

BASIC NATIONAL ELECTRIC CODE APPLICABLE TO MEASUREMENT

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The *National Electrical Code* (NEC) defines hazardous locations as those areas "where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or filings."

A substantial part of the NEC is devoted to the discussion of hazardous locations. That's because electrical equipment can become a source of ignition in these volatile areas. Articles 500 through 504, and 510 through 517 provide classification and installation standards for the use of electrical equipment in these locations. The writers of the NEC developed a short-hand method of describing areas classified as hazardous locations. One of the purposes of this discussion is to explain this classification system. Hazardous locations are classified in three ways by the *National Electrical Code*: TYPE, CONDITION, and NATURE.

Hazardous Location Types

Class I Locations

According to the NEC, there are three types of hazardous locations. The first type of hazard is one which is created by the presence of *flammable gases or vapors* in the air, such as natural gas or gasoline vapor. When these materials are found in the atmosphere, a potential for explosion exists, which could be ignited if an electrical or other source of ignition is present. The Code writers have referred to this first type of hazard as *Class I*. So, a *Class I Hazardous Location* is one in which *flammable gases or vapors* may be present in the air in sufficient quantities to be explosive or ignitable. Some typical Class I locations are:

- Petroleum refineries, and gasoline storage and dispensing areas;
- Dry cleaning plants where vapors from cleaning fluids can be present;
- Spray finishing areas;
- Aircraft hangars and fuel servicing areas; and
- Utility gas plants, and operations involving storage and handling of liquefied petroleum gas or natural gas.
- All of these are Class I . . . gas or vapor . . . hazardous locations. All require special Class I hazardous location equipment.

Class II Locations

The second type of hazard listed by the *National Electrical Code* are those areas made hazardous by the presence of combustible *dust*. These are referred to in the Code as "Class II Locations." Finely pulverized material, suspended in the atmosphere, can cause as powerful an explosion as one occurring at a petroleum refinery. Some typical Class II locations are:

- Grain elevators;
- Flour and feed mills;
- Plants that manufacture, use or store magnesium or aluminum powders;
- Producers of plastics, medicines and fireworks;
- Producers of starch or candies;
- Spice-grinding plants, sugar plants and cocoa plants; and
- Coal preparation plants and other carbon handling or processing areas.

Class III Locations

Class III hazardous locations, according to the NEC, are areas where there are *easily-ignitable fibers or filings* present, due to the types of materials being handled, stored, or processed. The fibers and filings are not likely to be suspended in the air, but can collect around machinery or on lighting fixtures and where heat, a spark or hot metal can ignite them. Some typical Class III locations are:

- Textile mills, cotton gins;

- Cotton seed mills, flax processing plants; and
- Plants that shape, pulverize or cut wood and create sawdust or filings.

Hazardous Location Conditions

In addition to the types of hazardous locations, the *National Electrical Code* also concerns itself with the kinds of conditions under which these hazards are present. The Code specifies that hazardous material may exist in several different kinds of *conditions* which, for simplicity, can be described as, first, normal conditions, and, second, abnormal conditions.

In the **normal** condition, the hazard would be expected to be present in everyday production operations or during frequent repair and maintenance activity.

When the hazardous material is expected to be confined within closed containers or closed systems and will be present only through accidental rupture, breakage or unusual faulty operation, the situation could be called "**abnormal**".

The Code writers have designated these two kinds of conditions very simply, as **Division 1 - normal** and **Division 2 - abnormal**. Class I, Class II and Class III hazardous locations can be either Division 1 or Division 2.

Good examples of Class I, Division 1 locations would be the areas near open dome loading facilities or adjacent to relief valves in a petroleum refinery, because the hazardous material would be present during *normal* plant operations.

Closed storage drums containing flammable liquids in an inside storage room would not normally allow the hazardous vapors to escape into the atmosphere. But, what happens if one of the containers is leaking? You've got a Division 2 -abnormal - condition . . . a Class I, Division 2 hazardous location.

So far we've covered the three types of hazardous locations:

- Class I - gas or vapor
- Class II - dust, and
- Class III - fibers and filings.

