# ELECTRICAL DESIGN, SAFETY, AND ENERGY CONSERVATION



ALBERT THUMANN, P.E.



THE FAIRMONT PRESS
134 PEACHTREE STREET N. E. • ATLANTA, GEORGIA 30303

*Electrical Design, Safety, and Energy Conservation*



ISBN 0-915586-05-3

Library of Congress Catalog Number: 76-57447

10 9 8 7 6 5 4 3 2

Printed in the United States of America

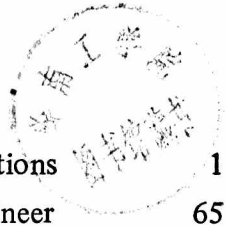
A JOB SIMULATION EXPERIENCE®

# ELECTRICAL DESIGN, SAFETY, AND ENERGY CONSERVATION

# Foreword

The understanding of electrical system design has become increasingly important not only to the electrical designer, but to safety, plant and project engineers as well. With the advent of the Occupational Safety and Health Act (OSHA), electrical citations have accounted for the single most common safety offender. Another factor which has caused plant and project engineers to become more aware of electrical systems has been high energy costs. Thus, to operate a plant efficiently, emphasis must be placed on energy conservation measures which affect electrical systems. Both safety and energy efficiency will be covered in this text along with the practical application problems for an industrial electrical design.

# Contents



# 1

# Reducing OSHA Related Electrical Violations

The Occupational Safety and Health Act (OSHA) has incorporated the National Electrical Code (NEC) into its standards. These OSHA standards were published in the 1974 *Federal Register* and are periodically updated. Thus a violation of the NEC is a violation of OSHA. In 1975 violations of the National Electrical Code were the most common violations of OSHA. Electrical violations were also number one in terms of penalties levied, with total assessments of almost $500,000.

As of the writing of this text, OSHA has adopted only the 1971 NEC specifications, even though 1978 NEC specifications are presently being used in industry. This has caused considerable confusion in industry. There is also confusion as to the degree of upgrading required as a result of modifications to an existing facility.

The material presented in this chapter has been adapted with permission from *Maintenance Engineering,* Cleworth Publishing Co., Inc., Cos Cob, Connecticut.[1,2,3,4,5]

## OSHA: – RECOGNIZE AND CORRECT ELECTRICAL VIOLATIONS

Whether a plant's electrical system is only four years old and built in compliance with the 1968 NEC or if it is 35 years old and built in compliance with the 1937 NEC standards, certain areas must be up-dated to conform with the 1971 NEC specifications.

- Grounding of circuits, systems, tools, and portable equipment is now mandatory.
- "Temporary" hookups and installations must be eliminated as soon as possible. Make them by-the-book.
- Live parts of tools and electrical equipment must be properly guarded so they present no danger.
- Identify electrical equipment as to voltage rating and purpose. This not only warns unauthorized personnel to beware, but it also simplifies emergency repairs.
- Use flexible cords only for specific, temporary purposes. Never run them under work bins, across aisles or through any other place where they may likely get shorted out.
- Make sure electrical equipment used in a hazardous area is designed specifically for that purpose. Check especially the wiring, grounding, guarding, proper receptacles and plugs, drainage, and sealing methods.
- Modify any installation that might put an employee into danger.

OSHA's final interpretation of what is dangerous and in violation and what is acceptable depends greatly upon the individual inspector who does a "walk-around" in the plant. Even if the equipment and wiring are UL-listed, he may not like a particular installation and issue a citation anyway. Since there is a disagreement on some of the interpretations of the NEC, it might be valuable to subscribe to the *B. N. A. Reporter.* Published by the Bureau of National Affairs, Washington, D.C., this loose-leaf publication gives a weekly summary of any event (an appeal of a citation, change in interpretation by OSHA, lists of fines, etc.). This keeps a plant engineer or safety director up-to-date on the law and can perhaps save a fine.

## Table 1-1. Most Commonly Cited Electrical Violations

A typical plant has many violations that can be cured by better housekeeping procedures. When an area is cleaned-up, a sloppy electrical installation tends to "jump out at you." Although the fines that can develop are often costly, the problems themselves usually take little time to abate.

**Water or oil on floor** around electrical machinery. Wipe it up and fix the leak.

**Exposed wiring** must be labelled as to where it goes and how much power. Replace covers on junction boxes and electrical enclosures.

**Unlocked door** and lack of a warning sign. The service entrance door must be locked and labelled to protect unauthorized personnel. Clearly mark each piece of electrical equipment as to its use.

**Empty sockets** should be permanently removed if they are not used for lighting. If they are used for lighting a bulb should be inserted.

