DOCUMENT RESUME

ED 238 728 SE 043 749

TITLE An Illustrated Guide to Electrical Safety. Revised
INSTITUTION Occupational Safety and Health Administration, Washington, D.C.
REPORT NO OSHA-3073
PUB DATE 83
NOTE 191p.; The manual was developed using a base document prepared by JRB Associates, Inc.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051) -- Legal/Legislative/Regulatory Materials (090)

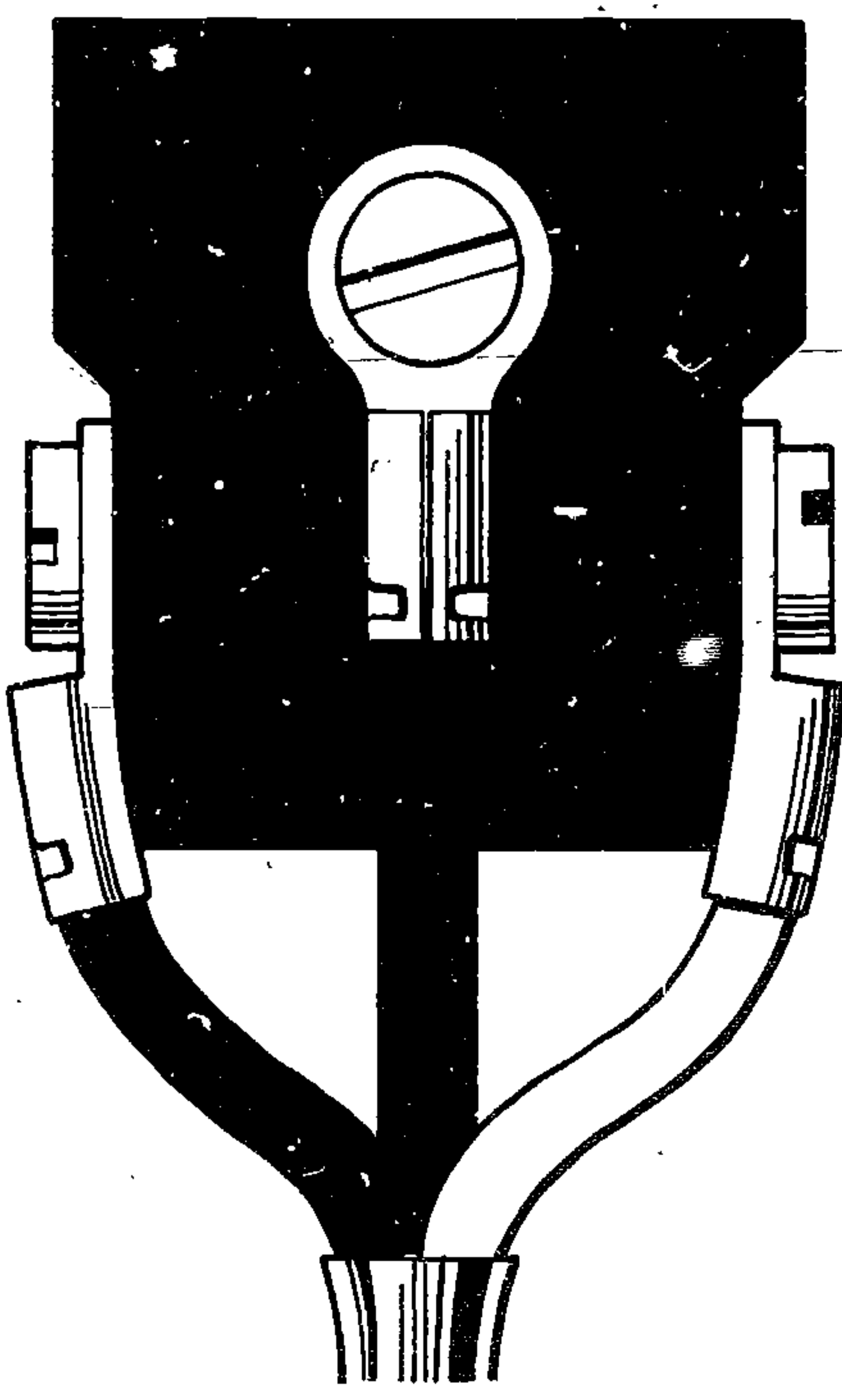
EDRS PRICE MF01/PC08 Plus Postage.
DESCRIPTORS *Electrical Systems; *Electric Circuits; *Electricity; *Electronic Equipment; Occupational Safety and Health; Postsecondary Education; *Safety; *Standards
IDENTIFIERS *Electrical Wiring

ABSTRACT

This guide was developed to serve as a supplement to the Occupational Safety and Health Administration's (OSHA) Electrical Safety Standards, 29 CFR 1910, Subpart S, Electrical. It is designed for use by a variety of people (layman, worker, employer, compliance safety and health officer, union official, educator, and others) in training, education, information, and assistance in complying with regulations. The guide provides additional explanation and clarification for individuals who have little or limited training or familiarity with the field of electricity. However, no attempt has been made to explain the basic principles of electricity. Some of the more technical provisions are explained to a level of detail appropriate to achieve an appreciation of the hazards involved and an understanding of the correct safeguards or precautions that should be employed. The illustrated guide (104 figures included) follows the format of 29 CFR 1920, Subpart S as it would appear in the Federal Register. Major topic areas include: general requirements; wiring design and protection; wiring methods, components and equipment for use; specific purpose equipment and installation; hazardous (classified) locations; and special systems (including systems over 600 volts- nominal, emergency power systems, communications systems, and others). (JN)

An Illustrated Guide to Electrical Safety

U.S. Department of Labor
Occupational Safety and Health Administration
1983 (Revised)
OSHA 3073



An Illustrated Guide to Electrical Safety

U.S. Department of Labor
Raymond J. Donovan, Secretary

Occupational Safety and Health Administration
Thorne G. Auchter, Assistant Secretary
1983 (Revised)
OSHA 3073

PREFACE

This Illustrated Electrical Safety Standards guide was developed by the Occupational Safety and Health Administration (OSHA) to serve as a supplement to OSHA's Electrical Safety Standards, 29 CFR 1910, Subpart S, Electrical. It is intended to serve as a guide to the Electrical Safety Standards to address the needs of the layman, both employer and employee alike. This safety standards guide provides additional explanation and clarification for use by individuals who have little or limited training or familiarity with the field of electricity. However, no attempt has been made to explain the basic principles of electricity, and an understanding of these principles would be useful. Some of the more technical provisions are explained to a level of detail appropriate to achieve an appreciation of the hazards involved and an understanding of the correct safeguards or precautions that should be employed.

The illustrated guide follows the format of 29 CFR 1910, Subpart S as it would appear in the Federal Register. A number of sections in the standards, which are marked with bullets (•), have been singled out for explanation. Explanations and illustrations, which follow these provisions, are printed in different type and are offset by lines framing the text and associated figures. Additionally, the table of contents is keyed with bullets to show which paragraphs are explained.

This document is designed to be used for many purposes: training, education, information, and assistance in complying with the regulations. It can be used by a variety of people in a variety of positions: the layman, worker, employer, compliance safety and health officer, union official, educator, and others. The intent, no matter how it is used or who uses it, is to provide a better understanding of the OSHA safety requirements in hopes of reducing the prospects of electrical injury.

ACKNOWLEDGMENTS

This manual was organized and coordinated by OSHA's Office of Electrical and Electronic Engineering Safety Standards (OSE) in conjunction with the Office of Training and Education. It was developed using a base document prepared by JRB Associates, Inc., under contract number J-9-F-9-0187. The original text material and graphic art work of the base document were thoroughly reviewed and revised by OSE for use in this manual. Some photographs used were provided by Daniel Woodhead, Inc., and Bryant Electric Company. Other photographs were provided by JRB Associates, Inc. The use of photographs and drawings in this publication is for illustrative purposes only and does not constitute or imply any endorsement, acceptance, or approval by OSHA of the equipment or systems shown.

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SUBPART S — ELECTRICAL

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(•) Sections which contain additional explanation.

Contents (continued)

(•) Sections which contain additional explanation.

Contents (continued)

(•) Sections which contain additional explanation.

Contents (continued)

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FIGURES

TABLES

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§1910.303 GENERAL REQUIREMENTS

§1910.303 General requirements.

(a) Approval. The conductors and equipment required or permitted by this subpart shall be acceptable only if approved.

(b) Examination, installation, and use of equipment.

(1) Examination. Electrical equipment shall be free from recognized hazards that are likely to cause death or serious physical harm to employees. Safety of equipment shall be determined using the following considerations:

(i) Suitability for installation and use in conformity with the provisions of this subpart. Suitability of equipment for an identified purpose may be evidenced by listing or labeling for that identified purpose.

(ii) Mechanical strength and durability, including, for parts designed to enclose and protect other equipment, the adequacy of the protection thus provided.

(iii) Electrical insulation.

(iv) Heating effects under conditions of use.

(v) Arcing effects.

(vi) Classification by type, size, voltage, current capacity, specific use.

(vii) Other factors which contribute to the practical safeguarding of employees using or likely to come in contact with the equipment.

(2) Installation and use. Listed or labeled equipment shall be used or installed in accordance with any instructions included in the listing or labeling.

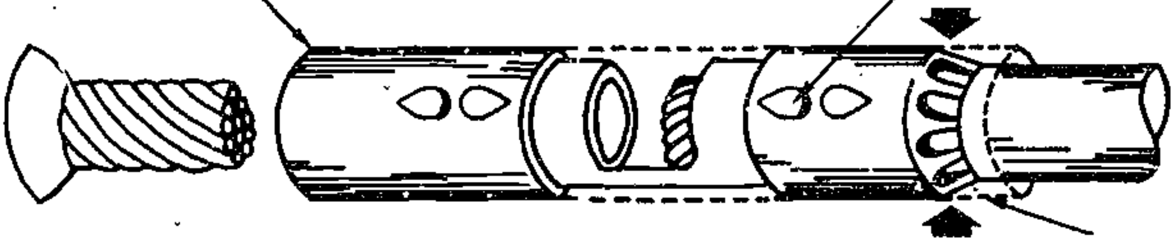
• (c) Splices. Conductors shall be spliced or joined with splicing devices suitable for the use or by brazing, welding, or soldering with a fusible metal or alloy. Soldered splices shall first be so spliced or joined as to be mechanically and electrically secure without solder and then soldered. All splices and joints and the free ends of conductors shall be covered with an insulation equivalent to that of the conductors or with an insulating device suitable for the purpose.

• SPLICES

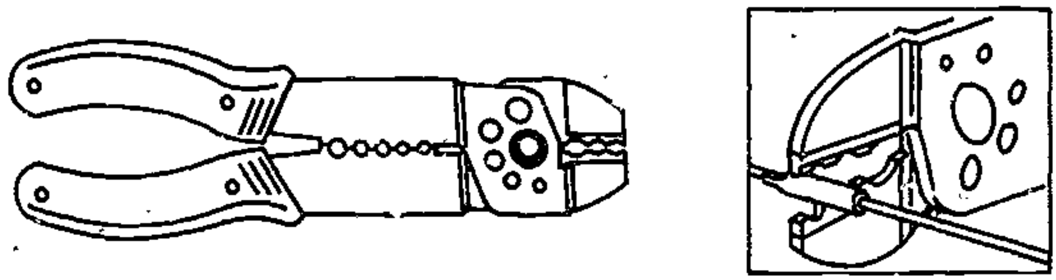
WHEN ELECTRICAL CONDUCTORS ARE JOINED TOGETHER BY SPLICING, THE CONNECTION MUST BE STRONG AND SAFE. IT MUST ALSO PROVIDE A PATH FOR THE CONTINUOUS FLOW OF ELECTRICITY THESE REQUIREMENTS CAN BE MET BY USING A MECHANICAL SPLICING DEVICE OR BY WELDING, BRAZING, OR SOLDERING THE CONNECTION.

MECHANICAL SPLICING DEVICES RANGE FROM COMMON WIRE NUTS TO THOSE THAT EMPLOY A COMPRESSION-TYPE FITTING TO HOLD THE CONDUCTORS SECURELY AND TO PROVIDE A SUITABLE, SAFE SPLICE. FIGURE 1 SHOWS SOME OF THE MORE COMMON MECHANICAL SPLICING DEVICES.

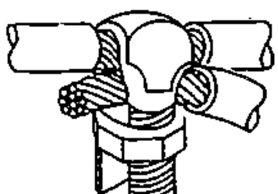
A SAFE SPLICE CAN ALSO BE MADE BY WELDING OR BRAZING THE ENDS OF THE CONDUCTORS TOGETHER, FORMING A PERMANENT BOND BETWEEN THE METALS. SOLDERED SPLICES, HOWEVER, ARE NOT SECURE CONNECTIONS UNLESS THEY ARE FIRST PROPERLY JOINED MECHANICALLY BEFORE SOLDERING TO ACHIEVE THE SAME



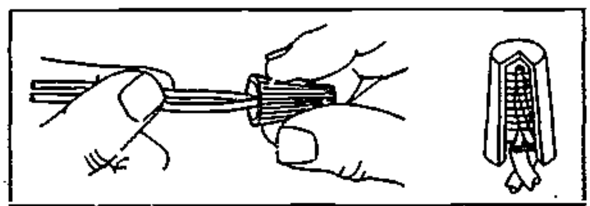
Mechanical Splicing Device



Splicing Device With Crimping Tool



Split-bolt Tap-joint Connector



Solderless screw-on connectors (commonly called wire nuts) can be used instead of soldering joints. These connectors are made of plastic, bakelite, or porcelain and are threaded inside to screw onto bare wires forming a pigtail splice. (The bare ends of the wire are first twisted together, then, the wire nut is threaded on in the same direction.)

