NEC Articles 500-516: Hazardous Locations

by Jim Phillips, P. E.

Mixing common elements like baking flour, coal dust, or gasoline with electricity could create a recipe for disaster.
Baking flour, coal dust and gasoline; what do these things have in common? They are not the ingredients for a strange new cake recipe. Each of these “ingredients” is the fuel that could cause a major explosion or fire. Grain silos, coal unloading facilities, refineries all have characteristics that if a spark occurs at the wrong place at the wrong time, it could be a recipe for disaster. These sites have areas that could be considered hazardous due to the presence of explosive material in the atmosphere. Something as simple as a small spark from opening a switch or the heat produced from a light fixture could be all it takes to ignite the fuel and create an explosion or fire. In fact, many electrical components have the capability to ignite an explosive or combustible atmosphere due to:

- Arcing of electrical components
- High temperatures produced by the equipment
- Electrical equipment failure from events such as short circuits.

The NEC and Hazardous Locations

The NEC defines a “Hazardous Location” as a location “where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.” There are 13 articles and 68 pages in the NEC regarding hazardous locations, installation practices and equipment requirements. Understanding what makes a location “hazardous” is the first step in providing a safer electrical system.

Materials that can cause a location to be classified as hazardous range from hydrogen, to grains, coal dust, petroleum products and many others. Hazardous locations are divided into three classes based on the type of material.

- Class I Flammable gases or vapors
- Class II Combustible or explosive dusts
- Class III Ignitable fibers or flyings

Each class is further divided into two sub-categories known as “divisions” that indicate how likely it is for the hazard to exist. Division 1 is defined as an explosive or flammable atmosphere being present during normal operation and Division 2 is defined as a hazardous atmosphere being present only during abnormal conditions.

Materials that make up the hazardous locations in Class I and Class II are further broken into categories known as “groups,” which are based on various properties of the material. Groups A through D are used for Class I, and Groups E through G are used for Class II. Class III does not have any groups. As an alternate to the division classification system, NEC Articles 505 and 506 cover the requirements for the zone classification system used by the IEC (International Electrotechnical Commission).

**Division Classification System**

<table>
<thead>
<tr>
<th>Class I</th>
<th>Division 1 or 2</th>
<th>Groups A–D</th>
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<tbody>
<tr>
<td>Class II</td>
<td>Division 1 or 2</td>
<td>Groups E–G</td>
</tr>
<tr>
<td>Class III</td>
<td>Division 1 or 2</td>
<td></td>
</tr>
</tbody>
</table>

Equipment that is designed for use in a hazardous location must be suitable for the class, division and group, which is why it is important to understand what hazardous locations are all about. Although the NEC provides the requirements for electrical installations in hazardous locations, the actual classification of the area is based on other documents and standards such as:
CLASS I LOCATIONS – Explosive Vapors and Gases

Facilities such as gasoline dispensing stations, refineries, chemical plants and many other facilities with flammable gases and vapors, are Class I locations. The vapors and gases in Class I are further categorized into one of four groups depending on various physical characteristics of the material and how volatile and dangerous it might be. Explosion-proof apparatus is one type of equipment used in a Class I location. This equipment must also be suitable for the material group.

Explosion-Proof Apparatus

The NEC defines Explosion-Proof Apparatus as:
“Apparatus enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor that may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and then operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby.”

“Explosion-Proof” equipment is not literally explosion proof. Contrary to popular belief, an explosion could occur inside the enclosure, but it must be capable of withstanding and safely releasing the pressure without igniting the surrounding atmosphere.

If the cover to the equipment is removed, the hazardous gas/vapor could enter the box and become trapped inside when the cover is reinstalled. Vapor may also enter through process connections and through gradual seepage. A spark that occurs inside the box could ignite the trapped gas/vapor producing an explosion. The box must not rupture and must safely release the pressure buildup from the rapid expansion of the hot gas and flame without igniting the surrounding atmosphere.

An explosion-proof design may use one of several methods to ensure that any explosion that occurs inside the explosion-proof enclosure does not propagate outside of it. Explosion pressures must be released, so the enclosure is designed to cool the gases so that they will not ignite any hazardous atmosphere outside of the enclosure.

One type of design uses a “ground surface flame path” construction as shown in Figure 1. This method uses two finely matched machined metal surfaces, which are bolted together. In the event of an internal explosion the hot gases are kept inside while the gap between the ground surfaces provides a path for the higher internal pressure to escape. The metal surfaces provide cooling of the hot gas and flame so they do not ignite the surrounding atmosphere.