And secondly, kinds of conditions:

- Division 1 - normal conditions, and
- Division 2 - abnormal conditions.

Now let's move on to a discussion of the **nature** of hazardous substances.

Nature of Hazardous Substances

The gases and vapors of Class I locations are broken into four groups by the Code: A, B, C, and D. These materials are grouped according to the ignition temperature of the substance, its explosion pressure, and other flammable characteristics.

The only substance in **Group A is acetylene**. Acetylene makes up only a very small percentage of hazardous locations. Consequently, little equipment is available for this type of location. Acetylene is a gas with extremely high explosion pressures.

Group B is another relatively small segment of classified areas. This group includes hydrogen and other materials with similar characteristics. If you follow certain specific restrictions in the Code, some of these Group B locations, other than hydrogen, can actually be satisfied with Group C and Group D equipment.

Group C and Group D are by far the most usual Class I groups. They comprise the greatest percentage of all Class I hazardous locations. Found in Group D are many of the most common flammable substances such as butane, gasoline, **natural gas and propane**.

In Class II - dust locations - we find the hazardous materials in Groups E, F, and G. These groups are classified according to the *ignition temperature* and the *conductivity* of the hazardous substance. Conductivity is an important consideration in Class

II locations, especially with metal dusts.

Metal dusts are categorized in the Code as Group E. Included here are aluminum and magnesium dusts and other metal dusts of similar nature.

Group F atmospheres contain such materials as carbon black, charcoal dust, coal and coke dust.

In Group G we have grain dusts, flour, starch, cocoa, and similar types of materials.

Review

Let's quickly review. Hazardous locations are classified in three ways by the *National Electrical Code*: TYPE, CONDITION, and NATURE.

There are three **types** of hazardous conditions: Class I - gas and vapor, Class II - dust, and Class III - fibers and filings.

There are two kinds of hazardous **conditions**: Division 1 - normal, and Division 2 - abnormal.

And finally, there is the nature of the hazardous substance . . . where we find Groups A, B, C, and D in Class I locations, and, in Class II locations: Groups E, F, and G.

Let's illustrate our Code "translation" with an example. How would we classify a storage area where LP gas is contained in closed tanks? LP gas is a Class I substance (gas or vapor). It's Division 2 because it would only be in the atmosphere if an accidental rupture or leakage occurred, and it is Group D material.

Natural Gas facilities would be classified as Class I, Division I or II, Group D. The table below summarizes the various hazardous (classified) locations.

Summary of Class I, II, III Hazardous Locations			
CLASSES	GROUPS	DIVISIONS	
		1	2
I Gases, vapors, and liquids (Art. 501)	A: Acetylene B: Hydrogen, etc. C: Ether, etc. D: Hydrocarbons, fuels, solvents, etc.	Normally explosive and hazardous	Not normally present in an explosive concentration (but may accidentally exist)
II Dusts (Art. 502)	E: Metal dusts (conductive,* and explosive) F: Carbon dusts (some are conductive,* and all are explosive) G: Flour, starch, grain, combustible plastic or chemical dust (explosive)	Ignitable quantities of dust normally are or may be in suspension, or conductive dust may be present	Dust not normally suspended in an ignitable concentration (but may accidentally exist). Dust layers are present.
III Fibers and flings (Art. 503)	Textiles, wood-working, etc. (easily ignitable, but not likely to be explosive)	Handled or used in manufacturing	Stored or handled in storage (exclusive of manufacturing)

TABLE 1. Summary of Hazardous Locations

*NOTE: Electrically conductive dusts are dusts with a resistivity less than 10^5 ohm-centimeter.

Classification of Locations In Gas Utility Areas

The best resource for classifying natural gas utility areas would be AGA Catalog # XL1001 "Classification of Locations for Electrical Installations in Gas Utility Areas". This document discusses the classification of areas based on the characteristics of the flammable gas, dispersion, normal and abnormal conditions, ventilation, air currents and many other factors. Of special interest are the recommended distances given in Appendix C. An example is shown here.