**Ungrounded electrical tools** must have a third-wire ground. (If the tool is a self-grounding type, it must be clearly identified.) Make sure your grounding plugs haven't been deliberately sawed or broken off for convenience. If missing a third prong, replace the plug.

**Extension cords** must be removed from under doors, across aisles, inside storage areas, or wherever movement of materials (or wheels of a fork lift truck) can damage the cord. Replace with permanent wiring or cord set designed for aisle use.

**Loose connections** should be tightened. This insures a low resistance impedance which facilitates the operation of overcurrent devices. Check connections with an ohmmeter and make connections "wrench-tight."

**Worn or frayed cables** anywhere in plant should be replaced.

**Live metal lamp guards** or live cases for lamps should be repaired at once. Defect is in the insulation, broken plug, or shorted receptacle.

**Unlabelled 220 volt outlets** can be mistaken for a normal 110 volt unit. Identify them so no confusion will ever exist.

**Bridged fuses** must be cleared.

**Portable, hand-held lamps** must be of molded composition—not the old paper-lined or brass-shell compositions. Don't use the old units.

**Attachment plugs** must be constructed for rough use and equipped with a cord grip that does not put strain on the terminal screw.

**Work habits.** Educate employees to be electrically-safe in their work habits. Be sure the equipment they are using is safe, and that they wear proper safety gear.

## DEGREE OF COMPLIANCE CAN VARY

An in-plant inspection should be done before an OSHA inspection is made.

When an electrical inspector is appointed by the plant engineer to check out the facility for possible violations, it must be kept in mind that OSHA does not require the same degree of compliance with every type of electrical installation. The inspector must realize there is no intent by OSHA to force a plant to rip out any old installations just to up-date them. The purpose is electrical safety. Of course, all systems must comply with the previously mentioned retroactive regulations.

- Existing installations that are in-place before March 15, 1972 can use replacement devices of the same type being presently used, unless specifically prohibited by the code. Extending branch circuits, shifting equipment within a plant, and replacing wiring plugs and receptacles are minor modifications that are included under this category. Some of the replacement devices may not even carry a UL-label anymore, but are still permitted in this application.
- Major modifications, repairs, and rehabilitations such as tearing down a wall, adding a new wing, or running a new power supply into a plant must follow the 1971 NEC.
- Job site wiring, both temporary and permanent, must conform to pertinent sections of the new NEC. A federal inspector will most likely put emphasis on the grounding requirements.
- New electrical work, of course, follows the latest code.

Keeping the above requirements in mind as an electrical inspection is made, may make it possible to save unneeded purchases of equipment by properly defining what kind of installation is being dealt with. But also remember, any installation that is in any way hazardous must be changed. If in doubt, bring it up to the newest NEC standards.

## USE THE BEST ELECTRICAL INSPECTOR

Only someone thoroughly familiar with the NEC and capable of using electrical test equipment can hope to do a proper check for electrical compliance. But, even so, years of living

with the same electrical violations can sometimes go unnoticed by the men who work around and on them. A large maintenance department has the luxury of bringing a technician in from another area; a small department must encourage their inspector to examine their facility in a "fresh light."

This "new-man" approach is similar to a real OSHA inspection, and it can lead to some startling discoveries. Maybe the storage of fuel or chemicals into a new area has changed the Hazardous Location classification from a Class II to a Class I. Or maybe the relocation of the welding crew's equipment has changed the classification of an area. This is the sort of thing more easily picked up by this fresh approach. A check must be made on all fittings, wiring methods, enclosures, and equipment to be sure that they comply.

The scope of the electrical check-out takes the greater part of an inspection. Personnel interviewed at one plant spent about 300 hours just interpreting the rules and establishing electrical check lists. In addition, local and state codes must be checked to be sure you are meeting their requirements. (Comply with OSHA if they are different in any way.)

## DECIDE IF THE INSTALLATION IS ACCEPTABLE

"Approved" means acceptable to the authority enforcing the code, the representative of the Department of Labor. It meets his requirements only if:

- It has been certified, listed, labelled, or otherwise determined to be safe by Underwriters' Laboratories, Inc., Factory Mutual Engineering Corporation, or another nationally recognized testing body.

***This means the purchasing department can prevent compliance headaches later on by specifying tested products from the start.***

- Equipment that is not checked out by a nationally-recognized testing laboratory is determined to be safe if it has been inspected by another federal agency, or by the state, local, or municipal authority responsible for enforcing the safety provisions of the NEC.

***All high voltage switchgear, and most low voltage switchgear, switchboards, and motor control equipment is not inspected by UL or Factory Mutual.***

• Custom-made equipment is determined to be safe for its intended use on the basis of the manufacturer's test data. The employer must keep this information available for inspection by any representative of the Department of Labor.

