a type K thermocouple positioned 1.6 mm from the heated wall. The sample and furnace temperatures are monitored as a function of time using a two-pen strip chart recorder.

A series of tests is conducted in which the furnace temperature is fixed and the sample basket is lowered into position for heating. In some cases the time to ignition (TTI) may be determined. This time period is determined as the time between which the sample reaches the furnace temperature and when the temperature has increased by an additional 25°C. The latter event corresponds roughly to the inflection point in the induction period, and is assumed to represent the start of ignition. Ignition is deemed to have occurred if the sample temperature rises to 50°C or more above the furnace temperature. If no ignition occurs the test is repeated at a higher temperature. Several tests may be conducted to determine the relationship of TTI to furnace temperature.

The minimum ignition temperature of a dust layer is reported as the temperature that causes ignition after approximately five minutes, or the average of the lowest temperature which causes ignition in less than 30 minutes and the highest temperature which fails to cause ignition in 30 minutes.

12. Test Method for Class 4 Division 4.2 (49 CFR 173)

This test method is specified in UN document ST/SG/AC.10/1/Rev.9*, Recommendations of the Transport of Dangerous Goods*, United Nations, New York and Geneva, 1995. This test method is referenced in 49 CFR 173.125 as the basis for specification of packing classification (packing group) for hazardous materials by the U.S. Department of Transportation.

Substances Liable to Spontaneous Combustion

This test evaluates the tendency for a packaged dust to spontaneously ignite upon exposure to a temperature of 140°C for up to 24 hours. Data is used to classify materials with respect to packaging class.
(Sample size required, 2000 g)

For detailed information on this test method, click on the link below.

https://www.govregs.com/regulations/expand/title49_chapterI_part173_subpartD_section173.124#title49_chapterI_part173_subpartD_section173.125

For the UN Reference of Substances Liable to Spontaneous Combustion and Classification of Self-Heating Substances, refer to pages 41-43 of the document link provided below.

http://www.unece.org/fileadmin/DAM/trans/danger/publi/manual/Rev4/English/04E_part3.pdf

13. Packing Classification of a Dust – Burn Rate Test (UN Test N.1)

This test determines the rate of flame propagation in dusts for the purpose of determining packaging classification. (Sample size required, 500 g)

For the UN Reference of Test method for Readily Combustible Solids UN Test N.1, refer to page 37 of the attached document link.

http://www.unece.org/fileadmin/DAM/trans/danger/publi/manual/Rev4/English/04E_part3.pdf

14. Percent Combustible Material/Percent Combustible Dust (OSHA/MH-102)

Percent combustible material is determined as follows:

1) Weigh crucibles and aliquots of material which passed through a 40 mesh sieve.
2) Ash samples, uncovered, for one hour at 600°C in a muffle furnace. Then reweigh the residue.
3) Calculate the combustible material as:

$$\%\ combustible\ material = \frac{(wet\ sample\ weight - ash\ weight)(100)}{wet\ sample\ weight}$$

Percent combustible dust is the product of the percent of material which went through a 40 mesh sieve and the percent combustible material. This is calculated as follows:

$$\%\ combustible\ dust = (\%\ through\ 40\ mesh)(\%\ combustible\ material)(100)$$

Decimal equivalents of the percentage values must be used to perform calculation (10% = 0.10).
Be aware of the distinction between combustible material and combustible dust.

Reference: https://www.osha.gov/dts/sltc/methods/partial/id201sg/id201sg.html

15. Volume Resistivity and Volume Resistance (Powder Resistivity) (ASTM D257)*

Volume resistivity and volume resistance measurements of powders are performed using a Dr. Thiedig Milli-TO-2 Wide Range Resistance Meter in conjunction with an ETS Model 871 Volume Resistivity Test Fixture. The model 871 is a dual cell probe with resistance to volume resistivity conversion ratios of 10:1 and 100:1. (Sample size required, 50 g)

Volume resistivity per ASTM D257 is one of the properties used to describe the conductive, dissipative, or insulative range of static control of material. Volume resistivity is a function of the area of the measuring electrode and the thickness of the material being measured and is expressed in ohms-cm. Volume resistance is used to evaluate static dissipative material. This resistance is equal to the actual resistance of the test material measured between the electrodes. A test voltage of 10 volts is specified for resistances between 10^4 and 10^6 ohms, and 100 volts for resistances between 10^6 and 10^{11} ohms. Volume resistance is expressed in ohms. Resistance measurements below or above these values may require different test voltages. Conductive materials (those materials with volume resistances below 104 ohms) are measured using either a current source or voltages equal to or less than 10 volts.

The sample is first poured into a stainless steel or glass container to allow even conditioning of the material at the requested relative humidity. After conditioning, the Model 828 Test Cell is filled. The volume resistance is measured and then the volume resistivity is calculated based on the cell used and the appropriate multiplier.

Three tests are performed at 100 volts and 500 volts. The volume resistivity is calculated as follows:

$$\rho_V = 100R_m$$

Where R_m = Volume resistance

The computed values of volume resistivity and resistance, along with the name and type of the sample, type of electrodes, test conditions, ambient conditions, applied voltage and measured values of resistance are reported.

*ASTM D257 testing is subcontracted to an electrostatics specialty laboratory.

16. Bulk Density Determination – Method A (ASTM D1895)

This test is carried out employing the apparatus and procedure as described in ASTM Standard Test Method D1895 “Standard Test Methods for Apparent Density, Bulk Factor, and Pourability of Plastic Materials,” Test Method A. Test Method A covers the measurement of the apparent density of the fine granules and powders that can be poured readily through a small funnel.

Bulk density is calculated as follows:

$$Apparent\ (Bulk\ Density) = \frac{W}{V}$$

Where: W = Weight of the material in the measuring cup, g
V = Volume of measuring cup, cm^3