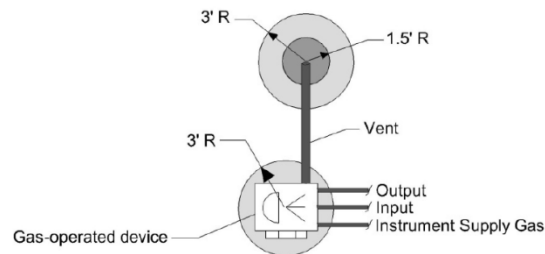


Figure 1. Recommendation Example from AGA Catalog #XL1001

Hazardous Location Equipment

Sources of Ignition

Now that we've completed our Code translation, we're ready to move to the next part of our discussion - hazardous location equipment. To do this, let's first take a look at the ways in which electrical equipment can become a source of ignition. There are three of them.

Arcs and sparks produced by the normal operation of equipment, like motor starters, contactors, and switches, can ignite a hazardous location atmosphere.

The high temperatures of some heat-producing equipment, such as lamps and lighting fixtures, can ignite flammable atmospheres if they exceed the ignition temperature of the hazardous material. The *National Electrical Code* requires special marking of heat - producing equipment with temperatures above 100°C (212°F).

Electrical equipment failure is another way an explosion could be set off. A burn out of a lamp socket or shorting of a terminal could spark a real disaster in a hazardous location.

Equipment Design and Construction

Now let's get down to specific hardware and how it is designed and constructed to be suitable for hazardous locations . . . starting with those designed for Class I . . . gas or vapor . . . applications.

The first requirement for a Class I enclosure is **strength**. The enclosure must be strong enough to contain an explosion **within**. The walls must be thick enough to withstand the internal strain. It has to be explosion-proof in case gas or vapors get inside. Secondly, it must function at a temperature **below** the ignition temperature of the surrounding atmosphere.

The equipment must also provide a way for the burning gases to escape from the device as they expand during an internal explosion; but, only after they have been cooled off and their flames "quenched." This escape route for the exploding gases is provided through several types of **flame paths**.

One type is the **ground surface** flame path. Here the surfaces are ground, mated, and held to a tolerance of 15 ten-thousandths of an inch. This permits gases to escape, but only after they've been sufficiently **cooled**, so they won't ignite the volatile surrounding atmosphere.

Another kind of flame path is the **threaded** flame path. After an explosion, the gas travels out the threaded joint . . . but as it does, it cools off.

Exploded gases may also escape around the shafts of operators used in the enclosure. But, here again, close tolerances are used to quench the burning gas.

Examples of two flame paths are shown below.