***The company's design engineer has ultimate responsibility for OSHA compliance of the equipment he specifies.*** All high voltage switchgear, most low voltage switchgear, and related equipment are assembled for a particular job, placing them in the "custom-made" category of OSHA. Some low voltage sections can be UL-listed for specific requirements, but if a non-listed part is contained within the system, the label is generally withheld. The data that is needed from the manufacturer relates to construction, tests and safety provisions of this custom equipment.

## COMPILE ELECTRICAL CHECK LISTS

Once it has been determined that the general physical layout of the plant is safe from the most common (and easily abated violations) it is necessary to check out NEC compliance (Table 1-2).

Make sure all electrical equipment is properly mounted—firmly with no wooden plugs driven into holes in masonry, concrete or similar materials. The mechanical execution of all work must be neat and by-the-book. Any temporary wiring situation that has lasted years must be eliminated. Answer check list questions either yes (out of compliance) or no (in compliance). If a doubt exists in your mind, use the more specific check lists for overcurrent devices, transformers, grounding, wiring, etc. If a doubt still exists, mark it out-of-compliance and check it out later.

The electrical check list that is developed for the plant should be a personalized tool. The value of the list is increased if the plant's foreman and technicians review them from time-to-time (the same as they do for a preventive maintenance job) to make sure the plant remains in compliance.

## Table 1-2. OSHA Check List—National Electrical Code

(Write Yes or No, Describe Equipment, Location)

• Are there installations and/or equipment in the plant that are not installed and maintained in accordance with the latest N.E.C., N.F.P.A., and ANSI?

**CONDUCTORS**

• Are there conductors used in the plant which are of materials other than copper?

**DETERIORATING AGENCIES**

• Are there conductors or equipment used in damp or wet locations, exposed to agents having a deteriorating effect on them, which are not approved for use in these areas?

**MECHANICAL EXECUTION OF WORK**

• Are there installations and/or equipment which is not installed in a neat and workmanlike manner?

**MOUNTING OF EQUIPMENT**

• Is there any equipment not firmly secured to the surface on which it is mounted?

**CONNECTIONS TO TERMINALS**

• Are there any connections of conductors to terminals which have been made by other means than pressure connector (including set screw type), solder, lugs, or splices to flexible leads?

(EXCEPTION: No. 8 or smaller solid conductors and No. 10 or smaller stranded conductors may be connected by means of clamps or screws with terminal plates having upturned legs.)

• Are there terminals being used for more than one conductor which is not of a type approved for this purpose?

• Are there installations and/or equipment where terminating devices such as pressure connectors and solder lugs have been used which are not suitable for the material and/or the size of the conductor?

• Are there installations and/or equipment where solder flukes, inhibitors or other compounds have been used that adversely affected the conductors, installation, or equipment?

**SPLICES**

• Are there conductors which have been spliced or joined by means other than with splicing devices approved for the use by brazing, welding, or soldering with a fusible metal or alloy?

• Are there soldered splices which have not been joined such that they were mechanically and electrically secure prior to the application of the solder? Are all splices and joints and free ends of conductors which are not covered with an insulation equivalent to that of the conductors?

**WORKING SPACE AROUND ELECTRICAL EQUIPMENT (600 VOLTS OR LESS)**

• Are there installations and/or equipment where sufficent access and working space is not provided and

*/more/*

## Table 1-2. OSHA Check List—National Electrical Code (continued)

maintained to permit safe operation and maintenance?
• Are there installations and/or equipment which does not comply with the following requirements:
WORKING CLEARANCE
Except as elsewhere required or permitted in this sub-part, the dimension of the working space in the direction of access to live parts operating at no more than 600 volts, which are likely to require examination, adjustment, servicing or maintenance while alive, shall not be less than indicated in the following table. Distances are to be measured from the live parts if such are exposed or from the enclosure front or opening when such are enclosed.

| VOLTAGE TO GROUND | MINIMUM CLEAR DISTANCE CONDITION (ft) | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 0 - 150 volts | 2½ | 2½ | 3 |
| 151 - 600 volts | 2½ | 3½ | 4 |

• Condition 1 is an exposed live part on one side and no live or grounded part on the other side of the working space, or exposed live parts on both sides effectively guarded by suitable wood or other insulated wire or insulated bus bars (operating at not more than 300 volts) are not be considered live parts.

them, which do not have a minimum of 3 feet of front working space?
ILLUMINATION
• Are there working spaces about switchboards and control centers which do not have adequate illumination?
HEADROOM
• Are there working spaces about switchboards and control centers where there are live parts exposed at any time which do not have a minimum of 6¼ feet of headroom?

