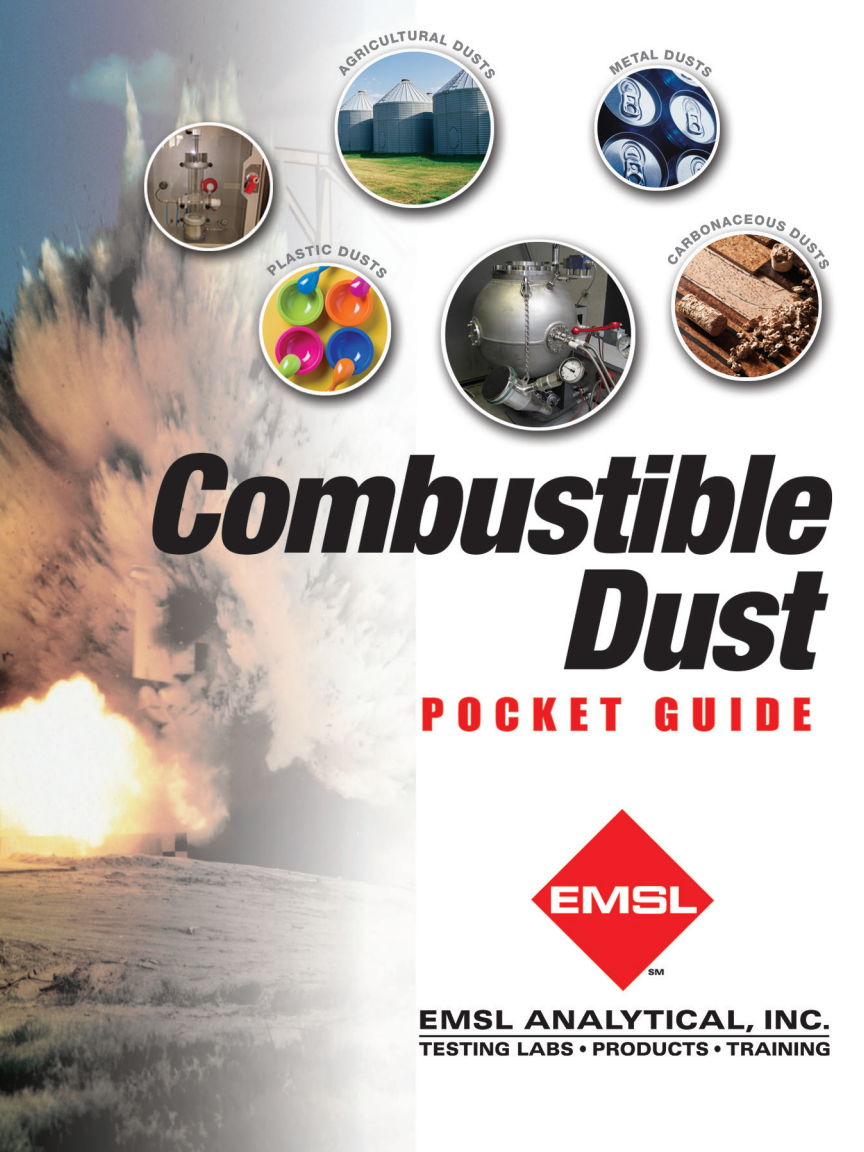

Combustible Dust

POCKET GUIDE

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United States and Canada Locations

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What is Combustible Dust

Combustible dusts are fine particles that present an explosion hazard when suspended in air under certain conditions. A dust explosion can cause catastrophic loss of life, injuries, and destruction of buildings. In many of these incidents, workers and managers were unaware of the potential for dust explosions, or failed to recognize the serious nature of dust explosion hazards. It is important to determine if your company has this hazard, and if you do, you must take action now to prevent tragic consequences.

How Dust Explosions Occur

In addition to the familiar fire triangle of oxygen, heat, and fuel (the dust), dispersion of dust particles in sufficient quantity and concentration can cause rapid combustion known as a deflagration. If the event is confined by an enclosure such as a building, room, vessel, or process equipment, the resulting pressure rise may cause an explosion. These five factors (oxygen, heat, fuel, dispersion, and confinement) are known as the "Dust Explosion Pentagon". If one element of the pentagon is missing, an explosion cannot occur.