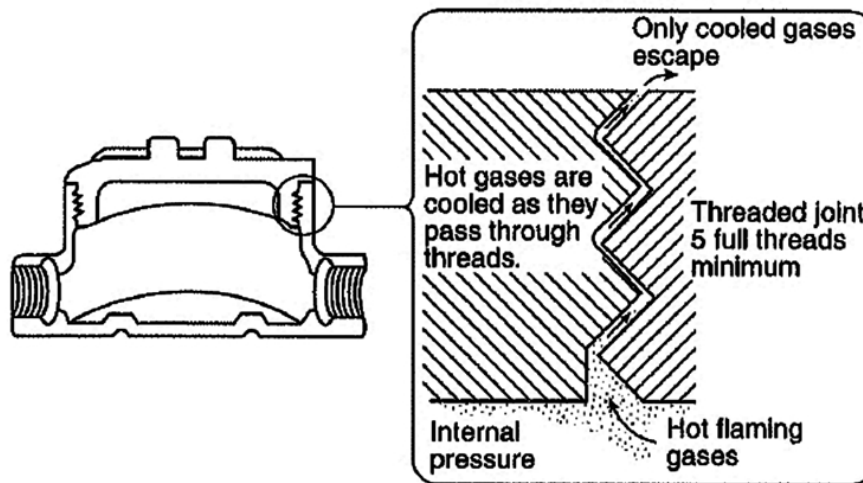


Figure 2. Flame Path Example 1

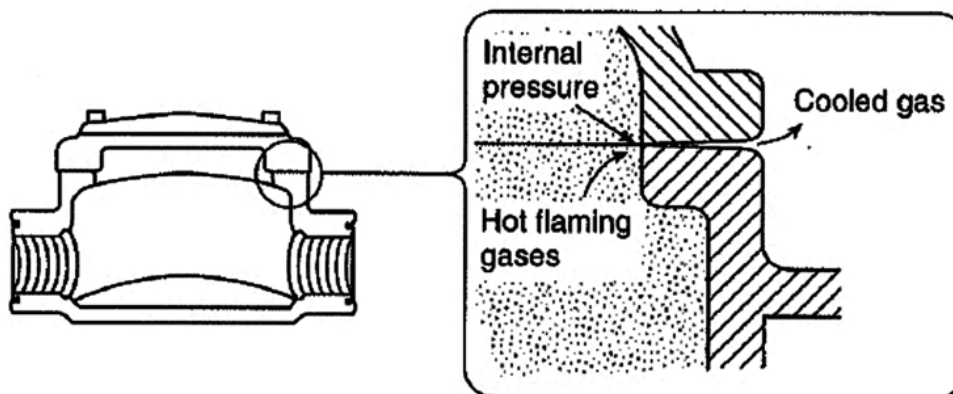


Figure 3. Flame Path Example 2

You can see how important it is to make certain that all flame paths are protected during installation and maintenance, and even during handling, shipping, and storage of explosion-proof material. Even slight damage to a flame path can permit burning gases to escape, igniting the surrounding atmosphere. Also, all cover bolts must be installed for the same reason. A single missing bolt could allow the release of flaming gases.

In designing equipment for Class I, Division 1 locations, it is assumed that the hazardous gases or vapors will be present and eventually seep into the enclosure, so there is a very real chance for an internal explosion to occur.

In the case of Class II, however, the assumptions are different and so the design is different. In Class II, the explosive dust is kept away from equipment housed within the enclosure so that no internal explosion can take place and there is no longer any need for heavy explosion-containing construction, or flame paths. This difference explains why Class I, Division 1 equipment can be called explosion-proof, and Class II equipment is called dust-ignition proof. Class II equipment has a different set of requirements:

1. It must seal out the dust.
2. It must operate below the ignition temperature of the hazardous substance.

3. It must allow for a *dust blanket*. That is, the build-up of dust collecting on top of the device that can cause it to run "hot" and ignite the surrounding atmosphere.

For Class III equipment, there is very little difference in the design from Class II. Class III equipment must minimize entrance of fibers and filings; prevent the escape of sparks, burning material or hot metal particles resulting from failure of equipment; and operate at a temperature that will prevent the ignition of fibers accumulated on the equipment.

There are many enclosures, devices, and fixtures suitable for all three classes. This simply means that it meets the specifications for each individual type. A Class I device which could contain an explosion of a specified gas would also have to prevent dust from entering the enclosure to be suitable for Class II. The close tolerance of the flame path which cools the burning gases is also close enough to exclude explosive dust so that a gasket would not be needed.

Proper installation of hazardous location equipment calls for the use of *seals*. Special fittings are required to keep hot gases from traveling through the conduit system igniting other areas if an internal explosion occurs in a Class I device. They are also needed in certain situations to keep flammable dusts from entering dust-ignition-proof enclosures through the conduit. As shown in the figure below, when arcs and sparks cause ignition of flammable gases and vapors, the equipment contains the explosion and vents only cool gases into the surrounding hazardous area.

