ELECTRICAL STANDARDS FOR CONSTRUCTION

INTRODUCTION

Electricity has long been recognized as a serious workplace hazard, exposing employees to such dangers as electric shock, electrocution, fires, and explosions.

Experts in electrical safety have traditionally looked toward the widely used *National Electrical Code* (NEC) for help in the practical safeguarding of persons from these hazards. The Occupational Safety and Health Administration (OSHA) recognized the important role of the NEC in defining basic requirements for safety in electrical installations by including the entire 1971 NEC by reference in Subpart K of 29 *Code of Federal Regulations* Part 1926 (Construction Safety and Health Standards).

In a final rule dated July 11, 1986, OSHA updated, simplified, and clarified Subpart K, 29 CFR 1926. The revisions serve these objectives:

- NEC requirements that directly affect employees in construction workplaces have been placed in the text of the OSHA standard, eliminating the need for the NEC to be incorporated by reference.

- Certain requirements that supplemented the NEC have been integrated in the new format.

- Performance language is utilized and superfluous specifications omitted and changes in technology accommodated.

In addition, the standard is easier for employers and employees to use and understand. Also, the OSHA revision of the electrical standards has been made more flexible, eliminating the need for constant revision to keep pace with the NEC, which is revised every three years.

SUBPART K

The NEC provisions directly related to employee safety are included in the body of the standard itself - making it unnecessary to continue the adoption by reference of the NEC. Subpart K is divided into four major groups plus a general definitions section:

- Installation Safety Requirements
  [29 CFR 1926.402 - 1926.415]

- Safety-Related Work Practices
  [29 CFR 1926.416 - 1926.430]

- Safety-Related Maintenance and Environmental Considerations
  [29 CFR 1926.431 - 1926.440]

- Safety Requirements for Special Equipment
  [29 CFR 1926.441 - 1926.448]

- Definitions
  [29 CFR 1926.449]

I. Installation Safety Requirements

Part I of the standard is very comprehensive. Only some of the major topics and brief summaries of these requirements are included in this discussion.

Sections 29 CFR 1926.402 through 1926.408 contain installation safety requirements for electrical equipment and installations used to provide electric power and light at the jobsite. These sections apply to installations, both temporary and permanent, used on the jobsite; but they *do not* apply to existing permanent installations that were in place before the construction activity commenced.

If an installation is made in accordance with the 1984 *National Electrical Code*, it will be considered to be in compliance with Sections 1926.403 through 1926.408, except for:

1926.404(b)(1)	Ground-fault protection for employees
1926.405(a)(2)(ii)(E)	Protection of lamps on temporary wiring
1926.405(a)(2)(ii)(F)	Suspension of temporary lights by cords
1926.405(a)(2)(ii)(G)	Portable lighting used in wet or conductive locations
1926.405(a)(2)(ii)(J)	Extension cord sets and flexible cords

Approval

The electrical conductors and equipment used by the employer must be approved.

Examination, Installation, and Use of Equipment

The employer must ensure that electrical equipment is free from recognized hazards that are likely to cause death or serious physical harm to employees. Safety of equipment must be determined by the following:

- Suitability for installation and use in conformity with the provisions of the standard. Suitability of equipment for an identified purpose may be evidenced by a listing, by labeling, or by certification for that identified purpose.
- Mechanical strength and durability. For parts designed to enclose and protect other equipment, this includes the adequacy of the protection thus provided.
- Electrical insulation.
- Heating effects under conditions of use.
- Arcing effects.
- Classification by type, size, voltage, current capacity, and specific use.
- Other factors that contribute to the practical safeguarding of employees who use or are likely to come in contact with the equipment.

Guarding

Live parts of electric equipment operating at 50 volts or more must be guarded against accidental contact. Guarding of live parts must be accomplished as follows:

- Location in a cabinet, room, vault, or similar enclosure accessible only to qualified persons.

- Use of permanent, substantial partitions or screens to exclude unqualified persons.
- Location on a suitable balcony, gallery, or platform elevated and arranged to exclude unqualified persons.
- Elevation of eight feet or more above the floor.

Entrance to rooms and other guarded locations containing exposed live parts must be marked with conspicuous warning signs forbidding unqualified persons to enter.

Electric installations that are over 600 volts and that are open to unqualified persons must be made with metal-enclosed equipment or enclosed in a vault or area controlled by a lock. In addition, equipment must be marked with appropriate caution signs.

Overcurrent Protection

The following requirements apply to overcurrent protection of circuits rated 600 volts, nominal, or less.