Catastrophic Secondary Explosions

An initial (primary) explosion in processing equipment or in an area where fugitive dust has accumulated may dislodge more accumulated dust into the air, or damage a containment system (such as a duct, vessel, or collector). As a result, if ignited, the additional dust dispersed into the air may cause one or more secondary explosions. These can be far more destructive than a primary explosion due to the increased quantity and concentration of dispersed combustible dust. Many deaths in past incidents, as well as other damage, have been caused by secondary explosions.

Industries at Risk

Combustible dust explosion hazards exist in a variety of industries, including: agriculture, chemicals, food (e.g., candy, sugar, spice, starch, flour, feed), grain, fertilizer, tobacco, plastics, wood, forest, paper, pulp, rubber, furniture, textiles, pesticides, pharmaceuticals, tire and rubber manufacturing, dyes, coal, metal processing (e.g., aluminum, chromium, iron, magnesium, and zinc), recycling operations, fossil fuel power generation (coal), and 3D welding (a form of 3D printing).

Where is Combustible Dust found?

Does your company or firm process any of these products or materials in powdered form? If you work in a industry or your company processes any of these products or materials, there is potential for a "Combustible Dust" explosion.

Agricultural Products
Egg white
Milk, powdered
Milk, nonfat, dry
Soy flour
Starch, corn
Starch, rice
Starch, wheat
Sugar
Sugar, milk
Sugar, beet
Tapioca
Whey
Wood flour

Agricultural Dusts
Alfalfa
Apple
Beet root
Carrageen
Carrot
Cocoa bean dust
Cocoa powder
Coconut shell dust
Coffee dust
Corn meal
Cornstarch
Cotton
Cottonseed
Garlic powder
Gluten
Grass dust
Green coffee
Hops (malted)
Lemon peel dust
Lemon pulp
Linseed
Locust bean gum
Malt
Oat flour
Oat grain dust
Olive pellets
Onion powder
Parsley (dehydrated)
Peach
Peanut meal and skins
Peat
Potato
Potato flour
Potato starch
Raw yucca seed dust
Rice dust
Rice flour
Rice starch
Rye flour
Semolina
Soybean dust
Spice dust
Spice powder
Sugar (10x)
Sunflower
Sunflower seed dust
Tea
Tobacco blend
Tomato
Walnut dust
Wheat flour
Wheat grain dust
Wheat starch
Xanthan gum

Carbonaceous Dusts
Charcoal, activated
Charcoal, wood
Coal, bituminous
Coke, petroleum
Lampblack
Lignite
Peat, 22%H20
Soot, pine
Cellulose
Cellulose pulp
Cork
Corn

Chemical Dusts
Adipic acid
Anthraquinone
Ascorbic acid
Calcium acetate
Calcium stearate
Carboxy-methylcellulose
Dextrin
Lactose
Lead stearate
Methyl-cellulose
Paraformaldehyde
Sodium ascorbate
Sodium stearate
Sulfur

Metal Dusts
Aluminum
Bronze
Iron carbonyl
Magnesium
Zinc

Plastic Dusts
(poly) Acrylamide
(poly) Acrylonitrile
(poly) Ethylene (low-pressure process)
Epoxy resin
Melamine resin
Melamine, molded (phenol-cellulose)
Melamine, molded (wood flour and mineral filled phenolformaldehyde)
(poly) Methyl acrylate
(poly) Methyl acrylate, emulsion polymer
Phenolic resin
(poly) Propylene
Terpene-phenol resin
Urea-formaldehyde/ cellulose, molded
(poly) Vinyl acetate/ ethylene copolymer
(poly) Vinyl alcohol
(poly) Vinyl butyral
(poly) Vinyl chloride/ ethylene/vinyl acetylene suspension copolymer
(poly) Vinyl chloride/ vinyl acetylene emulsion copolymer