FIGURE 1. SAMPLE MECHANICAL SPLICING DEVICES

STRENGTH AS THAT OF THE CONDUCTORS BEING JOINED. THIS CONNECTION MUST ALSO PROVIDE A PATH FOR THE CONTINUOUS FLOW OF ELECTRICITY. THE SOLDER CAN THEN BE APPLIED. ONE PROPER SPLICING METHOD IS ILLUSTRATED IN FIGURE 2.

TO PREVENT ELECTRIC SHOCK OR FIRE, ALL SPLICES AND FREE ENDS OF CONDUCTORS MUST BE COVERED WITH AN INSULATION THAT WILL WITHSTAND THE SAME ENVIRONMENTAL CONDITIONS AND VOLTAGES TO WHICH THE ORIGINAL CONDUCTORS ARE SUBJECTED. SUITABLE INSULATION FOR LOW VOLTAGE CONDUCTORS

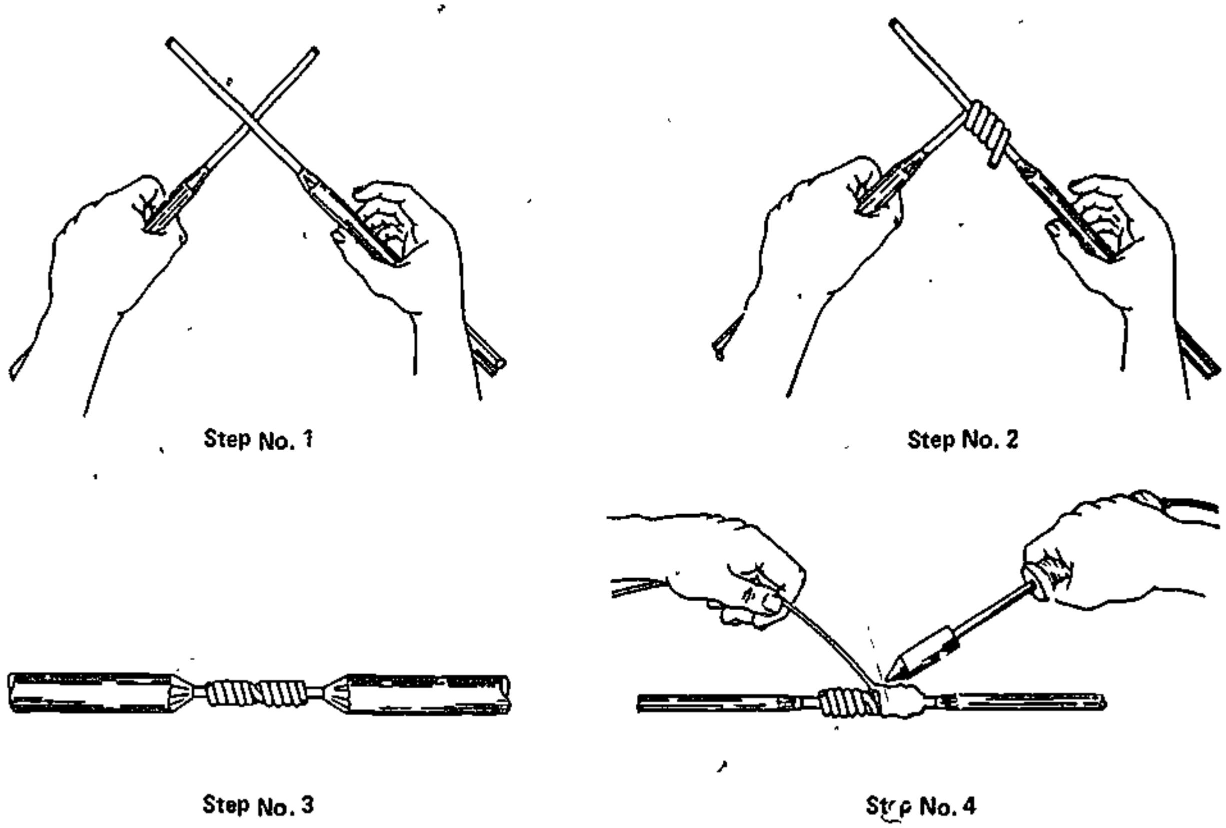


FIGURE 2. CONDUCTORS MECHANICALLY JOINED AND SOLDERED

(LESS THAN 600 VOLTS) INCLUDES ELECTRICAL TAPE, END CAPS THAT ARE APPROVED FOR THE PURPOSE, AND SHRINK SLEEVES. SHRINK SLEEVES PROVIDE A TIGHT-FITTING, UNIFORM INSULATION WHEN HEATED. FIGURE 3 ILLUSTRATES THE PROPER APPLICATION OF ELECTRICAL TAPE.

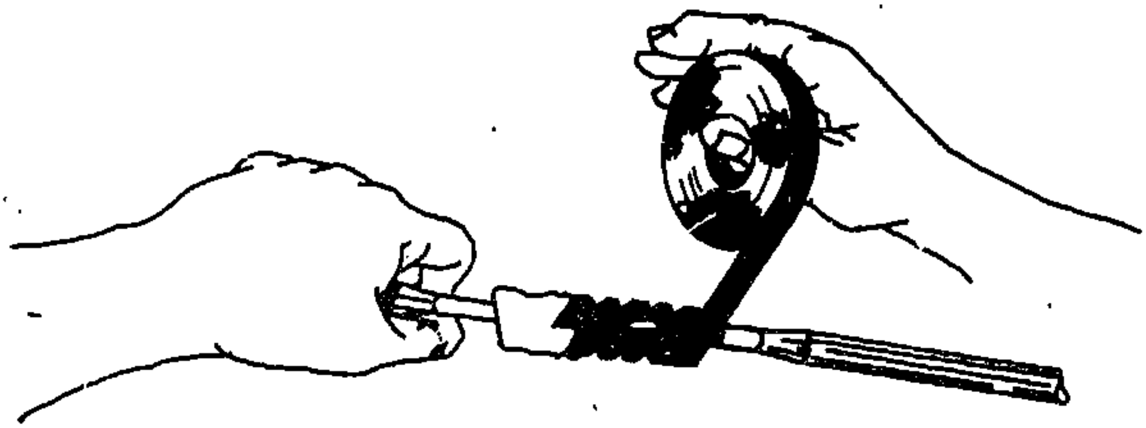


FIGURE 3. INSULATING A SPLICE WITH ELECTRICAL TAPE

(d) Arcing parts. Parts of electric equipment which in ordinary operation produce arcs, sparks, flames, or molten metal shall be enclosed or separated and isolated from all combustible material.

(e) Marking. Electrical equipment may not be used unless the manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified is placed on the equipment. Other markings shall be provided giving voltage, current, wattage, or other ratings as necessary. The marking shall be of sufficient durability to withstand the environment involved.

• (f) Identification of disconnecting means and circuits. Each disconnecting means required by this subpart for motors and appliances shall be legibly marked to indicate its purpose, unless located and arranged so the purpose is evident. Each service, feeder, and branch circuit, at its disconnecting means or overcurrent device, shall be legibly marked to indicate its purpose, unless located and arranged so the purpose is evident. These markings shall be of sufficient durability to withstand the environment involved.

- IDENTIFICATION OF DISCONNECTING MEANS

A DISCONNECTING MEANS IS A SWITCH THAT IS USED TO DISCONNECT THE CONDUCTORS OF A CIRCUIT FROM THE SOURCE OF ELECTRIC CURRENT. DISCONNECT SWITCHES ARE IMPORTANT BECAUSE THEY ENABLE A CIRCUIT TO BE OPENED, STOPPING THE FLOW OF ELECTRICITY, AND THUS CAN EFFECTIVELY PROTECT WORKERS AND EQUIPMENT.

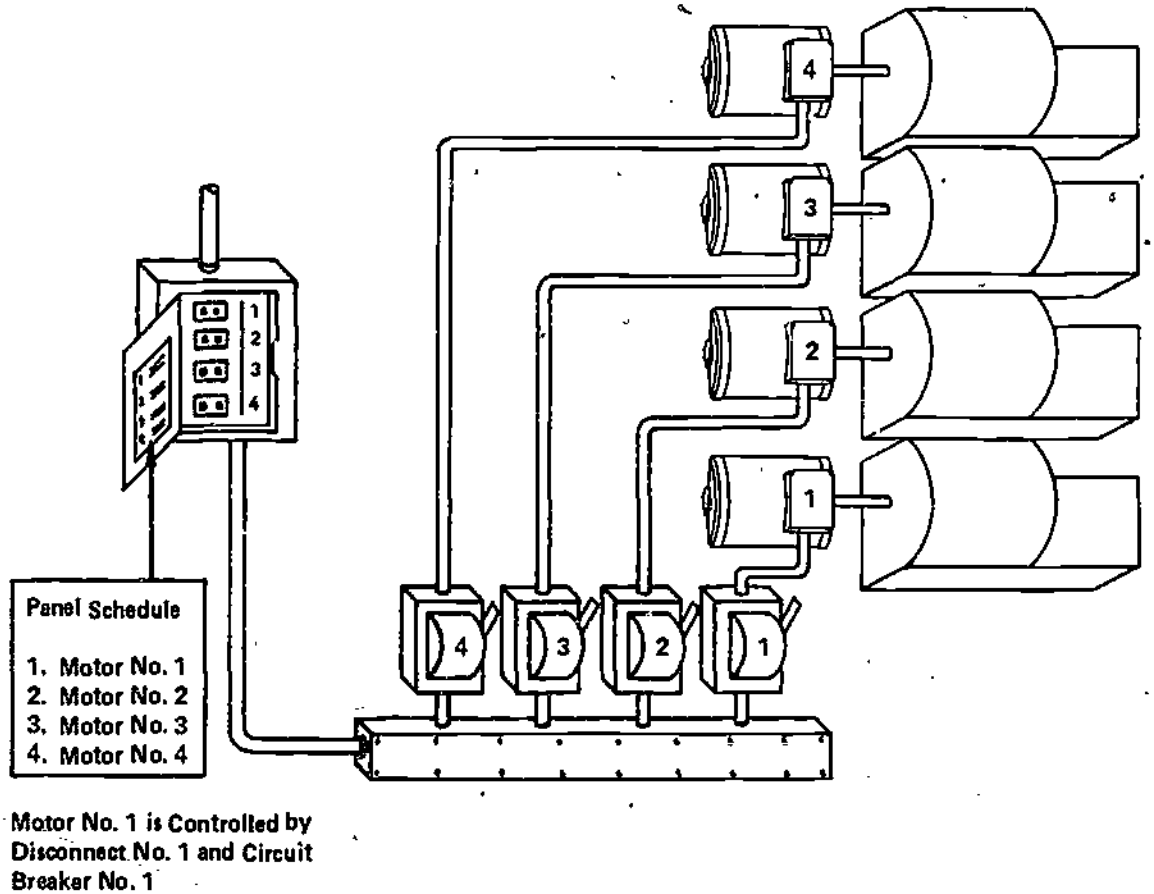
EACH DISCONNECT SWITCH OR OVERCURRENT DEVICE REQUIRED FOR A SERVICE, FEEDER, OR BRANCH CIRCUIT MUST BE CLEARLY LABELED TO INDICATE THE CIRCUIT'S FUNCTION, AND THE LABEL OR MARKING SHOULD BE LOCATED AT THE POINT WHERE THE CIRCUIT ORIGINATES. FOR EXAMPLE, ON A PANEL THAT CONTROLS SEVERAL MOTORS OR ON A MOTOR CONTROL CENTER, EACH DISCONNECT MUST BE CLEARLY MARKED TO INDICATE THE MOTOR TO WHICH EACH CIRCUIT IS CONNECTED. IN FIGURES 4 AND 5, THE NUMBER 2 CIRCUIT BREAKER IN THE PANEL BOX SUPPLIES CURRENT ONLY TO DISCONNECT NUMBER 2, WHICH IN TURN CONTROLS THE CURRENT TO MOTOR NUMBER 2. THIS CURRENT TO MOTOR NUMBER 2 CAN BE SHUT OFF BY THE NUMBER 2 CIRCUIT BREAKER OR THE NUMBER 2 DISCONNECT.

IDENTIFICATION SHOULD BE SPECIFIC RATHER THAN GENERAL. A BRANCH CIRCUIT SERVING RECEPTACLES IN THE MAIN OFFICE SHOULD BE LABELED AS SUCH, NOT SIMPLY LABELED "RECEPTACLES."

IF THE PURPOSE OF THE CIRCUIT IS OBVIOUS, NO IDENTIFICATION OF THE DISCONNECT IS REQUIRED. (SEE FIGURE 6).

ALL LABELS AND MARKINGS MUST BE DURABLE ENOUGH TO WITHSTAND WEATHER, CHEMICALS, HEAT, CORROSION, OR ANY OTHER ENVIRONMENT TO WHICH THEY MAY BE EXPOSED.

FIGURE 6 SHOWS A DISCONNECT SWITCH WHICH IS LOCATED ON MACHINE AND THUS ITS PURPOSE IS EVIDENT.



NOTE: As shown in diagram, the purposes of these disconnecting switches are clearly evident. In such cases identification may be omitted. In the actual installation however, the motors may not be within sight of the disconnects or arranged in such a way that the purpose is not evident and identification would be required.