- Conductors and equipment must be protected from overcurrent in accordance with their ability to safely conduct current and the conductors must have sufficient current-carrying capacity to carry the load.
- Overcurrent devices must not interrupt the continuity of the grounded conductor unless all conductors of the circuit are opened simultaneously, except for motor-running overload protection.
- Overcurrent devices must be readily accessible and not located where they could create an employee safety hazard by being exposed to physical damage or located in the vicinity of easily ignitable material.
- Fuses and circuit breakers must be so located or shielded that employees will not be burned or otherwise injured by their operation, e.g., arcing.

Grounding of Equipment Connected by Cord and Plug

Exposed noncurrent-carrying metal parts of cord- and plug-connected equipment that may become energized must be grounded in the following situations:

- When in a hazardous (classified) location.

- When operated at over 150 volts to ground, except for guarded motors and metal frames of electrically heated appliances if the appliance frames are permanently and effectively insulated from ground.

- When one of the types of equipment listed below. But see Item 6 for exemption.

  1. Hand held motor-operated tools.

  2. Cord- and plug-connected equipment used in damp or wet locations or by employees standing on the ground or on metal floors or working inside metal tanks or boilers.

  3. Portable and mobile X-ray and associated equipment.

  4. Tools likely to be used in wet and/or conductive locations.

  5. Portable hand lamps.

  6. [Exemption] Tools likely to be used in wet and/or conductive locations need not be grounded if supplied through an isolating transformer with an ungrounded secondary of not over 50 volts. Listed or labeled portable tools and appliances protected by a system of double insulation, or its equivalent, need not be grounded. If such a system is employed, the equipment must be distinctively marked to indicate that the tool or appliance uses a system of double insulation.

II. SAFETY-RELATED WORK PRACTICES

Protection of Employees

The employer must not permit an employee to work near any part of an electric power circuit that the employee could contact in the course of work, unless the employee is protected against shock by de-energizing the circuit and grounding it or by guarding it effectively by insulation or other means.

Where the exact location of underground electric power lines is unknown, employees using jack hammers or hand tools that may contact a line must be provided with insulated protective gloves.

Even before work is begun, the employer must determine by inquiry, observation, or instruments where any part of an exposed or concealed energized electric power circuit is located. This is necessary because a person, tool or machine could come into physical or electrical contact with the electric power circuit.

The employer is required to advise employees of the location of such lines, the hazards involved, and protective measures to be taken as well as to post and maintain proper warning signs.

Passageways and Open Spaces

The employer must provide barriers or other means of guarding to ensure that workspace for electrical equipment will not be used as a passageway during the time when energized parts of electrical equipment are exposed. Walkways and similar working spaces must be kept clear of electric cords. Other standards cover load ratings, fuses, cords, and cables.

Lockout and Tagging of Circuits

Tags must be placed on controls that are to be deactivated during the course of work on energized or de-energized equipment or circuits. Equipment or circuits that are de-energized must be rendered inoperative and have tags attached at all points where such equipment or circuits can be energized.

III. SAFETY-RELATED MAINTENANCE AND ENVIRONMENTAL CONSIDERATIONS

Maintenance of Equipment

The employer must ensure that all wiring components and utilization equipment in hazardous locations are maintained in a dust-tight, dust-ignition-proof, or explosion-proof condition without loose or missing screws, gaskets, threaded connections, seals, or other impairments to a tight condition.

Environmental Deterioration of Equipment

Unless identified for use in the operating environment, no conductors or equipment can be located:

- In damp or wet locations.
- Where exposed to gases, fumes, vapors, liquids, or other agents having a deteriorating effect on the conductors or equipment.
- Where exposed to excessive temperatures.

Control equipment, utilization equipment, and busways approved for use in dry locations only must be protected against damage from the weather during building construction.

For protection against corrosion, metal raceways, cable armor, boxes, cable sheathing, cabinets, elbows, couplings, fittings, supports, and support hardware must be of materials appropriate for the environment in which they are installed.

IV. Safety Requirements for Special Equipment

Batteries

Batteries of the unsealed type must be located in enclosures with outside vents or in well-ventilated rooms arranged to prevent the escape of fumes, gases, or electrolyte spray into other areas. Other provisions include the following:

Ventilation--to ensure diffusion of the gases from the battery and to prevent the accumulation of an explosive mixture.

Racks and trays--treated to make them resistant to the electrolyte.

Floors--acid-resistant construction unless protected from acid accumulations.

Face shields, aprons, and rubber gloves--for workers handling acids or batteries.

Facilities for quick drenching of the eyes and body--within 25 feet (7.62 m) of battery handling areas.