Various Industries
Agriculture
Food
Powder Chemical
Textile
Furniture
Metal Processing and Fabrication
Tire and Rubber Manufacturing
Pharmaceutical
Paper
Waste Water Treatment
Recycling Operation
Coal + Mining
Pigment
Plastics

Prevention of Dust Explosions

To identify factors that may contribute to a explosion, OSHA recommends a thorough hazard assessment of:

- All materials handled
- All operations conducted, including by-products
- All spaces (including hidden ones)
- All potential ignition sources

OSHA has created the "Hazard Communication Guidance for Combustible Dusts". This document is intended to help manufacturers and importers of chemicals recognize the potential for dust explosions and to identify appropriate protective measures as part of their hazard determination under the Hazard Communication Standard (HCS). This document is available for view and download at www.osha.gov

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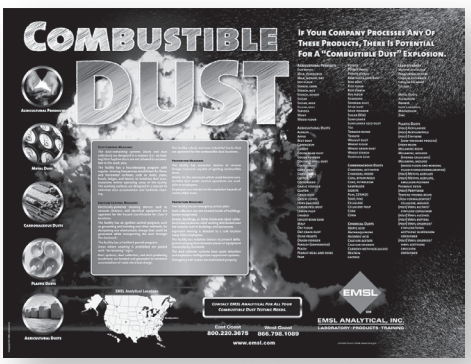


Should You be Concerned?

Combustible dust can be found in various industries. The force from a combustible dust can cause infrastructure damage, instrument damage, injuries, and even death. A concern is typically noted if a dust layer has accumulated 1/32" or greater over a surface area of at least 5% of the floor area. If you do not believe your employer is practicing good housekeeping and combustible dust is a concern in your workplace, you should alert your employer immediately. Always ask for an SDS of each material you are working with.

Dust Control Recommendations

- Implement a hazardous dust inspection, testing, housekeeping, and control program
- Use proper dust collection systems and filters
- Minimize the escape of dust from process equipment or ventilation systems
- Use surfaces that minimize dust accumulation and facilitate cleaning
- Provide access to all hidden areas to permit inspection
- Inspect for dust residues in open and hidden areas at regular intervals
- If ignition sources are present, use cleaning methods that do not generate dust clouds
- Use only vacuum cleaners approved for dust collection
- Locate relief valves away from dust deposits

Sampling Collection for Combustible Dust

Combustible dust sampling is straight forward. Air pumps or cassettes are not involved or required. The only type of samples that can be tested are bulk samples. Follow the below outline for sample collection:

- Air Sampling is not necessary
- Collection Tool: Natural bristle hand brush
- Collection Pan: Non-sparking, conductive dust pan (aluminum) for collecting settled dust
- Container: non-spark producing container, 1-Liter plastic jar or bottle
- Funnel: a non-spark producing funnel may be used to transport the dust from the dust pan to the jar/bottle.
- Dust from Cyclone: a non-spark producing scoop may be used to remove dust from cyclone containers or other ventilation equipment.
- Sample Weight: 500-1,000 grams, with up to 2,000 grams depending on sample type.
- **Make sure each sample is clearly labeled.**
- Once you have collected your sample(s) in your non-spark producing containers return the sample(s) to EMSL Analytical, Inc. for testing.

Sampling Submission

- Seal each sample tightly (use tape if necessary)
- Ensure weight requirement is met for testing
- Clearly label sample(s) containers with permanent marking
- Complete a copy of the Combustible Dust Chain of Custody
- Ensure testing option and turnaround time are checked
- Cross reference the sample(s) name and description with the label(s)
- Complete other documentation (included in quote package)
- Pack all material and paperwork into box/container acceptable for shipping
- Ship to: EMSL Materials Science Laboratory
  200 Route 130 North
  Cinnaminson, NJ 08077