FIGURE 4. EACH DISCONNECT AND CIRCUIT REQUIRES IDENTIFICATION

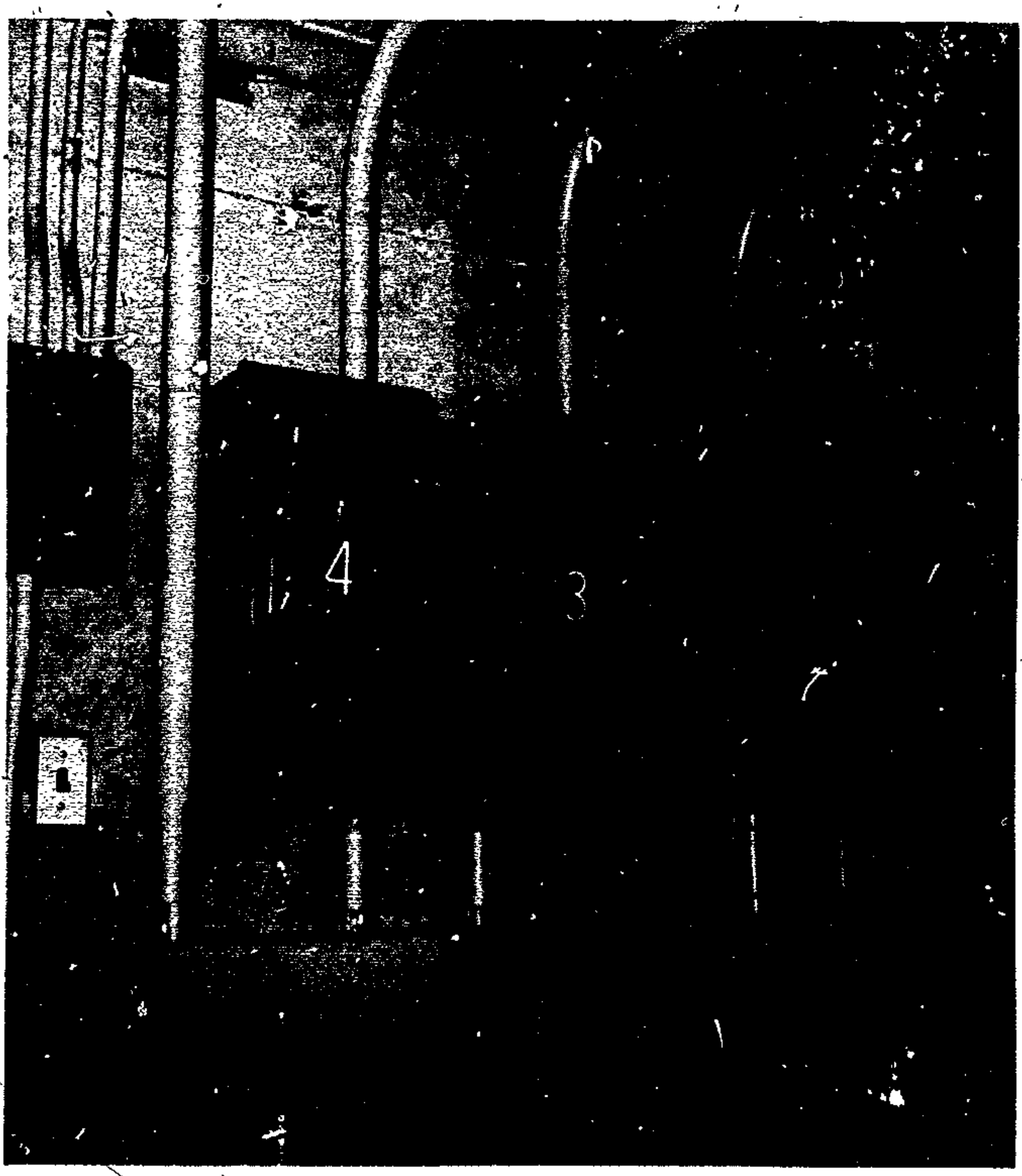


FIGURE 5. FOUR IDENTIFIED DISCONNECT SWITCHES

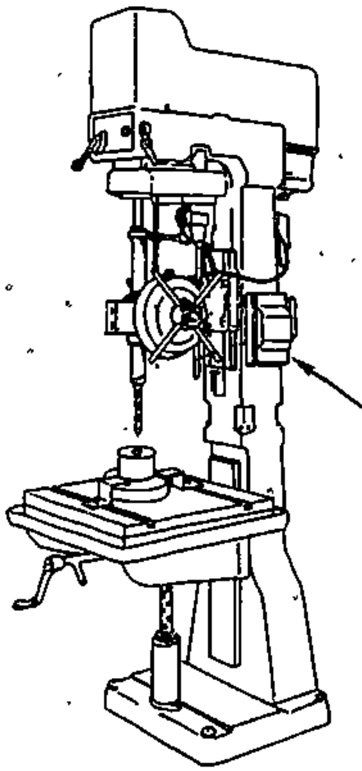


FIGURE 6. DISCONNECT SWITCH LOCATED ON MACHINE; NO LABEL REQUIRED

(g) 600 Volts, nominal, or less.

(1) Working space about electric equipment. Sufficient access and working space shall be provided and maintained about all electric equipment to permit ready and safe operation and maintenance of such equipment.

(i) Working clearances. Except as required or permitted elsewhere in this subpart, the dimension of the working space in the direction of access to live parts operating at 600 volts or less and likely to require examination, adjustment, servicing, or maintenance while alive may not be less than indicated in Table S-1. In addition to the dimensions shown in Table S-1, workspace may not be less than 30 inches wide in front of the electric equipment. Distances shall be measured from the live parts if they are exposed, or from the enclosure front or opening if the live parts are enclosed. Concrete, brick, or tile walls are considered to be grounded. Working space is not required in back of assemblies such as dead-front switchboards or motor control centers where there are no renewable or adjustable parts such as fuses or switches on the back and where all connections are accessible from locations other than the back.

Table S-1
Working Clearances

Nominal Voltage to Ground	Minimum clear distance for condition[2] (a)	(b)	(c)
	(Feet)	(Feet)	(Feet)
0-150	3[1]	3[1]	3
151-600	3[1]	3 1/2	4

[1]Minimum clear distances may be 2 feet 6 inches for installations built prior to April 16, 1981.

- [2]Conditions (a), (b), and (c) are as follows: (a) Exposed live parts on one side and no live or grounded parts on the other side of the working space, or exposed live parts on both sides effectively guarded by suitable wood or other insulating material. Insulated wire or insulated busbars operating at not over 300 volts are not considered live parts. (b) Exposed live parts on one side and grounded parts on the other side. (c) Exposed live parts on both sides of the workspace [not guarded as provided in Condition (a)] with the operator between.

- WORKING CLEARANCES

TABLE S-1 ESTABLISHES THE MINIMUM CLEAR DISTANCES THAT ARE REQUIRED AROUND ELECTRICAL EQUIPMENT RATED AT 600 VOLTS OR LESS. MINIMUM CLEAR DISTANCES ARE THE SHORTEST DISTANCES WHICH MUST BE PROVIDED TO AFFORD A WORKER ENOUGH ROOM TO WORK SAFELY NEAR ENERGIZED ELECTRICAL EQUIPMENT. SPECIFICALLY, THESE DISTANCES ARE ESTABLISHED ACCORDING TO THE TYPE OF ELECTRICAL HAZARD PRESENTED BY THE ARRANGEMENT OF EQUIPMENT, AS DESCRIBED IN CONDITIONS (a), (b), AND (c).

CONDITION (a) DESCRIBES A LOCATION WHERE THERE ARE LIVE ELECTRICAL PARTS ON ONE SIDE OF THE WORKER AND NO LIVE OR GROUNDED PARTS ON THE OTHER SIDE (SEE FIGURE 7). IF, FOR EXAMPLE, A WORKER IS SERVICING A PANELBOARD THAT HAS EXPOSED LIVE BUSBARS AND THERE IS A WALL CONSTRUCTED OF NON-CONDUCTIVE MATERIAL SUCH AS WOOD OR SHEETROCK BEHIND HIM, A MINIMUM SAFE WORKING CLEARANCE OF 3 FEET, MEASURED FROM THE LIVE PARTS TO THE WALL, IS REQUIRED. ADDITIONALLY, IF THERE ARE EFFECTIVELY GUARDED LIVE ELECTRICAL PARTS ON BOTH SIDES OF THE WORKER, THEN CONDITION (a) FOR SAFE CLEARANCES ALSO APPLIES. LIVE PARTS THAT ARE EFFECTIVELY GUARDED

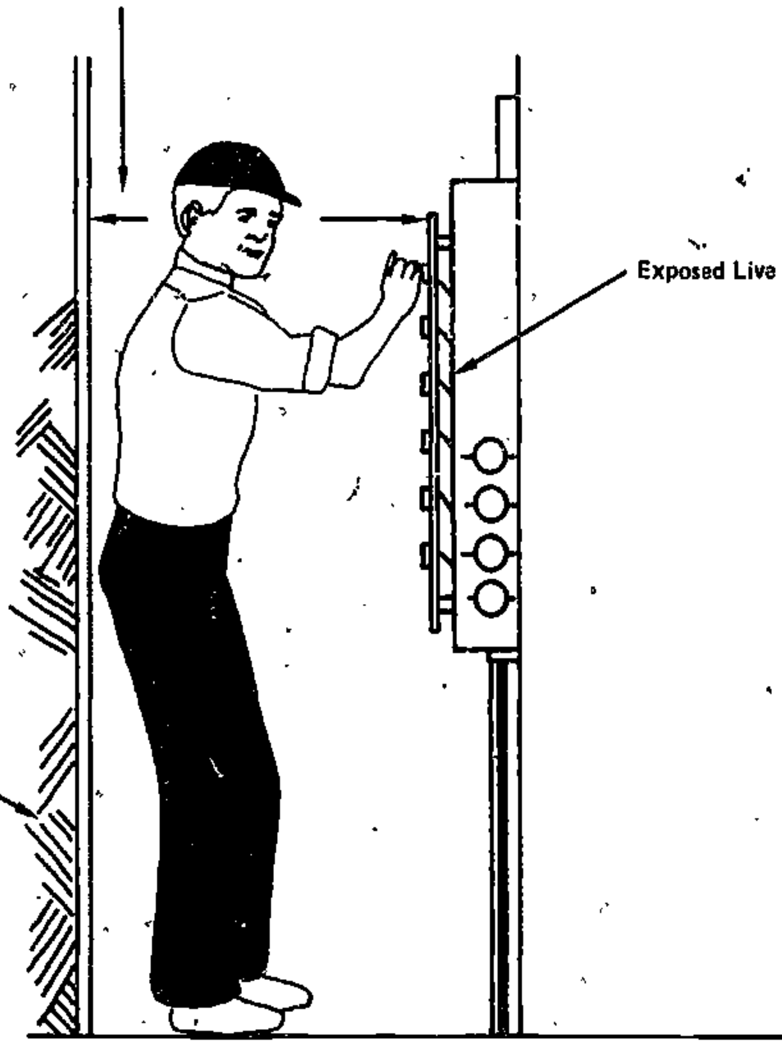


FIGURE 7. CONDITION (a) — LIVE PARTS ON ONE SIDE AND NO LIVE OR GROUNDED PARTS ON THE OTHER SIDE

INCLUDE INSULATED CONDUCTORS (OPERATING AT 300 VOLTS OR LESS) AND EXPOSED SWITCHGEAR GUARDED WITH AN INSULATING BARRIER.

HOWEVER, ELECTRICAL EQUIPMENT INSTALLED BEFORE APRIL 16, 1981, IS PERMITTED TO HAVE A MINIMUM CLEAR WORKING DISTANCE OF 2-1/2 FEET UNDER CONDITION (a).

CONDITION (b) DESCRIBES A SITUATION WHERE THERE ARE EXPOSED LIVE PARTS ON ONE SIDE OF THE WORKER AND GROUNDED PARTS ON THE OTHER. FOR EXAMPLE, IF LIVE SWITCHGEAR OR OPEN CONDUCTORS OPERATING AT 150 VOLTS TO GROUND OR LESS ARE IN FRONT OF THE WORKER AND A GROUNDED EQUIPMENT ENCLOSURE IS BEHIND (SEE FIGURE 8), THE MINIMUM CLEAR WORKING DISTANCE MUST BE 3 FEET (2-1/2 FEET FOR EQUIPMENT INSTALLED PRIOR TO APRIL 16, 1981). FOR EQUIPMENT

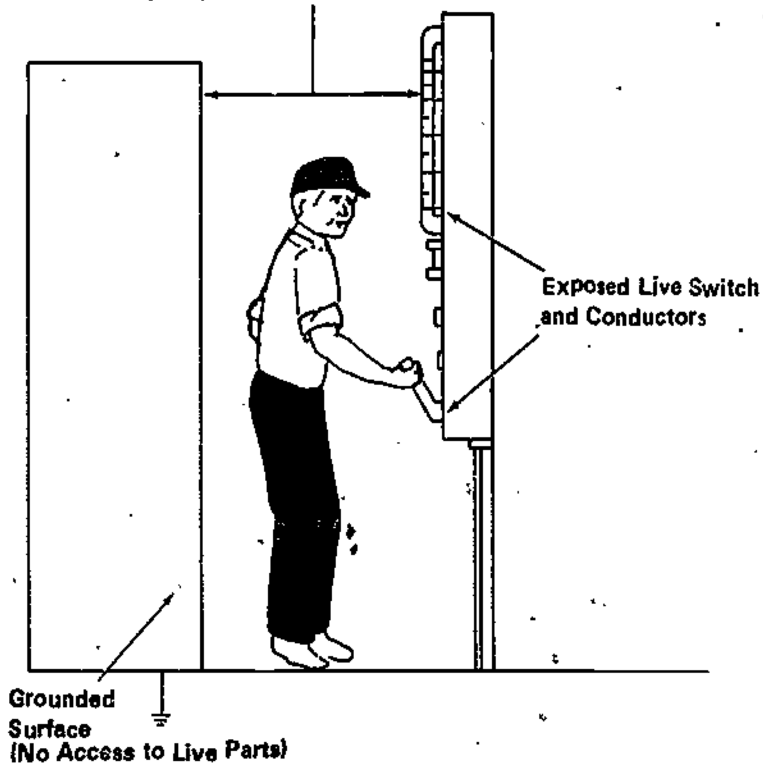


FIGURE B. CONDITION (b) – EXPOSED LIVE PARTS ON ONE SIDE AND GROUNDED PARTS ON THE OTHER SIDE

OPERATING AT 151 TO 600 VOLTS TO GROUND UNDER THE SAME CONDITIONS, THE WORKING DISTANCE MUST BE 3-1/2 FEET. THESE DISTANCES ALLOW ENOUGH ROOM TO WORK, REDUCING THE POSSIBILITY OF SIMULTANEOUS CONTACT WITH THE LIVE PARTS AND GROUND. CONCRETE, BRICK, AND TILE WALLS ARE CONSIDERED TO BE GROUNDED, ALONG WITH ELECTRICAL BOXES, CABINETS, AND ENCLOSURES THAT ARE GROUNDED.