Facilities--for flushing and neutralizing spilled electrolytes and for fire protection.

Battery Charging

Battery charging installations must be located in areas designated for that purpose. When batteries are being charged, vent caps must be maintained in functioning condition and kept in place to avoid electrolyte spray. Also, charging apparatus must be protected from damage by trucks.

GROUND-FAULT PROTECTION ON CONSTRUCTION SITES

INSULATION AND GROUNDING

Insulation and grounding are two recognized means of preventing injury during electrical equipment operation. Conductor insulation may be provided by placing nonconductive material such as plastic around the conductor. Grounding may be achieved through the use of a direct connection to a known ground such as a metal cold water pipe.

Consider, for example, the metal housing or enclosure around a motor or the metal box in which electrical switches, circuit breakers, and controls are placed. Such enclosures protect the equipment from dirt and moisture and prevent accidental contact with exposed wiring. However, there is a hazard associated with housings and enclosures. A malfunction within the equipment--such as deteriorated insulation--may create an electrical shock hazard. Many metal enclosures are connected to a ground to eliminate the hazard. If a "hot" wire contacts a grounded enclosure, a ground fault results which normally will trip a circuit breaker or blow a fuse. Metal enclosures and containers are usually grounded by connecting them with a wire going to ground. This wire is called an equipment grounding conductor. Most portable electric tools and appliances are grounded by this means. There is one disadvantage to grounding: a break in the grounding system may occur without the user's knowledge.

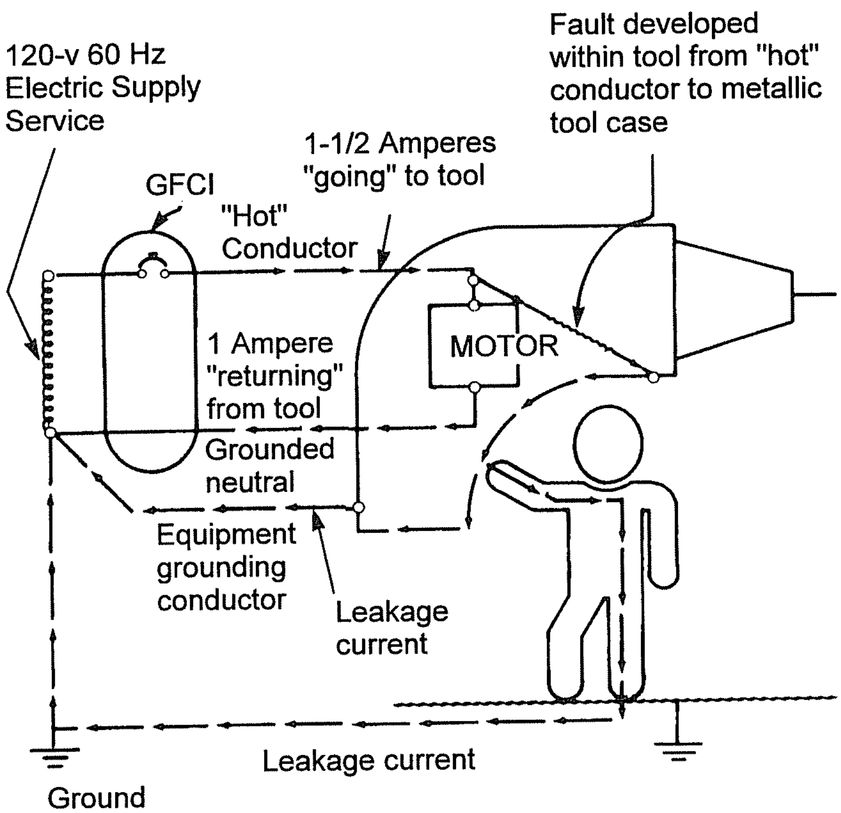
Insulation may be damaged by hard usage on the job or simply by aging. If this damage causes the conductors to become exposed, the hazards of shocks, burns, and fire will exist. Double insulation may be used as additional protection on the live parts of a tool, but double insulation does not provide protection against defective cords and plugs or against heavy moisture conditions.

The use of a ground-fault circuit interrupter (GFCI) is one method used to overcome grounding and insulation deficiencies.

WHAT IS A GFCI?

The ground-fault circuit interrupter (GFCI) is a fast-acting circuit breaker which senses small imbalances in the circuit caused by current leakage to ground and, in a fraction of a second, shuts off the electricity. The GFCI continually matches the amount of current going to an electrical device against the amount of current returning from the device along the electrical path. Whenever the amount "going" differs from the amount "returning" by approximately 5 milliamps, the GFCI interrupts the electric power within as little as 1/40 of a second. (See diagram.)