HAZARDOUS LOCATION EQUIPMENT SEALS

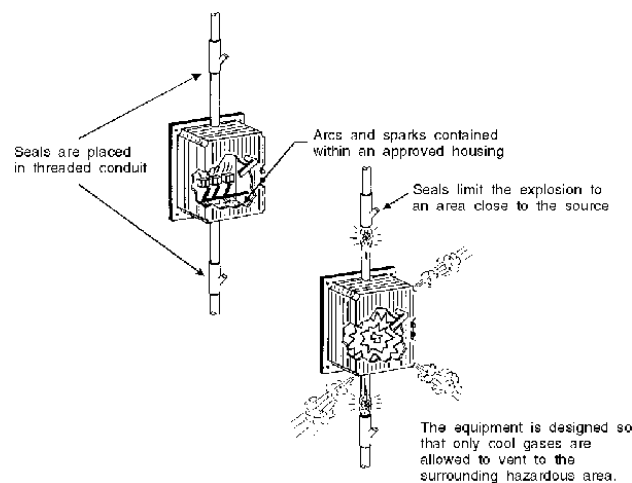


Figure 4. Seal Installation

Sealing fittings are designed to be filled with a chemical compound after the wires have been pulled. As the compound hardens, it seals passageways for dusts and gases. As shown in the figure below, in each conduit run entering an enclosure for switches, circuit breakers, fuses, relays, resistors, or other apparatus which may produce arcs, sparks, or high temperatures within Class I locations, conduit seals shall be placed as close as practicable and in no case more than 18 inches (457 mm) from such enclosures. Again, consult the Code for specific rules for the use of seals.

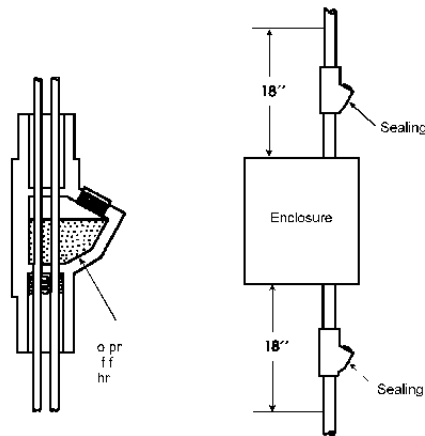


Figure 5. Seal Cross-Section

Rigorous standards for hazardous location equipment have been set. Nationally Recognized Testing Laboratories conduct actual explosion tests under laboratory conditions. For each Class I enclosure they experiment with different mixtures of gas and air . . . from very lean mixtures (a small percentage of gas) to very rich mixtures (a high percentage of gas) until they find the one that creates the *greatest explosion pressure*. To pass inspection, the equipment must not only prevent the ignition of the surrounding atmosphere, but also be able to withstand a hydrostatic test where oil is pumped into the enclosure at high pressure to test the limits of its strength. The device will not pass unless it can resist rupture at *four times* the maximum pressure found in the explosion tests. For example, if explosion testing shows a maximum pressure for a junction box of 250 pounds per square inch (psi), to get approval, the box must be able to withstand 1,000 psi of hydrostatic pressure - *FOUR TIMES the maximum anticipated pressure of 250 psi*.

Wiring Methods

Class I, Division I

Wiring methods in Class I, Division I areas must comply with the following:

- Threaded rigid metal conduit
- Threaded steel intermediate metal conduit
- Type MI cable with termination fittings approved for the location
- All boxes, fittings, and joints shall be threaded for connection to conduit or cable terminations and shall be explosion proof.
- Nonmetallic conduit is permitted when encased in concrete a minimum of 2 inches thick and buried 2 feet. Nonmetallic conduit must transition to metal conduit 2 feet before emergence.

Class I, Division II

Wiring methods in Class I, Division II areas must comply with the following:

- Threaded rigid metal conduit
- Threaded steel intermediate metal conduit
- Enclosed gasketed busways
- Enclosed gasketed wireways
- Type PLTC cable
- Type ITC cable
- Type MI, MC, MV or TC cable
- Boxes, fittings, and joints are not required to be explosion proof.

Intrinsically Safe Systems

The theory behind intrinsic safety is to ensure that the available electrical and thermal energy in the system is always low enough that ignition of the hazardous atmosphere cannot occur. This is achieved by ensuring that only low voltages and currents enter the hazardous area, and that all electric supply and signal wires are protected by Zener safety barriers. Sometimes an alternative type of barrier known as a galvanic isolation barrier may be used.

In normal uses, electrical equipment often creates internal tiny sparks in switches, motor brushes, connectors, and in other places. Such sparks can ignite flammable substances present in air.^[1] A device termed intrinsically safe is designed to not contain any components that produce sparks or which can hold enough energy to produce a spark of sufficient energy to cause an ignition.