Common Combustible Dust Tests

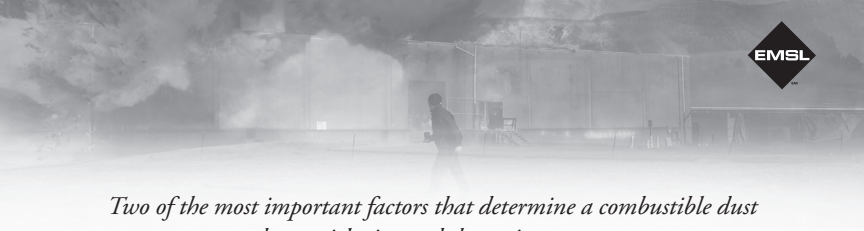
Below is a List of Common Tests & Methods Offered by **EMSL Analytical Testing Labs:**

EMSL Test Type	Method (ASTM)	Instrument	Ignition Source
Go/NoGo	E1226	Siwek 20 L	Chemical Igniter
Explosion Severity (Kst)	E1226	Siwek 20 L	Chemical Igniter
Minimum Ignition Energy (MIE)	E2019	Hartmann 1.2 L	Spark (Discharged Capacitor)
Minimum Explosive Concentration (MEC)	E1515	Siwek 20 L	Chemical Igniter
Minimum Ignition Temperature (MIT)	E1491	BAM Furnace	Heated Surface (Air)
Layer Ignition Temperature (LIT)	E2021	Hot Plate	Heated Surface (Layer)

A key difference between the combustible dust tests are the ignition sources used to ignite the dusts.

Initial Analysis – Sample Characterization

(ASTM D422 Standard Test Method for Particle-Size Analysis of Soils and OSHA ID201SG Explosibility and Combustibility Parameters) This test provides the following data points: particle size (percent through 40 mesh sieve), % moisture content, % combustible dust, % combustible material. The initial analysis should always be conducted first, prior to any combustible dust testing.



Two of the most important factors that determine a combustible dust are the particle size and the moisture content.

Go/NoGo

(ASTM E1226 Standard Test Method for Explosibility of Dust Clouds Explosive Screening) This is an economical and practical way to determine if the dust in the sample has the potential to be explosive. Testing consists of exposing the fine dust in the sample to low energy igniters inside the 20-Liter Siwek explosion chamber and determine the explosion over pressure. If the dust is not found to be an explosive threat, the analysis can be aborted to avoid unnecessary fees. If the sample turns out to be explosive on the screen testing, the more comprehensive analyses listed below should be conducted.

Qualifier: Go/No Go screening test was conducted using 5kJ ignition source. The criterion used for a "Go" qualifier is 1.0-bar explosion overpressure after accounting for the influence of the 5 kJ ignition source. Based on the example below, the explosion overpressure of 5.6 bar at 500 g/m3 indicates the material is an explosive "Go".

Go/NoGo Preliminary Screening Example Table:

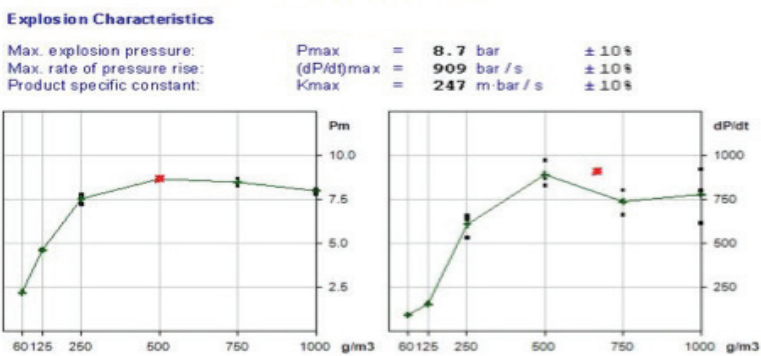
Customer Sample ID	500 g/m3	1000 g/m3	2000 g/m3
	Explosion Overpressure [Bar]	Explosion Overpressure [Bar]	Explosion Overpressure [Bar]
1	5.6	n/a	n/a

Note: Above table shows an example of an explosive "go" result based on ASTM E1226 testing conditions

Explosion Severity (Kst)

(ASTM E1226 Standard Test Method for Explosibility of Dust Clouds) This testing provides an indication of the severity of the dust explosion by determining the Deflagration parameters. The larger the value of Kst, the more severe the explosion. For this test, the dust is suspended and ignited in the Siwek 20L Chamber and the maximum pressure and the rate of pressure rise are measured. The Kst, Pmax, and dP/dt max are reported.