Ground-Fault Circuit Interrupter



GFCI monitors the difference in current flowing into the "hot" and out to the grounded neutral conductors. The difference (1/2 ampere in this case) will flow back through any available path, such as the equipment grounding conductor, and through a person holding the tool, if the person is in contact with a grounded object.

However, the GFCI will not protect the employee from line-to-line contact hazards (such as a person holding two "hot" wires or a hot and a neutral wire in each hand). It does provide protection against the most common form of electrical shock hazard--the ground fault. It also provides protection against fires, overheating, and destruction of insulation on wiring.

WHAT ARE THE HAZARDS?

With the wide use of portable tools on construction sites, the use of flexible cords often becomes necessary. Hazards are created when cords, cord connectors, receptacles, and cord- and plug-connected equipment are improperly used and maintained.

Generally, flexible cords are more vulnerable to damage than is fixed wiring. Flexible cords must be connected to devices and to fittings so as to prevent tension at joints and terminal screws. Because a cord is exposed, flexible, and unsecured, joints and terminals become more vulnerable. Flexible cord conductors are finely stranded for flexibility, but the strands of one conductor may loosen from under terminal screws and touch another conductor, especially if the cord is subjected to stress or strain.

A flexible cord may be damaged by activities on the job, by door or window edges, by staples or fastenings, by abrasion from adjacent materials, or simply by aging. If the electrical conductors become exposed, there is a danger of shocks, burns, or fire. A frequent hazard on a construction site is a cord assembly with improperly connected terminals.

When a cord connector is wet, hazardous leakage can occur to the equipment grounding conductor and to humans who pick up that connector if they also provide a path to ground. Such leakage is not limited to the face of the connector but also develops at any wetted portion of it.

When the leakage current of tools is below 1 ampere, and the grounding conductor has a low resistance, no shock should be perceived. However, should the resistance of the equipment grounding conductor increase, the current through the body also will increase. Thus, if the resistance of the equipment grounding conductor is significantly greater than 1 ohm, tools with even small leakages become hazardous.

PREVENTING AND ELIMINATING HAZARDS

GFCIs can be used successfully to reduce electrical hazards on construction sites. Tripping of GFCIs--interruption of current flow--is sometimes caused by wet connectors and tools. It is good practice to limit exposure of connectors and tools to excessive moisture by using watertight or sealable connectors. Providing more GFCIs or shorter circuits can prevent tripping caused by the cumulative leakage from several tools or by leakages from extremely long circuits.

EMPLOYER'S RESPONSIBILITY

OSHA ground-fault protection rules and regulations have been determined necessary and appropriate for employee safety and health. Therefore, it is the employer's responsibility to provide either: (a) ground-fault circuit interrupters on construction sites for receptacle outlets in use and not part of the permanent wiring of the building or structure; or (b) a scheduled and recorded assured equipment grounding conductor program on construction sites, covering all cord sets, receptacles which are not part of the permanent wiring of the building or structure, and equipment connected by cord and plug which are available for use or used by employees.

GROUND-FAULT CIRCUIT INTERRUPTERS

The employer is required to provide approved ground-fault circuit interrupters for all 120-volt, single-phase, 15- and 20-ampere receptacle outlets on construction sites which are not a part of the permanent wiring of the building or structure and which are in use by employees. Receptacles on the ends of extension cords are not part of the permanent wiring and, therefore, must be protected by GFCIs whether or not the extension cord is plugged into permanent wiring. These GFCIs monitor the current-to-the-load for leakage to ground. When this leakage exceeds 5 mA ± 1 mA, the GFCI interrupts the current. They are rated to trip quickly enough to prevent electrocution. This protection is required in addition to, not as a substitute for, the grounding requirements of OSHA safety and health rules and regulations, 29 CFR 1926. The requirements which employers must meet, if they choose the GFCI option, are stated in 29 CFR 1926.404(b)(1)(ii). (See appendix.)

ASSURED EQUIPMENT GROUNDING CONDUCTOR PROGRAM

The assured equipment grounding conductor program covers all cord sets, receptacles which are not a part of the permanent wiring of the building or structure, and equipment connected by cord and plug which are available for use or used by employees. The requirements which the program must meet are stated in 29 CFR 1926.404(b)(1)(iii), but employers may provide additional tests or procedures. (See appendix.) OSHA requires that a written description of the employer's assured equipment grounding conductor program, including the specific procedures adopted, be kept at the jobsite. This program should outline the employer's specific procedures for the required equipment inspections, tests, and test schedule.