CONDITION (c) DESCRIBES A SITUATION WHERE THERE ARE EXPOSED LIVE PARTS ON BOTH SIDES OF THE WORKSPACE. FOR EXAMPLE, IF TWO SWITCHBOARDS ARE INSTALLED OPPOSITE EACH OTHER THE MINIMUM CLEAR WORKSPACE BETWEEN THEM IS REQUIRED TO BE 3 FEET FOR EQUIPMENT OPERATING AT 150 VOLTS TO GROUND OR LESS. FOR EQUIPMENT OPERATING AT 151 TO 600 VOLTS TO GROUND, THE MINIMUM CLEAR WORKSPACE IS 4 FEET. THE REQUIRED DISTANCE INCREASES WITH THE VOLTAGE AT WHICH THE EQUIPMENT OPERATES AND IS GIVEN IN TABLES S-1 AND S-2. SEE FIGURE 9.

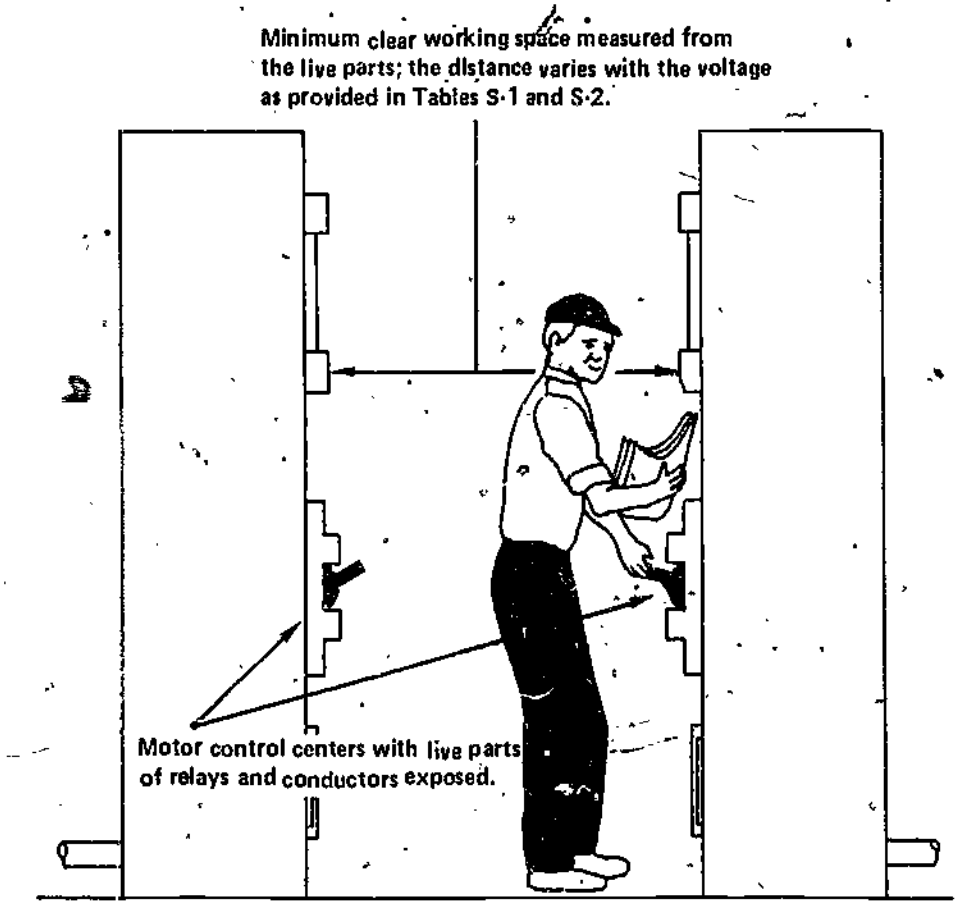


FIGURE 9. CONDITION (c) – EXPOSED LIVE UNGUARDED PARTS ON BOTH SIDES

(ii) Clear spaces. Working space required by this subpart may not be used for storage. When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, shall be suitably guarded.

(iii) Access and entrance to working space. At least one entrance of sufficient area shall be provided to give access to the working space about electric equipment.

(iv) Front working space. Where there are live parts normally exposed on the front of switchboards or motor control centers, the working space in front of such equipment may not be less than 3 feet.

(v) Illumination. Illumination shall be provided for all working spaces about service equipment, switchboards, panelboards, and motor control centers installed indoors.

(vi) Headroom. The minimum headroom of working spaces about service equipment, switchboards, panelboards, or motor control centers shall be 6 feet 3 inches.

NOTE: As used in this section a motor control center is an assembly of one or more enclosed sections having a common power bus and principally containing motor control units.

(2) Guarding of live parts.

(i) Except as required or permitted elsewhere in this subpart, live parts of electric equipment operating at 50 volts or more shall be guarded against accidental contact by approved cabinets or other forms of approved enclosures, or by any of the following means:

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

(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 the live parts or to bring conducting objects into contact with them.

(c) By location on a suitable balcony, gallery, or platform so elevated and arranged as to exclude unqualified persons.

(d) By elevation of 8 feet or more above the floor or other working surface.

(ii) In locations where electric equipment would be exposed to physical damage, enclosures or guards shall be so arranged and of such strength as to prevent such damage.

(h) Over 600 volts, nominal.

(1) General. Conductors and equipment used on circuits exceeding 600 volts, nominal, shall comply with all applicable provisions of paragraphs (a) through (g) of this section and with the following provisions which supplement or modify those requirements. The provisions of paragraphs (h)(2), (h)(3), and (h)(4) of this section do not apply to equipment on the supply side of the service conductors.

(2) Enclosure for electrical installations. Electrical installations in a vault, room, closet or in an area surrounded by a wall, screen, or fence, access to which is controlled by lock and key or other approved means, are considered to be accessible to qualified persons only. A wall screen, or fence less than 8 feet in height is not considered to prevent access unless it has other features that provide a degree of isolation equivalent to an 8 foot fence. The entrances to all buildings, rooms, or enclosures containing exposed live parts or exposed conductors operating at over 600 volts, nominal, shall be kept locked or shall be under the observation of a qualified person at all times.

(i) Installations accessible to qualified persons only. Electrical installations having exposed live parts shall be accessible to qualified persons only and shall comply with the applicable provisions of paragraph (h)(3) of this section.

(ii) Installations accessible to unqualified persons. Electrical installations that are open to unqualified persons shall be made with metal-enclosed equipment or shall be enclosed in a vault or in an area, access to which is controlled by a lock. If metal-enclosed equipment is installed so that the bottom of the enclosure is less than 8 feet above the floor, the door or cover shall be kept locked. Metal-enclosed switchgear, unit substations, transformers, pull boxes, connection boxes, and other similar associated equipment shall be marked with appropriate caution signs. If equipment is exposed to physical damage from vehicular traffic, suitable guards shall be provided to prevent such damage. Ventilating or similar openings in metal-enclosed equipment shall be designed so that foreign objects inserted through these openings will be deflected from energized parts.

(3) Workspace about equipment. Sufficient space shall be provided and maintained about electric equipment to permit ready and safe operation and maintenance of such equipment. Where energized parts are exposed, the minimum clear workspace may not be less than 6 feet 6 inches high (measured vertically from the floor or platform), or less than 3 feet wide (measured parallel to the equipment).

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The depth shall be as required in Table S-2. The workspace shall be adequate to permit at least a 90-degree opening of doors or hinged panels.

(i) Working space. The minimum clear working space in front of electric equipment such as switchboards, control panels, switches, circuit breakers, motor controllers, relays, and similar equipment may not be less than specified in Table S-2 unless otherwise specified in this subpart. Distances shall be measured from the live parts if they are exposed, or from the enclosure front or opening if the live parts are enclosed. However, working space is not required in back of equipment such as deadfront switchboards or control assemblies where there are no renewable or adjustable parts (such as fuses or switches) on the back and where all connections are accessible from locations other than the back. Where rear access is required to work on deenergized parts on the back of enclosed equipment, a minimum working space of 30 inches horizontally shall be provided.

- WORKING SPACE IN BACK OF EQUIPMENT

TABLE S-2 SHOWS THE MINIMUM CLEAR WORKING DISTANCES REQUIRED IN FRONT OF ELECTRIC EQUIPMENT THAT IS RATED OVER 600 V. HOWEVER, WORKING SPACE IS NOT REQUIRED BEHIND ELECTRIC EQUIPMENT SUCH AS DEADFRONT SWITCHBOARDS OR CONTROL PANELS WHERE PARTS THAT MAY NEED TO BE REPLACED OR ADJUSTED, AND ALL CONNECTIONS, CAN BE REACHED FROM LOCATIONS OTHER THAN THE BACK. IF IT IS NECESSARY FOR WORKERS TO GO BEHIND ENCLOSED EQUIPMENT TO WORK ON DE-ENERGIZED PARTS, THERE MUST BE A WORKING SPACE NO LESS THAN 30 INCHES WIDE SO THAT THE WORKER HAS ENOUGH ROOM TO MOVE AROUND AND TO ESCAPE IN AN EMERGENCY SITUATION. FIGURE 10 DEPICTS BOTH SITUATIONS.

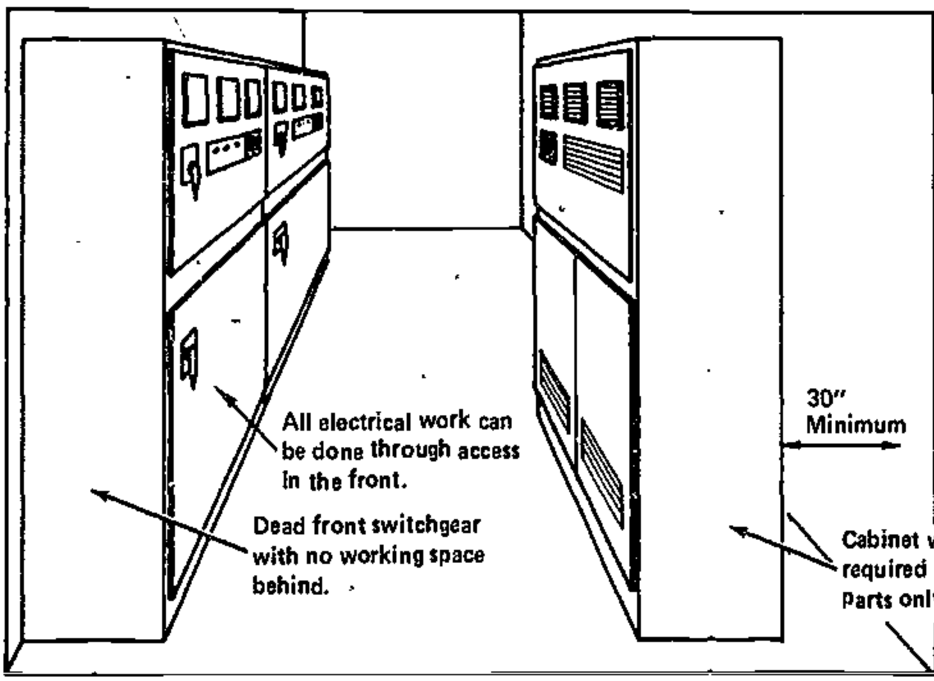


FIGURE 10. WORKING SPACES BEHIND ELECTRIC EQUIPMENT

Table S-2
Minimum Depth of Clear Working
Space in Front of Electric Equipment

Nominal Voltage to Ground	Conditions[2] (a)	(b)	(c)
	(Feet)	(Feet)	(Feet)
601 - 2,500	3	4	5
2,501 - 9,000	4	5	6
9,001 - 25,000	5	6	9
[1]25,001 - 75kV	6	8	10
[1]Above 75kV	8	10	12

[1]Minimum depth of clear working space in front of electric equipment with a nominal voltage to ground above 25,000 volts may be the same as for 25,000 volts under Conditions (a), (b), and (c) for installations built prior to April 16, 1981.

• [2]Conditions (a), (b), and (c) are as follows: (a) Exposed live parts on one side and no live or grounded parts on the other side of the working space, or exposed live parts on both sides effectively guarded by suitable wood or other insulating materials. Insulated wire or insulated busbars operating at not over 300 volts are not considered live parts. (b) Exposed live parts on one side and grounded parts on the other side. Concrete, brick, or file walls will be considered as grounded surfaces. (c) Exposed live parts on both sides of the workspace not guarded as provided in Condition (a) with the operator between.

- MINIMUM DEPTH OF CLEAR WORKING SPACE

CONDITIONS (a), (b), AND (c) OF THIS TABLE ARE DESCRIBED IN FIGURES 7, 8, AND 9. THEY ARE IDENTICAL TO THOSE PICTURES FOR LOW VOLTAGE SYSTEMS. ONLY THE DISTANCE VARIES ACCORDING TO THE DIFFERENT SYSTEM VOLTAGES.

(ii) Illumination. Adequate illumination shall be provided for all working spaces about electric equipment. The lighting outlets shall be so arranged that persons changing lamps or making repairs on the lighting system will not be endangered by live parts or other equipment. The points of control shall be so located that persons are not likely to come in contact with any live part or moving part of the equipment while turning on the lights.

(iii) Elevation of unguarded live parts. Unguarded live parts above working space shall be maintained at elevations not less than specified in Table S-3.