Below Sample: Pmax, dP/dt, and Kst example data showing pressure max and pressure rise with respect to time (dP/dt) vs. concentration (g/m3).



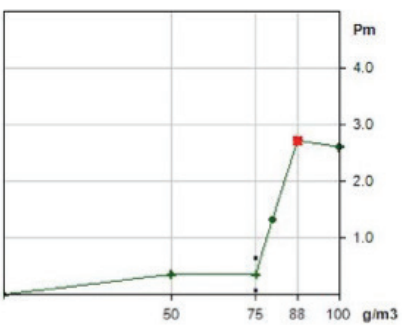
Explosion class determination from the maximum normalized rate of explosion.

Dust Explosion Class	Kst (bar.m/s)	Characteristic
St 0	0	No Explosion
St 1	>0 and ≤200	Weak Explosion
St 2	>200 and ≤300	Strong Explosion
St 3	>300	Very Strong Explosion

Minimum Explosive Concentration (MEC)

(ASTM E1515 Standard Test Method for Minimum Explosive Concentration of Combustible Dusts) MEC is the minimum concentration for explosivity of a combustible dust cloud. It is determined by suspending the dust in the Siwek 20L Chamber.

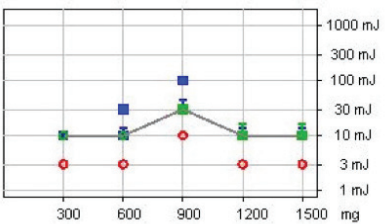
Below Sample: Minimum explosive concentration data showing pressure max (bar) vs. concentration (g/m3).



Minimum Ignition Energy (MIE)

(ASTM E2019 Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air) MIE is the electrical energy discharged from a capacitor, just sufficient to produce the ignition of the most ignitable mixture of air and dust. It is determined by suspending the dust in a Hartmann 1.2 Liter Vessel explosion chamber.

Below Sample: Minimum ignition energy showing millijoules plotted against concentration.



E2 [mJ]:		10	10
Es [mJ]:		4	7
E1 [mJ]:		3	3
tv [ms]:	90	120	150

Minimum Ignition Temperature (MIT)

(ASTM E1491 Standard Test Method for Minimum Autoignition Temperature of Dust Clouds) Dust Cloud - This test method covers the minimum temperature at which a dust cloud will auto ignite when exposed to air and heated in a furnace at atmospheric pressure. It is determined by introducing the dust into a BAM oven. As an alternative, the minimum temperature of self-ignition of dust layer can be measured using a hot plate set-up.

Layer Ignition Temperature (LIT)
(ASTM E2021 Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers) This test method determines the hot-surface ignition temperature of dust layers, that is, measuring the minimum temperature at which a dust layer will self-heat. The test consists of a dust layer heated on a hot plate.

Ignitability of Solids
(EPA 1030/ CFR § 49.173 (Ignitability of Solids) This method is suitable for the determination of the ignitability of solids. Material is formed into an unbroken strip or powder train. An ignition source is applied to one end of the test material to determine whether combustion will propagate within a specified time period. If propagation occurs, material is submitted to a burning rate test. In the burning rate test, burning time is measured over a distance and a burning rate is determined. Materials that do not ignite or propagate combustion do not require further testing.

Resistivity and Charge Relaxation Time
(ASTM D257 Standard Test Methods for DC Resistance or Conductance of Insulating Materials) The resistivity testing is particularly important for metal dust. The electrical nature of the dust is one criteria to determine if it is necessary to take special precaution with regard to electrical insulation of the equipment operating in a location with Class II dust.

Limiting Oxygen Concentration (LOC)
(ASTM E2931 Standard Test Method for Limiting Oxygen) Oxygen Concentration of Combustible Dust Clouds. This test method is designed to determine the limiting oxygen concentration of a combustible dust dispersed in a mixture of air with an inert/nonflammable gas. The testing is performed in the 20-L Siwek chamber.