The required tests must be recorded, and the record maintained until replaced by a more current record. The written program description and the recorded tests must be made available, at the jobsite, to OSHA and to any affected employee upon request. The employer is required to designate one or more **competent persons** to implement the program.

Electrical equipment noted in the assured equipment grounding conductor program must be visually inspected for damage or defects before each day's use. Any damaged or defective equipment must not be used by the employee until repaired.

Two tests are required by OSHA. One is a continuity test to ensure that the equipment grounding conductor is electrically continuous. It must be performed on all cord sets, receptacles which are not part of the permanent wiring of the building or structure, and on cord- and plug-connected equipment which is required to be grounded. This test may be performed using a simple continuity tester, such as a lamp and battery, a bell and battery, an ohmmeter, or a receptacle tester.

The other test must be performed on receptacles and plugs to ensure that the equipment grounding conductor is connected to its proper terminal. This test can be performed with the same equipment used in the first test.

These tests are required before first use, after any repairs, after damage is suspected to have occurred, and at 3-month intervals. Cord sets and receptacles which are essentially fixed and not exposed to damage must be tested at regular intervals not to exceed 6 months. Any equipment which fails to pass the required tests shall not be made available or used by employees.

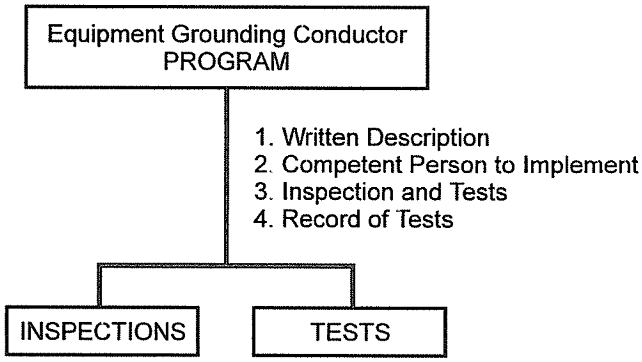
SUMMARY

This discussion provides information to help guide employers and employees in protecting themselves against 120-volt electrical hazards on the construction site, through the use of ground-fault circuit interrupters or through an assured equipment grounding conductor program.

When planning your program, remember to use the OSHA rules and regulations as a guide to ensure employee safety and health. Following these rules and regulations will help reduce the number of injuries and accidents from electrical hazards. Work disruptions should be minor, and the necessary inspections and maintenance should require little time.

An effective safety and health program requires the cooperation of both the employer and employees.

If you need additional information planning your program, contact the OSHA office nearest you.



<u>Visual inspection of following</u>:

1. cord sets
2. cap, plug and receptacle of cord sets
3. equipment connected by cord and plug

<u>Exceptions</u>:

- receptacles and cord sets which are fixed and not exposed to damage

<u>Frequency of Inspections</u>:

- before each day's use

<u>Conduct tests for</u>:

1. continuity of equipment grounding conductor
2. proper terminal connection of equipment grounding conductor

<u>Frequency of Tests</u>:

- before first use
- after repair, and before placing back in service
- before use, after suspected damage
- every 3 months, except that cord sets and receptacles that are fixed and not exposed to damage must be tested at regular intervals not to exceed 6 months.

APPENDIX

Construction Safety and Health Regulations Part 1926 Subpart K (Partial)

§1926.404 Wiring design and protection.

(b) Branch circuits--(1) Ground-fault protection--(i) General.
The employer shall use either ground-fault circuit interrupters as specified in paragraph (b)(l)(ii) of this section or an assured equipment grounding conductor program as specified in paragraph (b)(l)(iii) of this section to protect employees on construction sites. These requirements are in addition to any other requirements for equipment grounding conductors.

(ii) Ground-fault circuit interrupters. All 120-volt, single-phase, 15- and 20-ampere receptacle outlets on construction sites, which are not a part of the permanent wiring of the building or structure and which are in use by employees, shall have approved ground-fault circuit interrupters for personnel protection. Receptacles on a two-wire, single-phase portable or vehicle-mounted generator rated not more than 5kW, where the circuit conductors of the generator are insulated from the generator frame and all other grounded surfaces, need not be protected with ground-fault circuit interrupters.

(iii) Assured equipment grounding conductor program. The employer shall establish and implement an assured equipment grounding conductor program on construction sites covering cord sets, receptacles which are not a part of the building or structure, and equipment connected by cord and plug which are available for use or used by employees. This program shall comply with the following minimum requirements:

(A) A written description of the program, including the specific procedures adopted by the employer, shall be available at the jobsite for inspection and copying by the Assistant Secretary and any affected employee.