Another common design uses threaded joint construction as shown in Figure 2. The equipment uses a threaded cover that allows the internal pressure to escape through the threaded path. Similar to the ground surface flame path construction, the metal cools the gas so that it will not ignite the surrounding atmosphere.

Equipment Temperature

In general, equipment must be marked with either the temperature class (T Rating) or operating temperature based
on a 40°C ambient temperature, unless it falls under one of the exceptions to the NEC. A “T” Rating is a temperature classification method based on the maximum surface temperature of the equipment. The equipment must not operate at temperatures that could ignite the atmosphere.

**Ambient Temperature Rating**

Equipment designed for use in classified locations is intended for use under normal atmospheric conditions within ambient temperature conditions ranging from -25°C to +40°C unless it is otherwise marked. If the equipment is used in higher atmospheric pressures, or higher ambient temperatures, an increase in the likelihood of ignition is possible. It is also possible that lower ambient temperatures could increase the pressure created during an explosion inside the equipment. Based on the inverse relationship between pressure and temperature, as temperature goes down, pressure goes up.

**Ignition Temperature.**

The ignition temperature is the minimum temperature at normal atmospheric pressure that will ignite the explosive or combustible material even though a spark or flame is not present. The temperature of the equipment in a hazardous location cannot exceed the ignition temperature of the specific material in the area or it could ignite. As an example, if a component could produce enough heat for its surface temperature to reach 300°C and the hazardous substance had an ignition temperature of 280°C, there could be a fire or explosion.

**Flash Point.**

The flash point is the minimum temperature required for a flammable liquid to give off enough vapor to ignite when it makes contact with a spark or flame. A lower flash point means the liquid will give off vapors at lower temperatures and as a result, be more susceptible to ignition sources.

**Maximum Experimental Safe Gap – MESG**

The MESG, known as the Maximum Experimental Safe Gap, is the maximum clearance between two parallel metal surfaces such as the flange of an enclosure and its cover, that has been determined under test to prevent an explosion. The experiment is conducted in a test chamber where an explosion is created inside the enclosure. The explosion must not propagate into a secondary chamber containing the same gas or vapor of the same concentration. The MESG is used to help define the group of a material. The NEC uses the units of millimeters e.g. MESG of 0.75 mm.

**Minimum Igniting Current Ratio – MIC Ratio**

The MIC Ratio is determined by dividing the minimum current required from an inductive spark discharge to ignite the most easily ignitable mixture of gas or vapor by the minimum current required from an inductive spark discharge to ignite methane under the same test conditions. It is also used to help define the group of the material.

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\text{MIC Ratio} = \frac{\text{Minimum Current from Inductive Spark to Ignite Gas or Vapor}}{\text{Minimum Current from Inductive Spark to Ignite Methane}}
\]

The NEC classifies the materials into one of four groups according to its maximum MESG value and maximum MIC Ratio.

<table>
<thead>
<tr>
<th>Group</th>
<th>Typical Material in Group</th>
<th>MESG</th>
<th>MIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Acetylene</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>Hydrogen</td>
<td>&lt; 0.45</td>
<td>&lt; 0.40</td>
</tr>
<tr>
<td>C</td>
<td>Ethylene</td>
<td>&gt; 0.45</td>
<td>&gt; 0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 0.75</td>
<td>&lt; 0.8</td>
</tr>
<tr>
<td>D</td>
<td>Propane/Gasoline</td>
<td>&gt; 0.75</td>
<td>&gt; 0.8</td>
</tr>
</tbody>
</table>

**Flammable Limits**

For an ignition source to cause flammable vapors and gases to burn or explode, there must be a good mix of both oxygen and fuel. Just like an automobile engine, too much oxygen with not enough fuel and the mix is too “lean” to burn and will not ignite. This is known as the lower flammable limit or LFL. The same problem occurs at the other end of the scale as well. Too much fuel with not enough oxygen and the mixture is too “rich” to burn, which is the upper flammable limit (UFL). The concentration of a flammable gas or vapor in air that will ignite...
and continue to burn falls somewhere between the upper and lower flammable limits.

**Vapor Density**
Hazardous location design also depends on how heavy the gas or vapor is. Vapor density is an indicator of whether a gas will tend to rise towards the ceiling or settle towards the floor in normal atmospheric pressure and temperature. The density is based on the weight of a volume of the vapor or gas with no air compared to the weight of the same volume of air. A ratio of less than one indicates the vapor is lighter than air and will rise towards the ceiling where hot lighting fixtures are located. A ratio greater than one indicates the vapor is heavier than air and will settle towards the ground.