**GUARDING OF LIVE PARTS (NOT MORE THAN 600 VOLTS)**
ENCLOSURES
• Are there installations and/or equipment operating at more than 50 volts which are not guarded against accidental contact by approved enclosures or any of the following methods:

(a) By location in a room, vault, or similar enclosure which is accessible only to qualified personnel.

(b) By suitable permanent, substantial partitions or screens so arranged that only qualified persons will have access to the space within reach of the live parts. Any openings in such partitions or screens shall be so sized and located that persons are not likely to come into accidental contact with

/more/

## Table 1-2. OSHA Check List—National Electrical Code (continued)

• Condition 2 is exposed live parts on one side and grounded parts on the other side. Concrete, brick, or tile walls are considered grounded.
• Condition 3 is exposed live parts on both sides of the work space (not guarded as in #1) with the operator between.
(Exception: Working space is not required in back of assemblies such as deadfront switchboards or control centers when there are no renewable parts such as fuses or switches on the back and when all connections are accessable from other locations than the back. Smaller spaces may be permitted where it is judged that the particular arrangement of the installation will provide adequate accessibility.)

CLEAR SPACES
• Are there working spaces as required being used for storage?
• Are there working spaces, where normally exposed live parts are exposed for inspection or servicing, which are located in passageway or general open spaces?

ACCESS AND ENTRANCE TO WORKING SPACE
• Are there working spaces about electrical equipment which do not have at least one entrance of sufficient area to allow working space?

FRONT WORKING SPACE
• Are there switchboards and control centers, where there are live parts normally exposed on the front of the live parts or to bring conducting objects into contact with them.
(c) By a guard rail, provided the live parts operate at 600 volts or less and provided the location is such that it makes contact with live parts unlikely.
(d) By location on a suitable balcony, gallery, or platform so elevated and arranged as to exclude unqualified persons.
(e) By elevation at least 8 feet above the floor or other working surface.

GUARDS
• Are there installations and/or equipment exposed to potential physical damage which are not protected by enclosures or guards so arranged and of such strength as to prevent such damage?

ENTRANCES
• Are there entrances to room and other guarded locations containing live exposed parts which are unmarked with conspicous warning sign forbidding unqualified persons to enter?

ARCING PARTS
• Are there parts of electrical equipment (excluding the welding equipment) which in ordinary operation produce arcs, sparks, flames, or molten metal which are not enclosed or separated and isolated from all combustible material?

*/more/*

## Table 1-2. OSHA Check List—National Electrical Code (continued)

MARKING

- Is there equipment which is not marked with the manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified?
- Is there equipment which is not marked with the voltage, current, wattage, or other electrical ratings?

IDENTIFICATION

- Are there disconnecting means for motors and appliances and service, feeder, or branch circuit (at the point where they originate) which are not legibly marked to indicate its purpose, unless located and arranged so that the purpose is evident?
- Are there markings on equipment which are not sufficiently durable to withstand the environment involved?

**OVERCURRENT PROTECTION**

PROTECTION OF EQUIPMENT

- Is there any equipment not protected against overcurrent?

INTERRUPTING CAPACITY

- Are there devices intended to break current which do not have sufficient interrupting capacity for the voltage employed and for the current which must be interrupted?

LOCATION IN PREMISES

- Are there overcurrent devices located where they are exposed to physical damage.
- Are there overcurrent devices located in the vicinity of easily ignitible materials?

ENCLOSURES FOR OVERCURRENT DEVICES

- Are there overcurrent devices, other than those which are a part of a specially approved assembly which affords equivalent protection or unless mounted on switchboards, panelboards, or controllers located in rooms or enclosures free from easily ignitible or dampness, which are not enclosed in cutout boxes or cabinets?

(NOTE: The operating handle of a circuit breaker may be accessible without opening a door or cover.)

- Are there enclosures for overcurrent devices in damp or wet locations which are not of the type approved for such locations?
- Are there enclosures in damp or wet locations which are not mounted so there is at least ¼-inch air space between the enclosure and the wall or other supporting surface?

ARCING AND SUDDEN MOVING PARTS

- Are there fuses and/or circuit breakers which are not located and shielded such that persons will not be burned or otherwise injured by their operation?

*/more/*

## Table 1-2. OSHA Check List—National Electrical Code (concluded)

CIRCUIT IMPEDANCE AND OTHER CHARACTERISTICS

• Are there circuit protective devices which will not clear a fault without the occurrence of extensive damage to the electrical components of the circuit? (NOTE: This fault may be assumed to be between two or more of the circuit conductors, or between any circuit conductor and the grounding conductor or enclosing metal raceway.)

SUDDEN MOVING PARTS

• Are there handles or levers of circuit breakers, and similar parts which move suddenly in such a way that a person in the vicinity is liable to be injured by being struck by them, which are not guarded or isolated?