(B) The employer shall designate one or more competent persons [as defined in §1926.32(f)] to implement the program.

(C) Each cord set, attachment cap, plug and receptacle of cord sets, and any equipment connected by cord and plug, except cord sets and receptacles which are fixed and not exposed to damage, shall be visually inspected before each day's use for external defects, such as deformed or missing pins or insulation damage, and for indications of possible internal damage. Equipment found damaged or defective shall not be used until repaired.

(D) The following tests shall be performed on all cord sets, receptacles which are not a part of the permanent wiring of the building or structure, and cord- and plug-connected equipment required to be grounded:

(1) All equipment grounding conductors shall be tested for continuity and shall be electrically continuous.

(2) Each receptacle and attachment cap or plug shall be tested for correct attachment of the equipment grounding conductor. The equipment grounding conductor shall be connected to its proper terminal.

(E) All required tests shall be performed:

(1) Before first use;

(2) Before equipment is returned to service following any repairs;

(3) Before equipment is used after any incident which can be reasonably suspected to have caused damage (for example, when a cord set is run over); and

(4) At intervals not to exceed 3 months, except that cord sets and receptacles which are fixed and not exposed to damage shall be tested at intervals not exceeding 6 months.

(F) The employer shall not make available or permit the use by employees of any equipment which has not met the requirements of this paragraph (b)(l)(iii) of this section.

(G) Tests performed as required in this paragraph shall be recorded. This test record shall identify each receptacle, cord set, and cord- and plug-connected equipment that passed the test and shall indicate the last date it was tested or the interval for which it was tested. This record shall be kept by means of logs, color coding, or other effective means and shall be maintained until replaced by a more current record. The record shall be made available on the jobsite for inspection by the Assistant Secretary and any affected employee.

HAZARDOUS (CLASSIFIED) LOCATIONS

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 flyings."

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 liquified 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 flyings present, due to the types of materials being handled, stored, or processed. The fibers and flyings 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 flyings.

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 flyings.

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 flyings.

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.

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 flyings (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)

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

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).

Recognized Laboratories Inc.
LISTED
ELECTRIC LIGHTING FIXTURES FOR HAZARDOUS LOCATIONS

CLASS I GROUP C, D	SER. NO. [redacted]	CLASS II GROUP E, F, G

LISTED FOR LOCATIONS HAVING DEPOSITS OF
READILY COMBUSTIBLE PAINT RESIDUE

CAUTION: TO PREVENT IGNITION OF HAZARDOUS ATMOSPHERES, DISCONNECT THE FIXTURE FROM THE SUPPLY CIRCUIT BEFORE OPENING. KEEP TIGHTLY CLOSED WHEN IN OPERATION.

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.

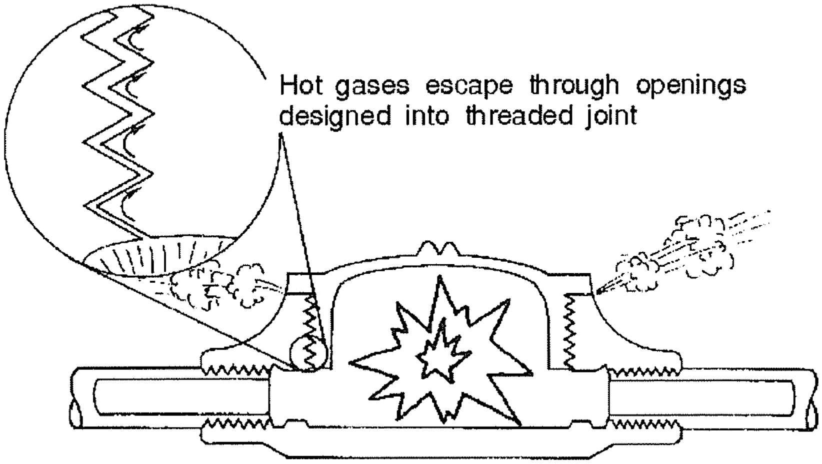
One type is the ground surface flame path. Here the surfaces are ground, mated, and held to a tolerance of 15 ten-thousandths of an inch. This permits gases to escape, but only after they've been sufficiently cooled, so they won't ignite the volatile surrounding atmosphere.

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.