**CLASS II LOCATIONS – Combustible Dust**
Dusts can be suspended in air for a period of time, forming a dust cloud. Similar to Class I locations, when there is a sufficient concentration of dust in the air, there can be a violent explosion when ignited. Combustible dusts have many characteristics that define their ignition properties. These properties indicate how easily the dust ignites and how severe the explosion would be. Dusts with similar ignition properties are classified into one of three groups that the NEC defines as:

- **Group E** Metal dust
- **Group F** Coal and similar dust
- **Group G** Grain dust

A measurement used to determine how easily a combustible dust can ignite is defined as the ignition sensitivity. Dust ignition is a function of the concentration of the dust, the ignition temperature and the minimum energy that it takes for ignition to occur.

Explosion severity is the measure of how violent the explosion will be. This is based on the maximum explosion pressure, maximum rate of pressure rise, and how long the pressure will last. All of these help determine the destructive capability of the explosion.

**Ignition Temperature**
In the absence of a spark or flame, a combustible dust could also be ignited due to an electrical component’s temperature exceeding the ignition temperature of the dust. The ignition temperature of a dust layer is usually lower than a dust cloud. Dust clouds are unlikely to ignite from high temperatures alone. Most dust clouds need a large amount of energy to ignite, so it usually takes a spark or flame to cause the explosion.

The size of the dust particles as well as their moisture content can have an effect on the explosiveness. Smaller particles are easier to ignite – as the particle size gets smaller, the pressure rise will be greater and the ignition temperature, explosive limit concentration, and energy required for ignition, will be lower. Dust that has a higher moisture content will have a higher ignition temperature rating and it also affects electrical conductivity. However most ignition sources have more than enough heat to evaporate the moisture.

In the absense of a spark or flame, a combustible dust could also be ignited due to an electrical component's temperature exceeding the ignition temperature of the dust.
important that the exterior surface of the enclosure remains cool enough to not ignite dust that might accumulate on it or be suspended in the surrounding atmosphere. The equipment’s design must also consider the increase in heat that results from the insulating effect of the dust buildup on the equipment’s surface.

**Small Dust Cloud – Big Explosion**

How can an entire facility be destroyed by the ignition of a dust cloud unless the cloud filled the entire place? Many major explosions have occurred that began with the ignition of a small localized dust cloud. Research and investigations have shown that even an explosion of a small localized dust cloud can be devastating because often two explosions actually occur. The first is the explosion created by ignition of the local dust cloud. This initial explosion shakes loose the years of dust that has settled through other parts of the building, which then ignites, resulting in a much bigger secondary explosion.

**Class III Locations – Ignitable Fibers and Flyings**

Class III locations may contain easily ignitable fibers or flyings such as found in textile mills or sawmills. In these types of facilities, the fibers or flyings are not likely to be suspended in the atmosphere, forming a cloud that could ignite or explode like Class II locations. However, if enough material accumulates on the surface of equipment such as lamps, motors or other similar heat producing components and the surface becomes hot enough to ignite the fibers or flyings, a fast burning fire could result.

Similar to equipment used for Class II locations, equipment designed for Class III locations must minimize the ability of fibers and flyings to enter the equipment. The design must also prevent sparks, hot metal particles or burning material that could occur during an equipment failure from leaving the box. To prevent the ignition of the fibers that accumulate on the box, the equipment must operate at temperatures below the material’s ignition temperature.

**Dust-Tight Apparatus**

Dust-tight apparatus is frequently used in Class III locations. This type of apparatus is sealed so that dust, fibers and flyings do not enter the enclosure under specific test conditions.

**Reducing the Risk**

Since it takes fuel, oxygen and an ignition source to create a fire or explosion, eliminating any one of the three components is critical to providing a safer electrical system. Keeping sparks and heat away from the fuel is the main objective of most electrical equipment installations in classified locations. Whether this is done with explosion-proof apparatus, dust-ignition-proof or dust-tight enclosures, the goal is the same. Keep the ignition source away from the fuel and oxygen.

The NEC also addresses other protection methods that might be used in hazardous locations. These methods include the use of purged or pressurized systems that keep the fuel away from the ignition source, intrinsically safe systems (per ANSI/UL 913), as well as a few other methods. In addition the NEC addresses suitable conduit, wiring and conduit seals to create a complete system.

In all, the NEC provides 13 Articles covering 68 pages so that the design and installation of electrical systems in hazardous locations will be safer. One final design method that is frequently used is actually the safest method of all. Locate electrical equipment outside of the hazardous area whenever possible. Don’t let the wrong mix of ingredients be your recipe for disaster! 🟢

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The presence of coal dust, which is highly combustible, poses less risk of ignition and explosion outdoors than it does indoors where it constitutes an NEC Class II Hazardous Location.

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