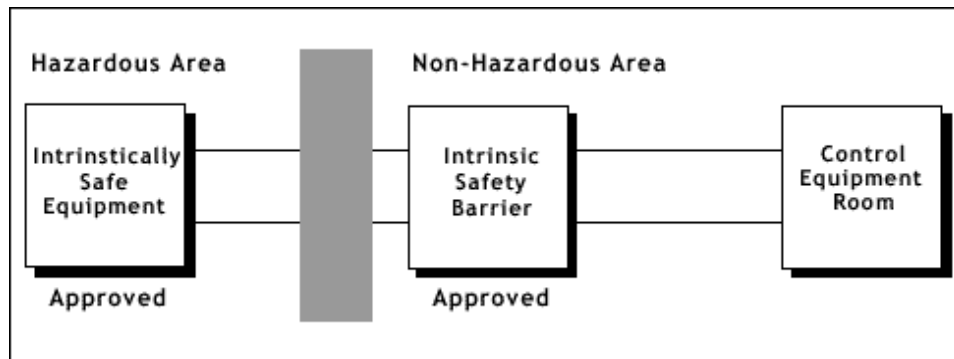


Figure 6. Intrinsic Safety Barrier

Most applications require a signal to be sent out of or into the hazardous area. The equipment mounted in the hazardous area must first be approved for use in an intrinsically safe system. The barriers designed to protect the system must be mounted outside of the hazardous area in an area designated as Non-hazardous or Safe in which the hazard is not and will not be present.

Equipment which has been designed for and is available for use in hazardous areas with intrinsically safe barriers includes:

- 4-20 mAdc Two Wire Transmitters
- Thermocouples
- RTDs
- Strain Gages
- Pressure, Flow, & Level Switches
- I/P Converters
- Solenoid Valves
- Proximity Switches
- Infrared Temperature Sensors
- Potentiometers
- LED Indicating Lights
- Magnetic Pickup Flowmeters

Most of the apparatus that is mounted in the Hazardous area will have to be approved and certified for use in the Hazardous area with an approved barrier designed for use with that apparatus. Some simple devices like thermocouples, RTDs, LEDs and contacts can be used in the hazardous area without certification as long as it is wired in conjunction with an approved barrier.

Intrinsically safe equipment and wiring can be installed using any of the wiring methods suitable for unclassified locations. Conduit for intrinsically safe systems must be sealed as we discussed above and cannot be installed in the same conduit as non-intrinsically safe systems.

Summary

Regardless of the cause of a hazardous location, it is necessary that every precaution be taken to guard against ignition of the atmosphere. Electrical equipment can be a potential source of ignition through one of three ways:

1. Arcs and sparks
2. High temperatures
3. Electrical equipment failure

Hazardous location equipment is designed and constructed to eliminate the potential for ignition of the atmosphere.

The *National Electrical Code* is the "Bible" of the Electrical Industry, and the primary source of reference for hazardous locations. The NEC is also the basis for OSHA standard [1926.407](#), Hazardous (Classified) Locations. There are several OSHA standards that require the installation of electrical wiring and equipment in hazardous (classified) locations according to the requirements of Subpart K, Electrical. The NEC should be consulted as a supplement to the OSHA standards for additional background information concerning hazardous locations.

Recommended reading for this topic:

- National Electrical Code, [NFPA 70](#), Chapter 5, Article 500
- [29 CFR 1910 Subpart S](#), Electrical 1910.307
- [NFPA 497](#), "Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous Classified Locations"
- NFPA Handbook, "[Electrical Installations in Hazardous Locations](#)," by P. J. Schram and M. W. Earley
- [NFPA 70E](#), Chapter 5, "Hazardous (Classified) Locations"
- [NFPA 325](#), "Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids"
- [ANSI/UL 913](#), "Intrinsically Safe Apparatus"
- [NFPA 496](#), "Purged and Pressurized Enclosure for Electrical Equipment in Hazardous Locations."
- American Gas Association [Catalog No. XL1001](#) "Classification Of Locations For Electrical Installations In Gas Utility Areas", revised by Distribution And Transmission Engineering Committee, revised Sept. 2010