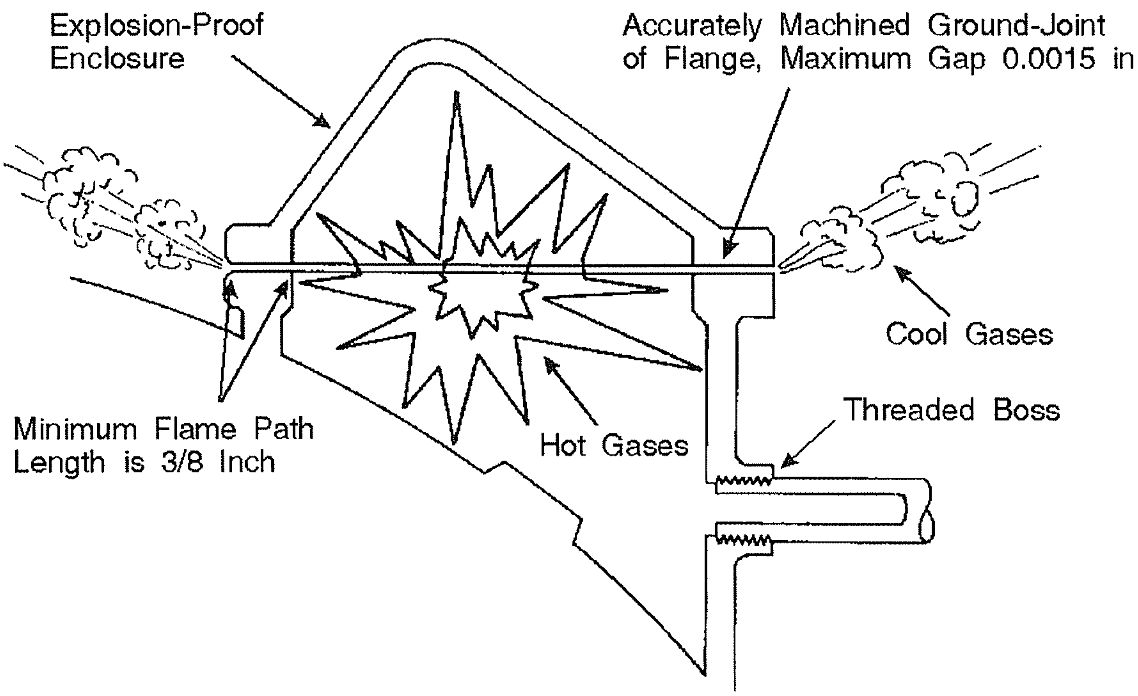
Exploded gases may also escape around the shafts of operators used in the enclosure. But, here again, close tolerances are used to quench the burning gas.

Examples of two flame paths are shown below.

Flame Paths



OPENINGS DESIGNED INTO THREADED JOINT



OPENINGS DESIGNED INTO GROUND JOINT

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.