Class II Dust Analysis

Class II dust analysis includes the following tests; initial analysis/sample characterization, explosion severity, MEC, MIE, and MIT.

This level of testing involves a number of parameters that determine if the sampled dust is considered a Class II hazardous material. Class II locations are defined as locations with combustible dust having Ignition Sensitivity (I.S.) greater than or equal to 0.2 or Explosion Severity (E.S.) greater than or equal to 0.5. I.S. is calculated from MIT, MIE, and MEC for the sample normalized to Pittsburgh coal dust, whereas E.S. is calculated from Pmax and[dP/dt]max for the sample, also normalized to Pittsburgh coal dust.

Class II locations: Class II locations are those that are hazardous because of the presence of combustible dust. Class II locations include the following:

(i) Class II, Division 1. A Class II, Division 1 location is a location: (a) In which combustible dust is or may be in suspension in the air under normal operating conditions, in quantities sufficient to produce explosive or ignitable mixtures; or (b) where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitable mixtures to be produced, and might also provide a source of ignition through simultaneous failure of electric equipment, operation of protection devices, or from other causes, or (c) in which combustible dusts of an electrically conductive nature may be present.

Note: This classification may include areas of grain handling and processing plants, starch plants, sugar-pulverizing plants, malting plants, hay-grinding plants, coal pulverizing plants, areas where metal dusts and powders are produced or processed, and other similar locations which contain dust producing machinery and equipment (except where the equipment is dust-tight or vented to the outside). These areas would have combustible dust in the air, under normal

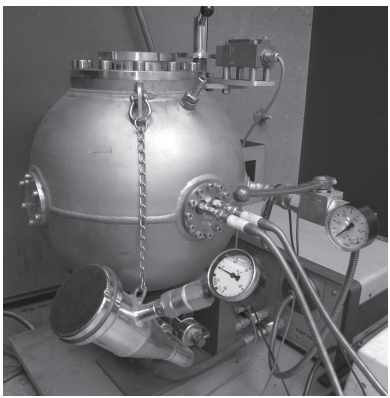
operating conditions, in quantities sufficient to produce explosive or ignitable mixtures. Combustible dusts which are electrically non-conductive include dusts produced in the handling and processing of grain and grain products, pulverized sugar and cocoa, dried egg and milk powders, pulverized spices, starch and pastes, potato and wood flour, oil meal from beans and seed, dried hay, and other organic materials which may produce combustible dusts when processed or handled. Dusts containing magnesium or aluminum are particularly hazardous and the use of extreme caution is necessary to avoid ignition and explosion.

(ii) Class II, Division 2. A Class II, Division 2 location is a location in which: (a) combustible dust will not normally be in suspension in the air in quantities sufficient to produce explosive or ignitable mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus; or (b) dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment, and dust accumulations resulting there from may be ignitable by abnormal operation or failure of electrical equipment or other apparatus.

Note: This classification includes locations where dangerous concentrations of suspended dust would not be likely but where dust accumulations might form on or in the vicinity of electric equipment. These areas may contain equipment from which appreciable quantities of dust would escape under abnormal operating conditions or be adjacent to a Class II Division 1 location, as described above, into which an explosive or ignitable concentration of dust may be put into suspension under abnormal operating conditions."

References: OSHA Instruction (2008).
CPL 03-00-008 Combustible Dust National Emphasis Program (Revised), Abstract 03-E6.

Laboratory Testing Equipment



Siwek 20L Spehere

MIKE3 Apparatus

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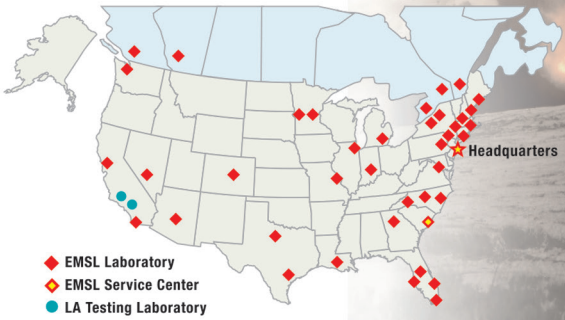

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