Table S-3
Elevation of Unguarded Energized Parts Above Working Space

Nominal Voltage Between Phases	Minimum Elevation
601 - 7,500	*8 feet 6 inches
7,501 - 35,000	9 feet
Over 25kV	9 feet + 0.37 inches per kV above 35kV

*NOTE: Minimum elevation may be 8 feet 0 inches for installations built prior to April 16, 1981, if the nominal voltage between phases is in the range of 601-6600 volts.

(4) Entrance and access to workspace. (See §1910.302(b)(3).)

• (i) At least one entrance not less than 24 inches wide and 6 feet 6 inches high shall be provided to give access to the working space about electric equipment. On switchboard and control panels exceeding 48 inches in width, there shall be one entrance at each end of such board where practicable. Where bare energized parts at any voltage or insulated energized parts above 600 volts are located adjacent to such entrance, they shall be suitably guarded.

• ENTRANCES AND ACCESS TO WORKSPACE

IN ANY WORKSPACE WHERE THERE IS ELECTRIC EQUIPMENT OPERATING AT OVER 600 VOLTS, THERE MUST BE AT LEAST ONE ENTRANCE/EXIT LARGE ENOUGH TO ALLOW THE WORKER TO SAFELY ENTER THE WORK AREA AND TO EASILY ESCAPE FROM IT IN THE EVENT OF AN EMERGENCY. THIS ENTRANCE MUST BE AT LEAST 24 INCHES WIDE AND 6 FEET, 6 INCHES HIGH. IF A SWITCHBOARD OR CONTROL PANEL IS MORE THAN 48 INCHES WIDE, THERE GENERALLY HAS TO BE ONE ENTRANCE AT EACH END OF THE BOARD. BOTH OF THESE ENTRANCES SHOULD ALSO BE AT LEAST 24 INCHES WIDE AND 6 FEET, 6 INCHES HIGH. FIGURE 11 SHOWS THE REQUIRED TWO EXITS FOR A SWITCHBOARD WITH INTERNAL WORKSPACE.

ANY EXPOSED ENERGIZED ELECTRIC PARTS OPERATING AT ANY VOLTAGE AND LOCATED NEAR THE ENTRANCES MUST BE GUARDED TO PREVENT ACCIDENTAL CONTACT BY THE WORKER. ANY INSULATED ENERGIZED PARTS OPERATING AT MORE THAN 600 VOLTS AND LOCATED NEXT TO THE DOORS MUST ALSO BE GUARDED.

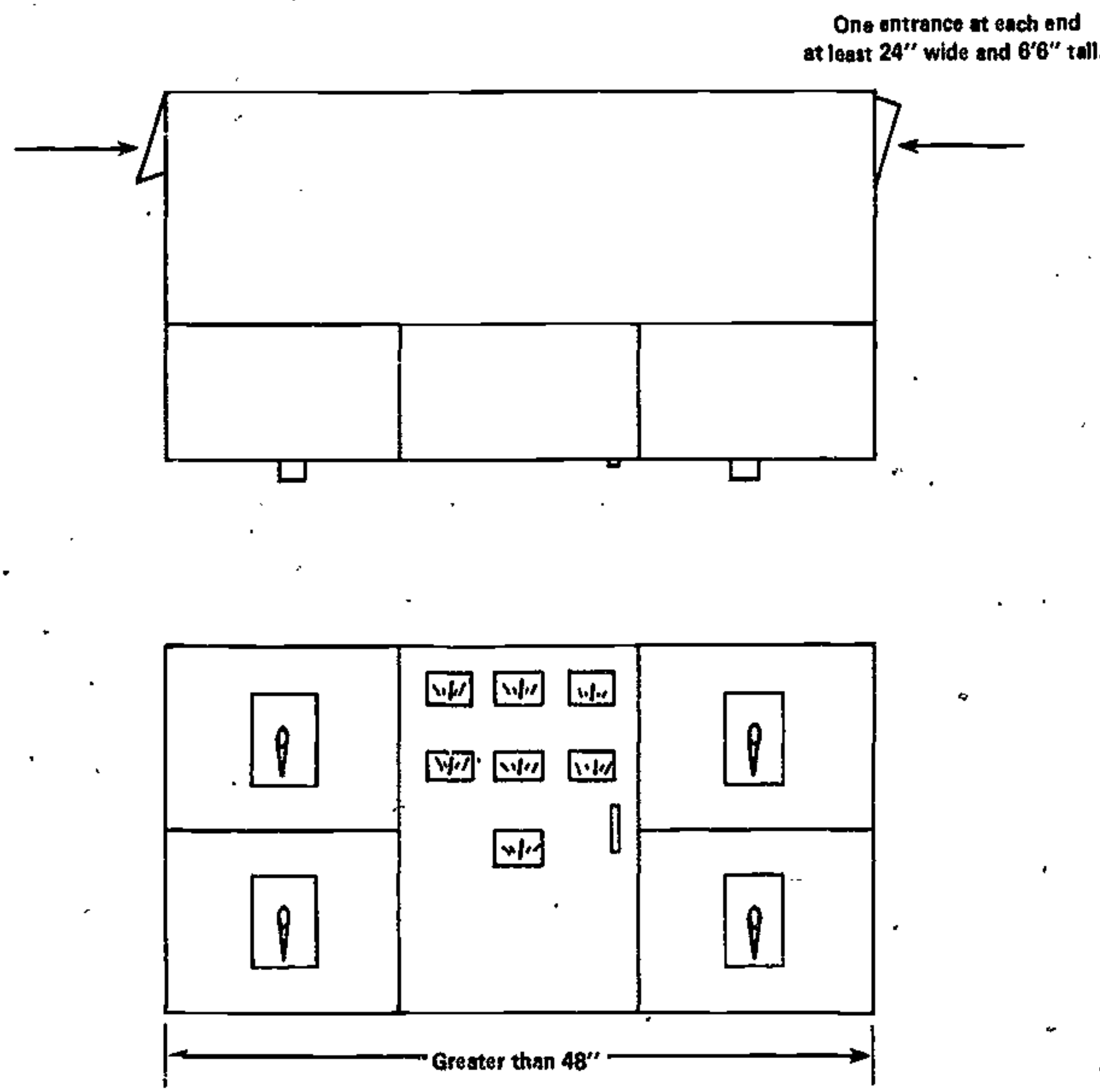


FIGURE 11. SWITCHBOARD WITH INTERNAL WORKSPACE

(ii) Permanent ladders or stairways shall be provided to give safe access to the working space around electric equipment installed on platforms, balconies, mezzanine floors, or in attic or roof rooms or spaces.

§1910.304 WIRING DESIGN AND PROTECTION

§1910.304 Wiring design and protection.

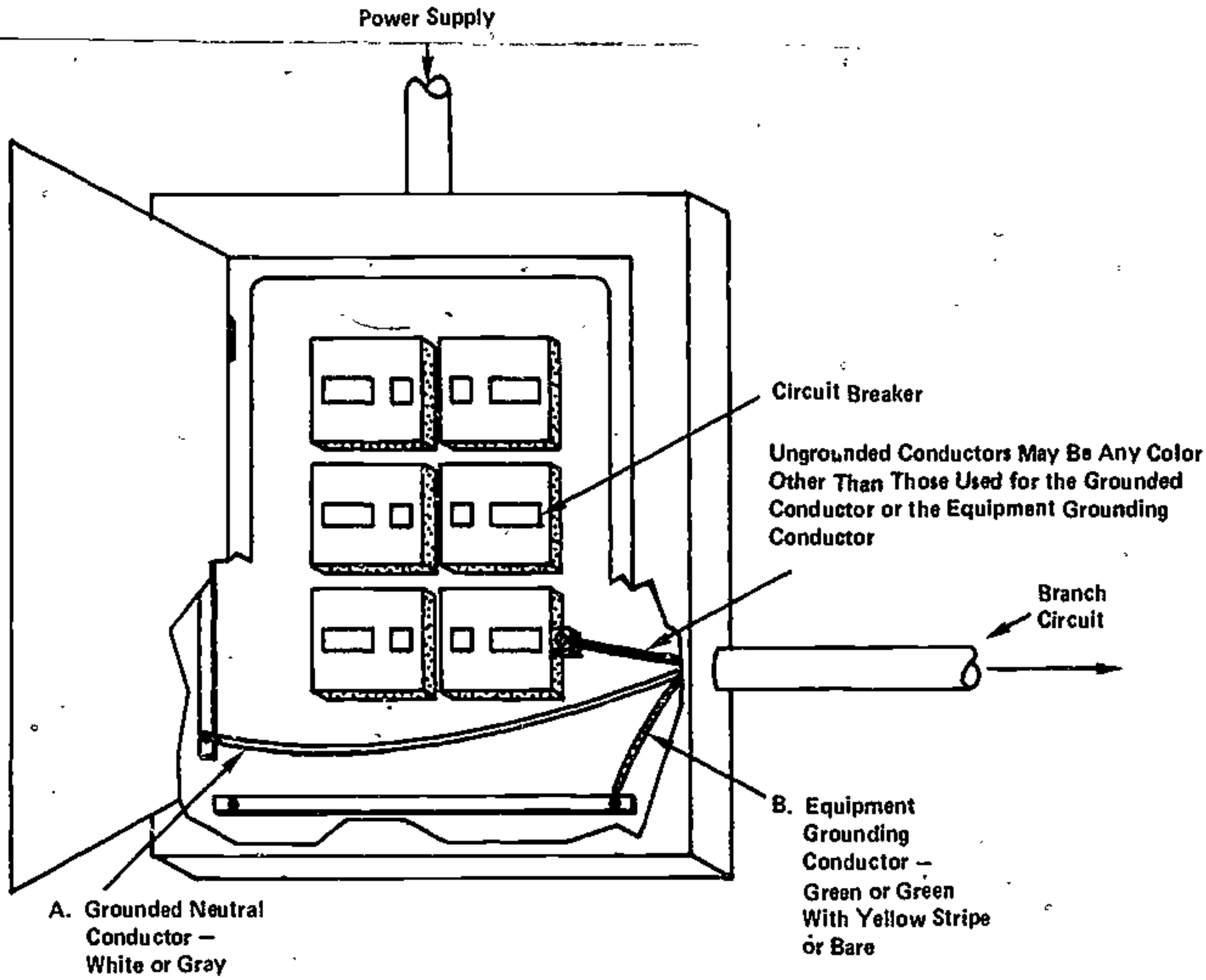
(a) Use and identification of grounded and grounding conductors.

- (1) Identification of conductors. A conductor used as a grounded conductor shall be identifiable and distinguishable from all other conductors. A conductor used as an equipment grounding conductor shall be identifiable and distinguishable from all other conductors.

- THE GROUNDED CONDUCTOR IS AN ENERGIZED CIRCUIT CONDUCTOR THAT IS CONNECTED TO EARTH THROUGH THE SYSTEM GROUND. IT IS COMMONLY REFERRED TO AS THE NEUTRAL. THE EQUIPMENT GROUNDING CONDUCTOR IS NOT AN ENERGIZED CONDUCTOR UNDER NORMAL CONDITIONS. THE EQUIPMENT GROUNDING CONDUCTOR ACTS AS A SAFEGUARD AGAINST INSULATION FAILURE OR FAULTS IN THE OTHER CIRCUIT CONDUCTORS. THE EQUIPMENT GROUNDING CONDUCTOR IS ENERGIZED ONLY IF THERE IS A LEAK OR FAULT IN THE NORMAL CURRENT PATH, AND IT DIRECTS THIS CURRENT BACK TO THE SOURCE. DIRECTING THE FAULT CURRENT BACK TO THE SOURCE ENABLES PROTECTIVE DEVICES, SUCH AS CIRCUIT BREAKERS OR FUSES, TO OPERATE THUS PREVENTING FIRES AND REDUCING THE HAZARD OF ELECTRICAL SHOCKS.

THE GROUNDED AND EQUIPMENT GROUNDING CONDUCTORS OF AN ELECTRICAL CIRCUIT MUST BE MARKED OR COLOR CODED IN A WAY THAT ALLOWS EMPLOYEES TO IDENTIFY THEM AND TELL THEM APART FROM EACH OTHER AND FROM THE OTHER CONDUCTORS IN THE CIRCUIT.

FIGURE 12 SHOWS A CUTAWAY ILLUSTRATION OF A DISTRIBUTION PANELBOARD. ONE MEANS BY WHICH EACH CONDUCTOR'S USE IS IDENTIFIED AND MADE DISTINGUISHABLE FROM THE OTHER CIRCUIT CONDUCTORS IS THE USE OF COLOR CODING. ACCEPTABLE COLOR CODING INCLUDES THE METHOD REQUIRED BY THE NATIONAL ELECTRICAL CODE, SECTION 210-5. THE CODE STATES: "THE GROUNDED CONDUCTOR OF A BRANCH CIRCUIT SHALL BE IDENTIFIED BY A CONTINUOUS WHITE OR NATURAL GRAY COLOR." ALSO, "THE EQUIPMENT GROUNDING CONDUCTOR OF A BRANCH CIRCUIT SHALL BE IDENTIFIED BY A CONTINOUS GREEN COLOR OR A CONTINUOUS GREEN COLOR WITH ONE OR MORE YELLOW STRIPES UNLESS IT IS BARE." BARE COPPER OR ALUMINUM WIRE IS PERMITTED FOR USE AS A GROUNDING CONDUCTOR.



A. The grounded conductor is identified and distinguished from other conductors by using white or gray color-coded insulated wires.

B. The equipment grounding conductor is identified and distinguished from other conductors by using green, or green with yellow stripe, color coding on wires or run as a bare conductor.