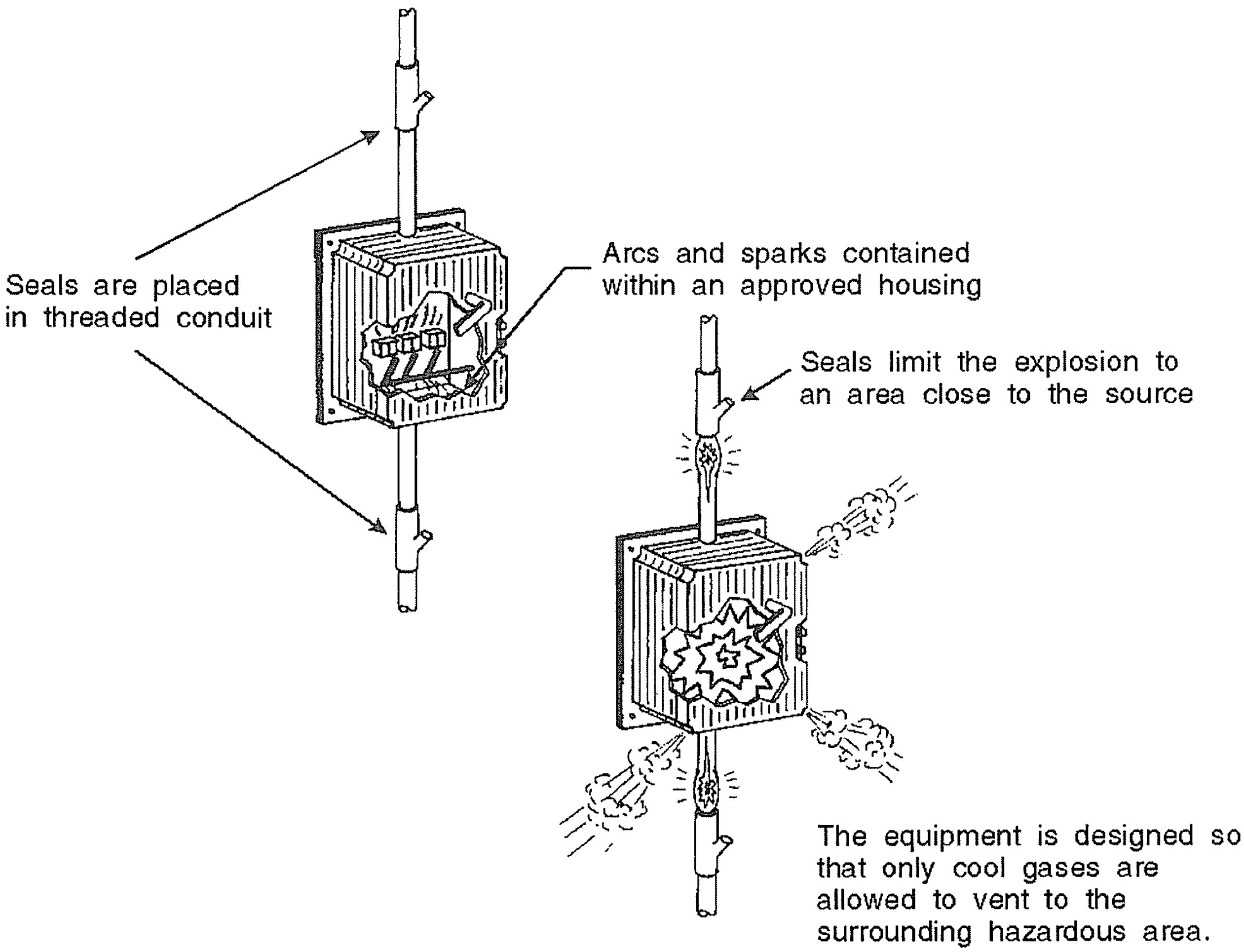
3. It must allow for a dust blanket. That is, the build-up of dust collecting on top of the device that can cause it to run "hot" and ignite the surrounding atmosphere.

For Class III equipment, there is very little difference in the design from Class II. Class III equipment must minimize entrance of fibers and flyings; 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.

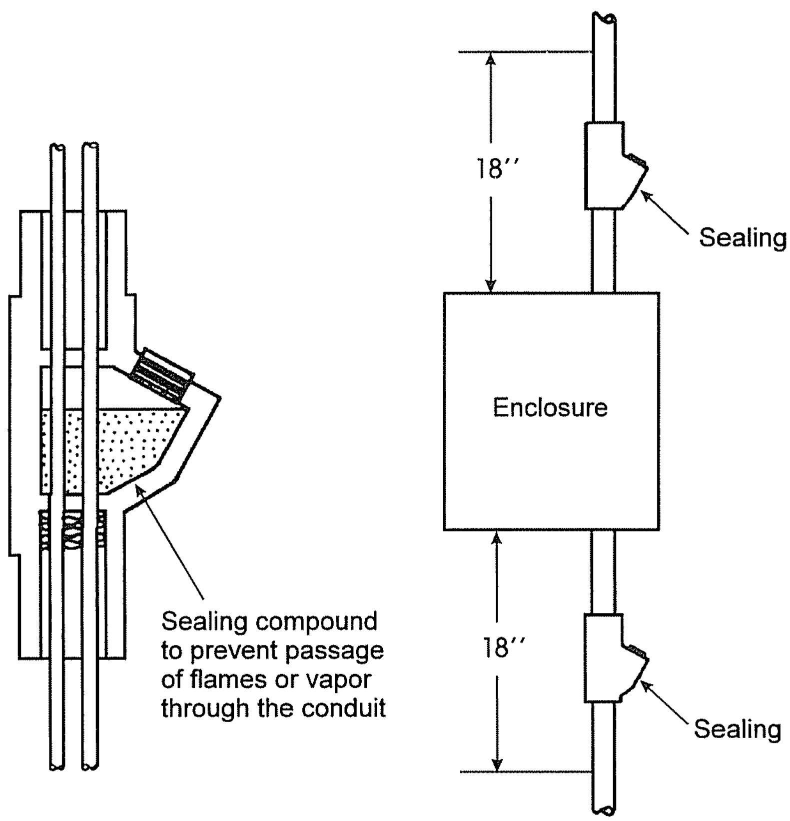
There are many enclosures, devices, and fixtures suitable for all three classes. This simply means that it meets the specifications for each individual type. A Class I device which could contain an explosion of a specified gas would also have to prevent dust from entering the enclosure to be suitable 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



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.



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.

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.