FIGURE 12. DISTRIBUTION PANELBOARD

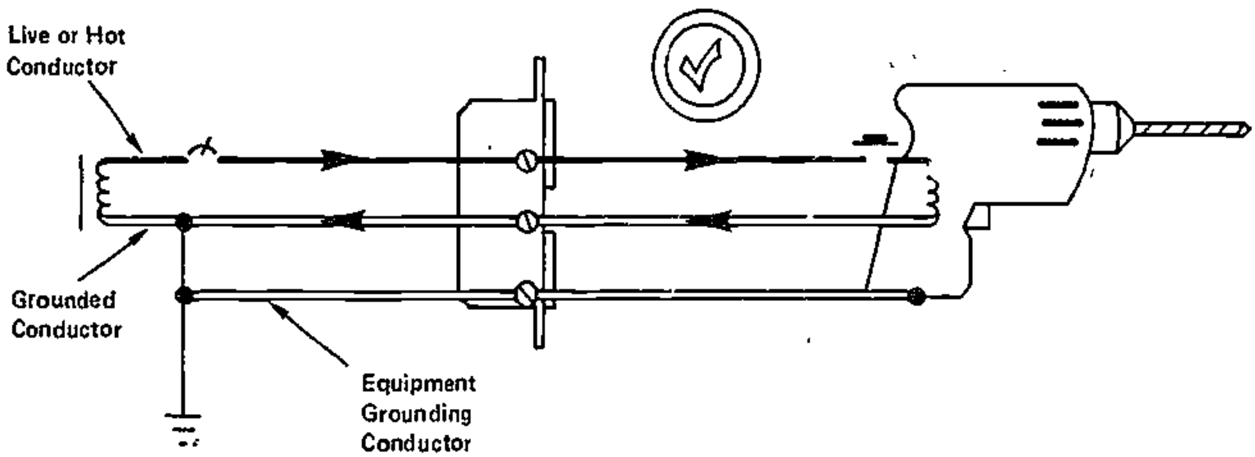
- (2) Polarity of connections. No grounded conductor may be attached to any terminal or lead so as to reverse designated polarity.
- (3) Use of grounding terminals and devices. A grounding terminal or grounding-type device on a receptacle, cord connector, or attachment plug may not be used for purposes other than grounding.

- WHEN PLUGS, RECEPTACLES, AND CONNECTORS ARE USED IN AN ELECTRICAL BRANCH CIRCUIT, CORRECT POLARITY BETWEEN THE UNGROUNDED (HOT) CON-

DUCTOR, THE GROUNDED (NEUTRAL) CONDUCTOR, AND THE GROUNDING CONDUCTOR MUST BE MAINTAINED.

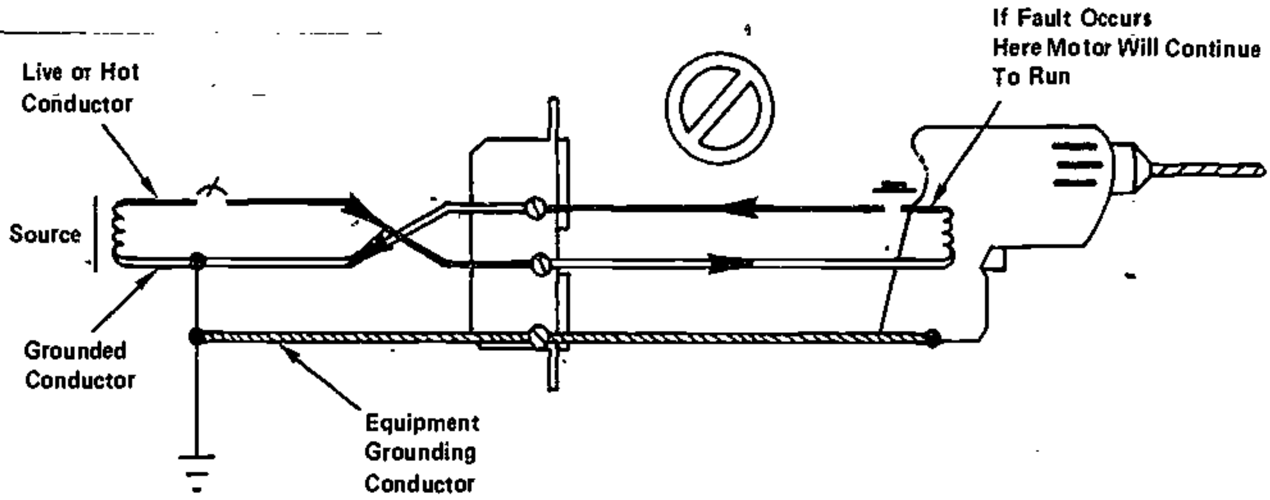
REVERSED POLARITY IS A CONDITION WHEN THE IDENTIFIED CIRCUIT CONDUCTOR (THE GROUNDED CONDUCTOR OR NEUTRAL) IS INCORRECTLY CONNECTED TO THE UNGROUNDED OR 'HOT' TERMINAL OF A PLUG, RECEPTACLE, OR OTHER TYPE OF CONNECTOR. A CORRECTLY WIRED CIRCUIT IS SHOWN IN FIGURE 13A. IF THE IDENTIFIED CONDUCTOR IS REVERSED WITH THE HOT CONDUCTOR, THE CURRENT PATH DOWNSTREAM OF THE IMPROPER CONNECTION IS REVERSED. FIGURE 13B ILLUSTRATES REVERSED POLARITY. UNDER THESE CONDITIONS MOTOR WINDINGS OF TOOLS AND APPLIANCES AND THE SCREW SHELLS OF LAMPHOLDERS REMAIN LIVE AFTER THE EQUIPMENT IS TURNED OFF. SIMULTANEOUS CONTACT WITH THESE PARTS AND GROUND WILL CAUSE A SHOCK, AND THE ONLY PLACE TO TURN OFF THE POWER WOULD BE AT THE BRANCH CIRCUIT DISCONNECT.

FIGURES 13C AND D ILLUSTRATE TWO OTHER POSSIBLE INCORRECT WIRING CONDITIONS WHICH ARE PROHIBITED BY PARAGRAPH (a)(3). THE GROUNDING TERMINAL MAY BE USED ONLY FOR ATTACHMENT OF THE GROUNDING CONDUCTOR. THE EXAMPLE IN FIGURE 13C WOULD NOT BE HAZARDOUS AS SHOWN WITH A SINGLE RECEPTACLE. HOWEVER, UNDER CERTAIN CONDITIONS, SUCH AS THAT RECEPTACLE PLACED IN A CIRCUIT FOLLOWING A RECEPTACLE WITH REVERSED POLARITY, A HAZARD WOULD EXIST. THE EXAMPLE IN FIGURE 13D IS THE MOST HAZARDOUS CONDITION SHOWN WITH THE UNGROUNDED CIRCUIT CONDUCTOR CONNECTED TO THE DRILL HOUSING.



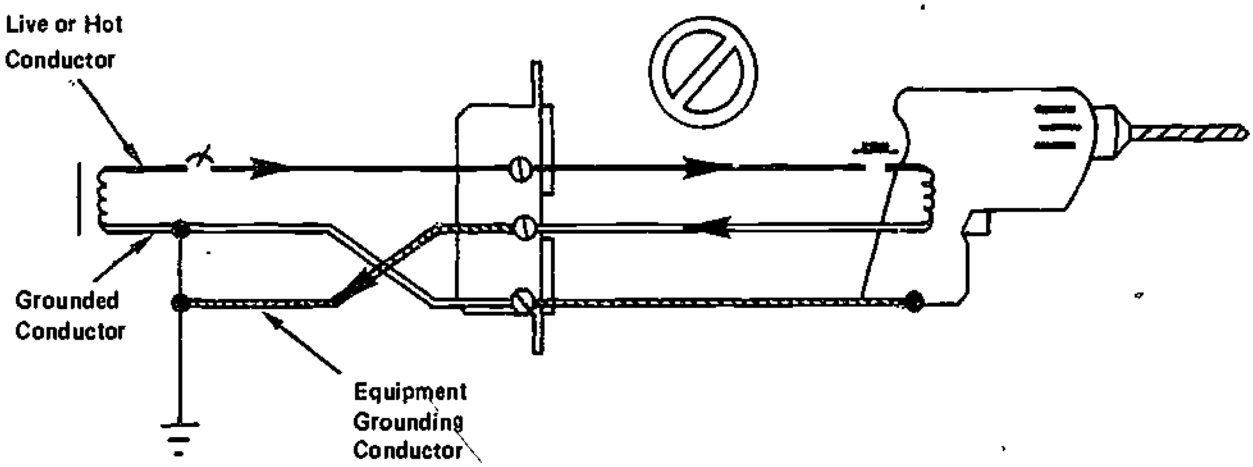
Correct Polarity
Normal Current Path
A.

FIGURE 13. CORRECT AND INCORRECT WIRING OF DUPLEX RECEPTACLES



Reversed Polarity
The Hot and the Neutral are Reversed
The current path reversed. If switch is off
most of the circuit inside tool remains energized.

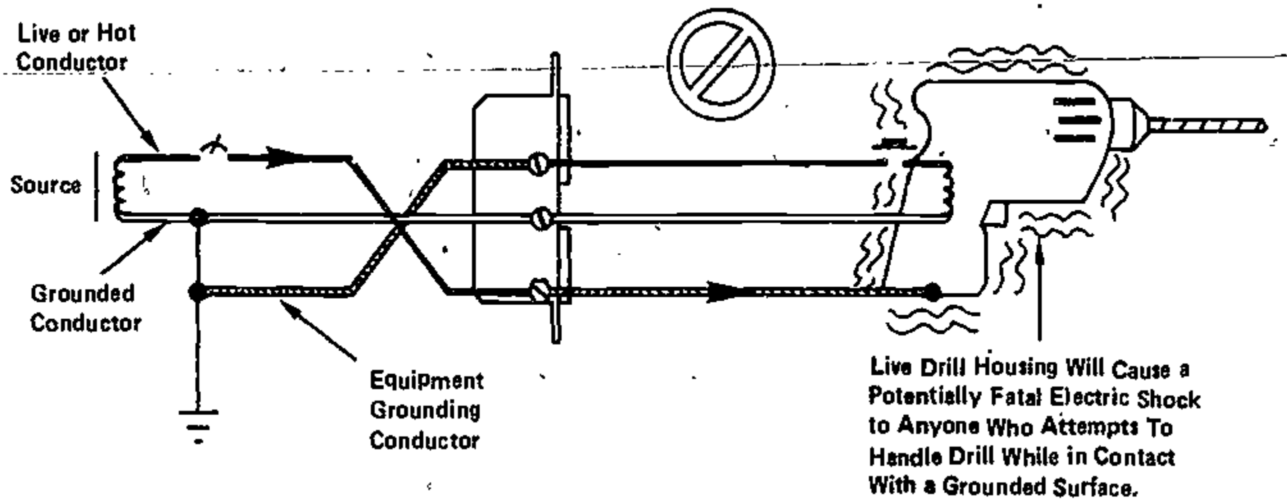
B.



Ground and Neutral Reversed
Showing Current Path Through Equipment Grounding Conductor
Under certain conditions, this condition could be hazardous.

C.

FIGURE 13. CORRECT AND INCORRECT WIRING OF DUPLEX RECEPTACLES
(CONTINUED)



Hot and Ground Reversed Showing Current Path to Equipment Housing.

D.

FIGURE 13. CORRECT AND INCORRECT WIRING OF DUPLEX RECEPTACLES (CONTINUED)

CORRECT POLARITY IS ACHIEVED WHEN THE GROUNDED CONDUCTOR IS CONNECTED TO THE CORRESPONDING GROUNDED TERMINAL AND THE UNGROUNDED CONDUCTOR IS CONNECTED TO THE CORRESPONDING UNGROUNDED TERMINAL. THE REVERSE OF THE DESIGNATED POLARITY IS PROHIBITED. FIGURE 14 ILLUSTRATES A

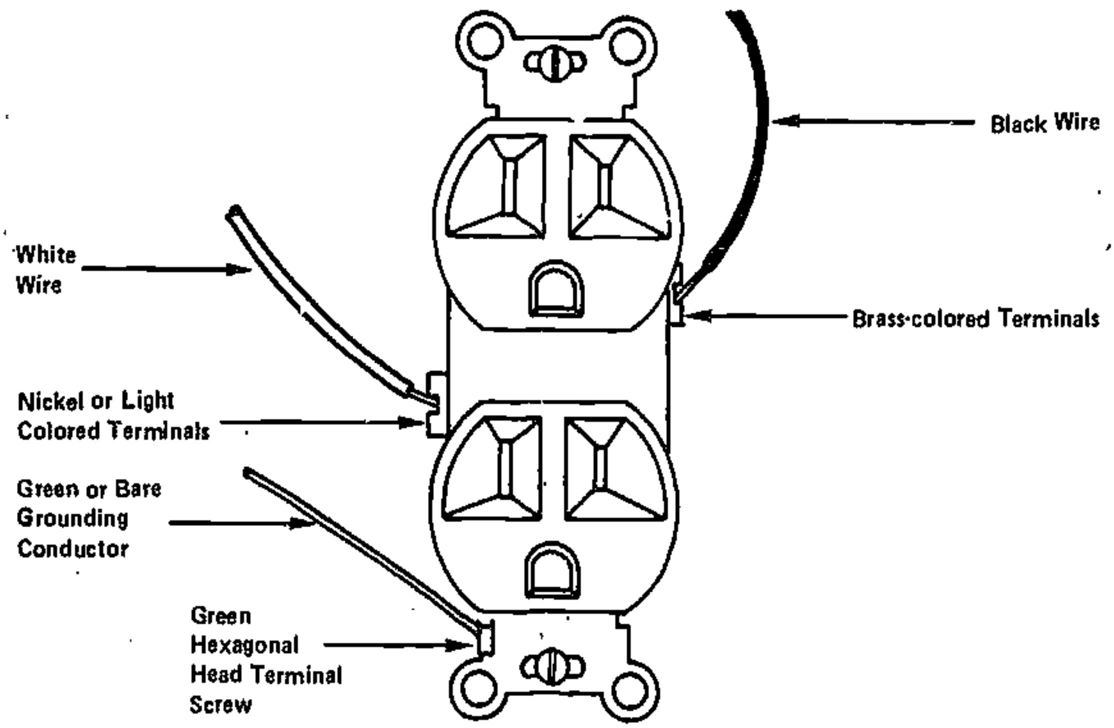


FIGURE 14. DUPLEX RECEPTACLE CORRECTLY WIRED TO DESIGNATED TERMINALS

DUPLEX RECEPTACLE CORRECTLY WIRED. TERMINALS ARE DESIGNATED AND IDENTIFIED TO AVOID CONFUSION. AN EASY WAY TO REMEMBER THE CORRECT POLARITY IS "WHITE TO LIGHT"—THE WHITE WIRE SHOULD BE CONNECTED TO THE LIGHT OR NICKEL COLORED TERMINAL; "BLACK TO BRASS"—THE BLACK OR MULTI-COLORED WIRE SHOULD BE CONNECTED TO THE BRASS TERMINAL; AND "GREEN TO GREEN," THE GREEN OR BARE WIRE SHOULD BE CONNECTED TO THE GREEN HEXAGONAL HEAD TERMINAL SCREW. OTHER METHODS USED TO IDENTIFY DEVICE TERMINALS ARE GIVEN IN NATIONAL ELECTRICAL CODE SECTION 200-10.

(b) Branch circuits.

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

(i) 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.

(ii) Assured equipment grounding conductor program. The employer shall establish and implement an assured equipment grounding conductor program on construction sites covering 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. 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 29 CFR 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 indication of possible internal damage. Equipment found damaged or defective may 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 may not make available or permit the use by employees of any equipment which has not met the requirements of this paragraph (b)(1)(ii) 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.

(2) Outlet devices. Outlet devices shall have an ampere rating not less than the load to be served.

•(c) Outside conductors, 600 volts, nominal, or less. Paragraphs (c)(1), (c)(2), (c)(3), and (c)(4) of this section apply to branch circuit, feeder, and service conductors rated 600 volts, nominal, or less and run outdoors as open conductors. Paragraph (c)(5) applies to lamps installed under such conductors.

• OPEN CONDUCTORS ARE WIRES THAT ARE RUN AS SEPARATE CONDUCTORS IN CONTRAST TO WIRES RUN THROUGH CONDUIT, CABLES, OR RACEWAYS. THEY CAN BE EITHER INSULATED, COVERED, OR BARE BUT WHEN RUN OUTDOORS THEY ARE USUALLY COVERED TO PROTECT AGAINST WEATHER OR PHYSICAL DAMAGE. OPEN CONDUCTORS MUST BE INSTALLED ON INSULATORS. FIGURE 15 SHOWS AN INSTALLATION ON A BUILDING WHERE INSULATORS ARE USED TO MAINTAIN SEPARATION FROM THE SURFACE OF THE BUILDING AND BETWEEN OPEN CONDUCTORS.

THE FOLLOWING FOUR PARAGRAPHS, (c)(1) CONDUCTORS ON POLES, (c)(2) CLEARANCE FROM GROUND, (c)(3) CLEARANCE FROM BUILDING OPENINGS, AND (c)(4) CLEARANCE OVER ROOFS, COVER SAFETY REQUIREMENTS REGARDING LOW VOLTAGE CIRCUITS RUN OUTDOORS AS OPEN CONDUCTORS.

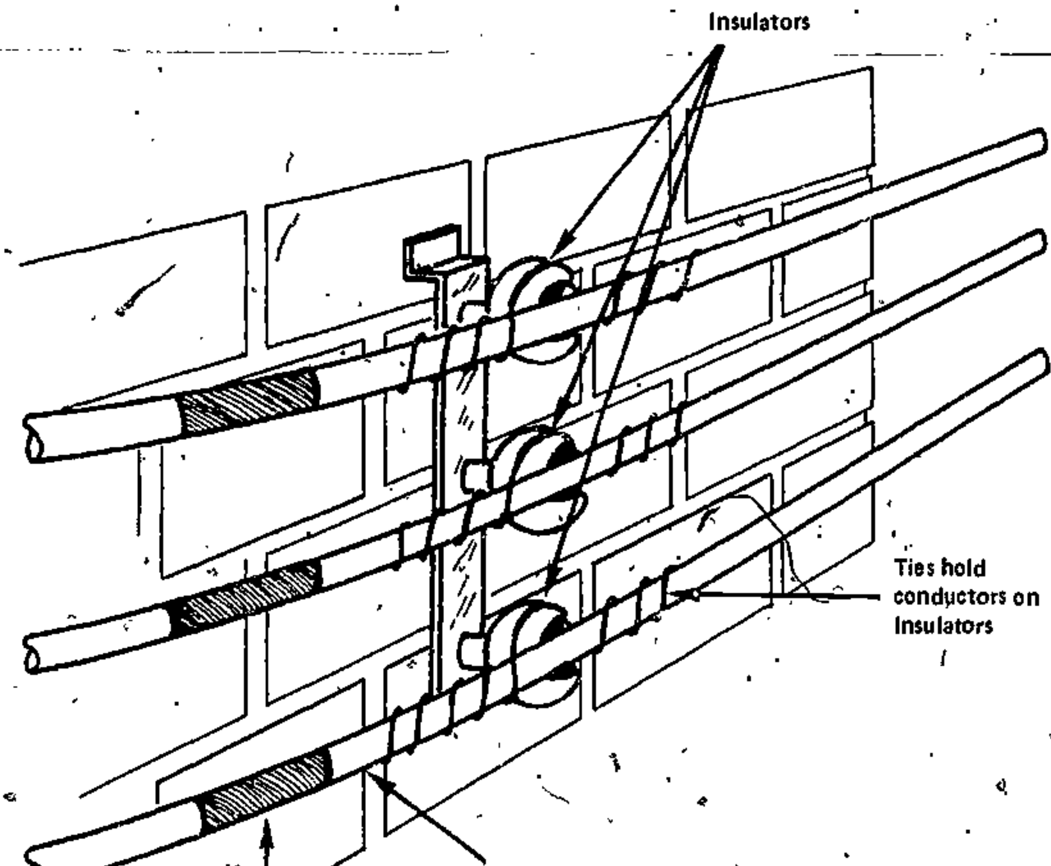


FIGURE 15. OPEN CONDUCTORS INSTALLED ON INSULATORS ON THE SURFACE OF A BUILDING

- (1) Conductors on poles. Conductors supported on poles shall provide a horizontal climbing space not less than the following:
  - (i) Power conductors below communication conductors—30 inches.
  - (ii) Power conductors alone or above communication conductors: 300 volts or less—24 inches; more than 300 volts—30 inches.
  - (iii) Communication conductors below power conductors: with power conductors 300 volts or less—24 inches; more than 300 volts—30 inches.

- CONDUCTORS ON UTILITY POLES PRESENT A SERIOUS ELECTRICAL SHOCK HAZARD TO WORKERS WHO ARE REQUIRED TO CLIMB THESE POLES. THESE CONDUCTORS MUST BE INSTALLED TO ALLOW A WORKER ENOUGH ROOM TO SAFELY CLIMB BETWEEN THEM WITHOUT MAKING ACCIDENTAL CONTACT WITH THE CONDUCTOR (SEE FIGURE 16). THE MINIMUM SAFE SPACE THAT IS ALLOWED VARIES WITH THE TYPE CONDUCTOR, THE ARRANGEMENT OF CONDUCTORS, AND THE VOLTAGE INVOLVED. TABLE 1 SHOWS THE SAFE CLIMBING SPACES BETWEEN CONDUCTORS AS DESCRIBED IN THE REGULATION.

TABLE 1
SAFE CLIMBING SPACES
BETWEEN LOW VOLTAGE CONDUCTORS
(600 VOLTS OR LESS)

ARRANGEMENT	MINIMUM SAFE CLIMBING SPACE MEASURED HORIZONTALLY	
	BETWEEN POWER CONDUCTORS	BETWEEN COMMUNICATION CONDUCTORS
POWER CONDUCTORS BELOW COMMUNICATION CONDUCTORS:		
600 VOLTS OR LESS	30 INCHES	NO REQUIREMENT
POWER CONDUCTORS ALONE:		
300 VOLTS OR LESS	24 INCHES	N/A
301-600 VOLTS	30 INCHES	N/A
POWER CONDUCTOR ABOVE COMMUNICATION CONDUCTORS:		
300 VOLTS OR LESS	24 INCHES	24 INCHES
301-600 VOLTS	30 INCHES	30 INCHES

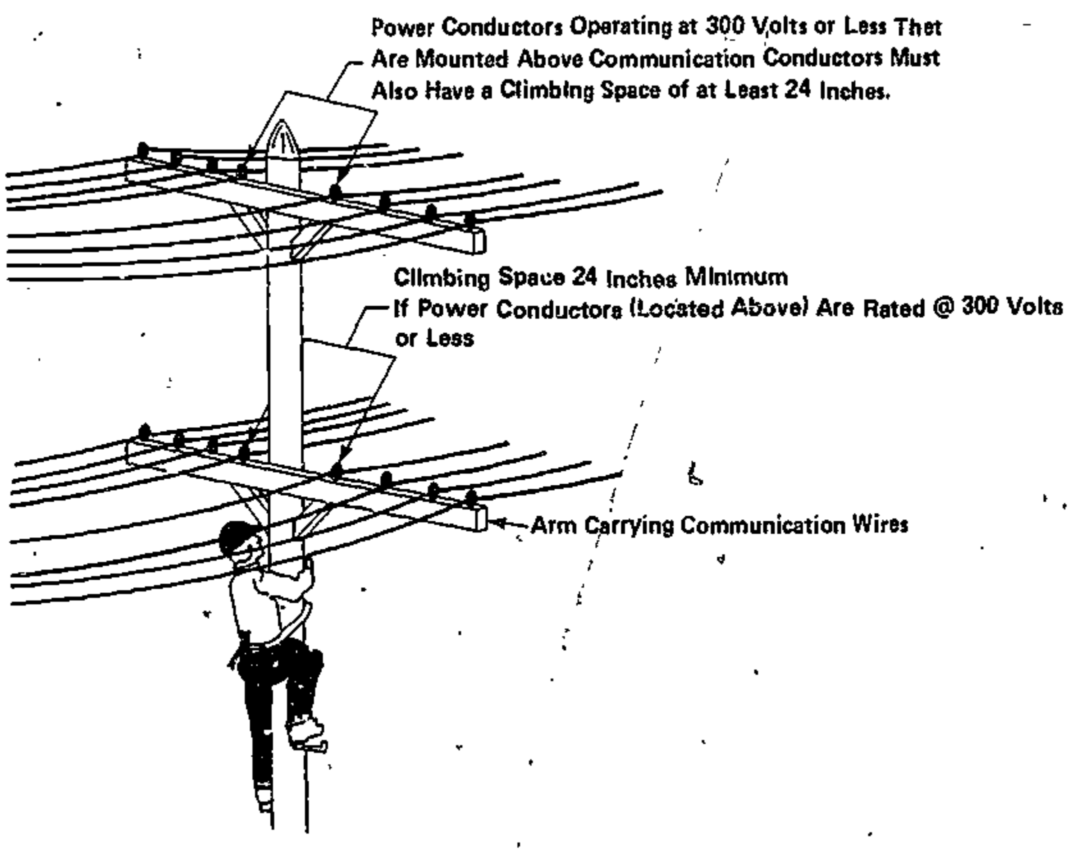


FIGURE 16. SAFE CLIMBING SPACES FOR POWER CONDUCTORS
LOCATED OVER COMMUNICATION CONDUCTORS

(2) Clearance from ground. Open conductors shall conform to the following minimum clearances:

(i) 10 feet--above finished grade, sidewalks, or from any platform or projection from which they might be reached.

(ii) 12 feet--over areas subject to vehicular traffic other than truck traffic.

(iii) 15 feet--over areas other than those specified in paragraph (c)(2)(iv) of this section that are subject to truck traffic.

(iv) 18 feet--over public streets, alleys, roads, and driveways.

(3) Clearance from building openings. Conductors shall have a clearance of at least 3 feet from windows, doors, porches, fire escapes, or similar locations. Conductors run above the top level of a window are considered to be out of reach from that window and, therefore, do not have to be 3 feet away.

• (4) Clearance over roofs. Conductors shall have a clearance of not less than 8 feet from the highest point of roofs over which they pass, except that

• OUTSIDE BRANCH CIRCUIT, FEEDER, AND SERVICE CONDUCTORS WHICH PASS OVER ROOFS, MUST BE AT LEAST 8 FEET ABOVE THE HIGHEST POINT OF THE ROOF (SEE FIGURE 17).

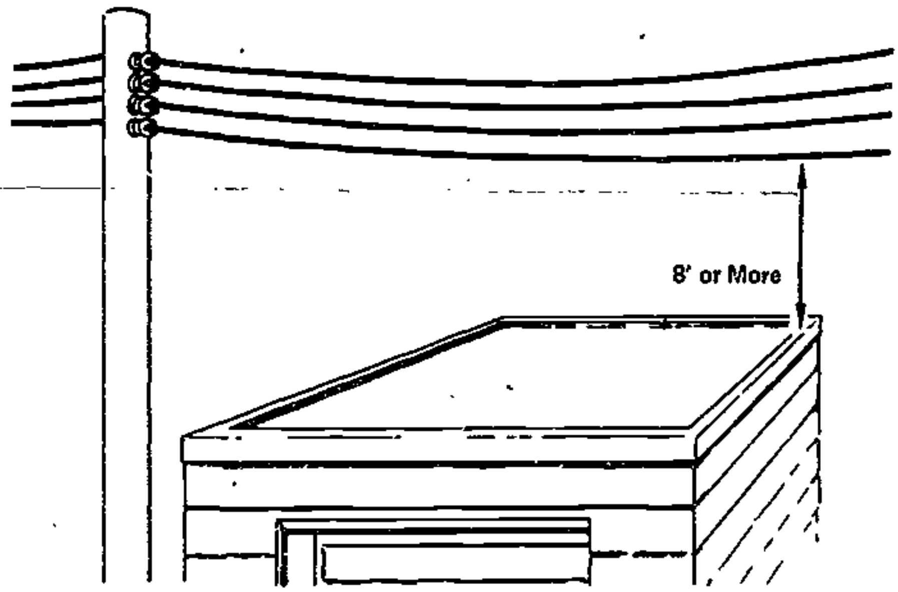


FIGURE 17. 8 FEET OR MORE ABOVE A FLAT ROOF

• (i) Where the voltage between conductors is 300 volts or less and the roof has a slope of not less than 4 inches in 12, the clearance from roofs shall be at least 3 feet, or

• IF THE VOLTAGE BETWEEN CONDUCTORS IS 300 VOLTS OR LESS AND IF THE INCLINE OF THE ROOF IS AT LEAST 4 VERTICAL INCHES FOR EVERY 12 HORIZONTAL INCHES, THESE OUTSIDE CONDUCTORS CAN COME NO CLOSER THAN 3 FEET OF THE

HIGHEST POINT OF THE ROOF (SEE FIGURE 18). EMPLOYEES ARE NOT LIKELY TO WALK ON ROOFS WHERE THE PITCH IS 4 INCHES IN 12 OR GREATER.

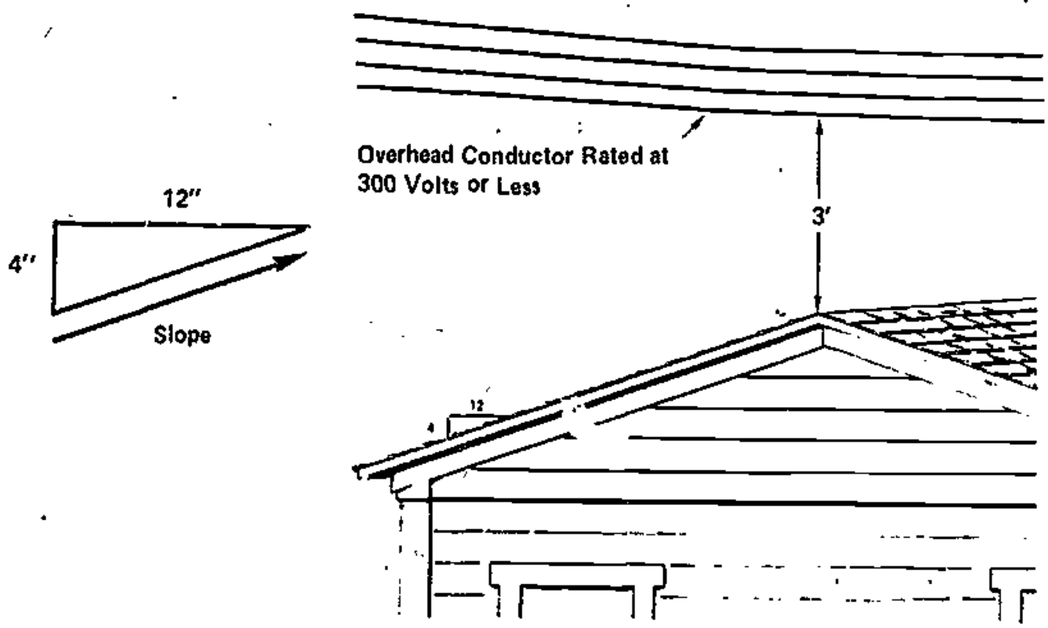


FIGURE 18. MINIMUM DISTANCE OF 3 FEET FROM SLOPING ROOF TO OVERHEAD WIRES

(ii) Where the voltage between conductors is 300 volts or less and the conductors do not pass over more than 4 feet of the overhang portion of the roof and they are terminated at a through-the-roof raceway or approved support, the clearance from roofs shall be at least 18 inches.

- FIGURE 19 SHOWS ACCEPTABLE INSTALLATION FOR SLOPING AND FLAT ROOFS.

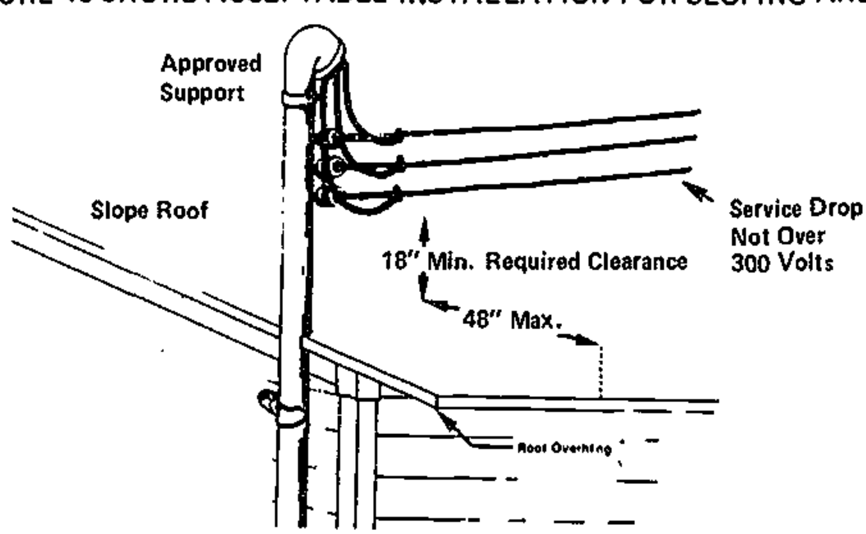


FIGURE 19. MINIMUM CLEARANCE FROM ROOF TO WIRES OVER ROOF OVERHANG

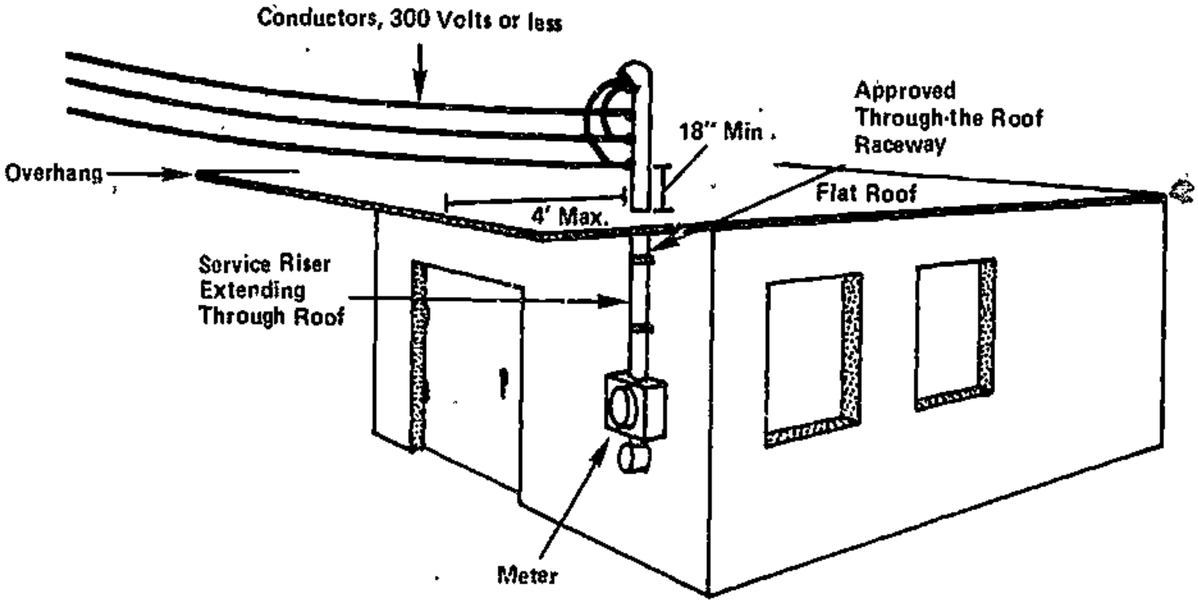


FIGURE 19. MINIMUM CLEARANCE FROM ROOF TO WIRES OVER ROOF OVERHANG (CONTINUED)

(5) Location of outdoor lamps. Lamps for outdoor lighting shall be located below all live conductors, transformers, or other electric equipment, unless such equipment is controlled by a disconnecting means that can be locked in the open position or unless adequate clearances or other safeguards are provided for relamping operations.

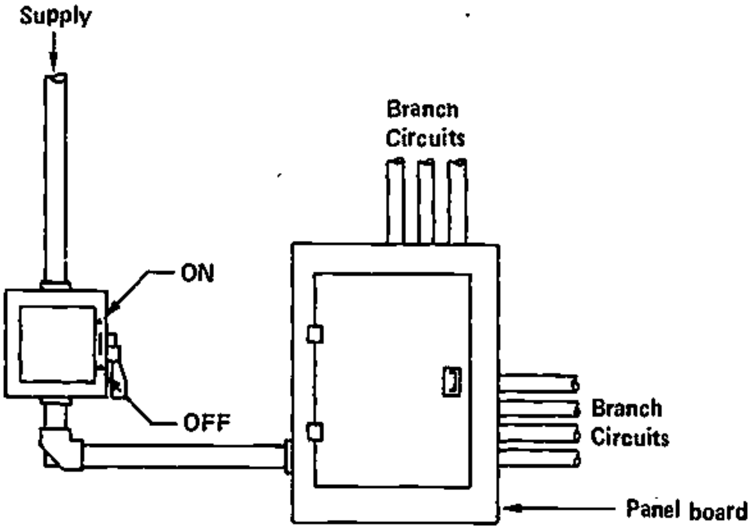
(d) Services.

(1) Disconnecting means.

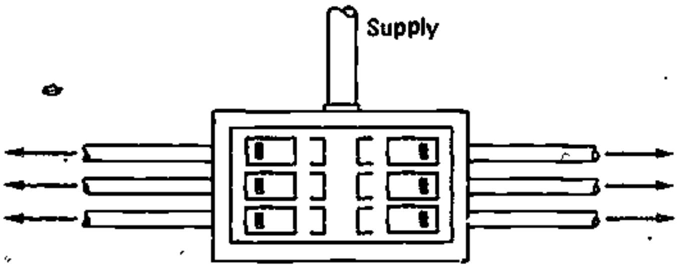
(i) General. Means shall be provided to disconnect all conductors in a building or other structure from the service-entrance conductors. The disconnecting means shall plainly indicate whether it is in the open or closed position and shall be installed at a readily accessible location nearest the point of entrance of the service-entrance conductors.

• A READILY ACCESSIBLE MEANS OF DISCONNECTING CONDUCTORS IS REQUIRED TO BE LOCATED AT A POINT NEAR THE SERVICE ENTRANCE. THE SERVICE ENTRANCE IS THE LOCATION WHERE THE SERVING CONDUCTORS ENTER A BUILDING. THE DISCONNECTING MEANS CAN BE A SWITCH OR CIRCUIT BREAKER, AND MUST BE CAPABLE OF INTERRUPTING THE CIRCUIT FROM THE SOURCE OF SUPPLY. THIS WILL DISCONNECT THE ELECTRICAL EQUIPMENT WITHIN THE BUILDING FROM ITS SOURCE OF SUPPLY IN THE EVENT OF AN EMERGENCY OR DURING NORMAL SERVICING OPERATIONS.

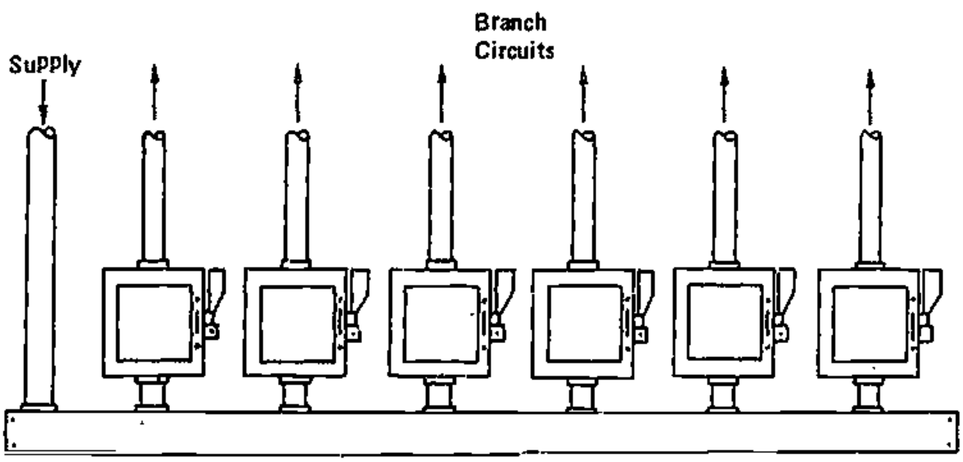
THREE ACCEPTABLE ARRANGEMENTS PERMITTED BY THE NATIONAL ELECTRICAL CODE FOR SERVICE-ENTRANCE DISCONNECTS ARE SHOWN IN FIGURE 20. THE FIRST IS A SINGLE DISCONNECT THAT OPENS ALL UNDERGROUNDED CONDUCTORS OF A



Single disconnect switch must open all ungrounded conductors simultaneously.



Up to six switches or circuit breakers that enable disconnecting with no more than six movements of the hand are permitted. See National Electrical Code Section 384-16(a) for lighting and appliance panelboards.



Up to six disconnects may be grouped in one location near the point where the service enters the building.

FIGURE 20. THREE ACCEPTABLE ARRANGEMENTS FOR SERVICE-ENTRANCE DISCONNECTING MEANS

FEEDER SIMULTANEOUSLY. THE SECOND IS A CIRCUIT BREAKER PANEL WITH UP TO SIX CIRCUIT BREAKERS THAT WILL DISCONNECT ALL UNGROUNDED CONDUCTORS TO A BUILDING WITH NO MORE THAN SIX MOVEMENTS OF THE HAND. THE THIRD IS A GROUP OF UP TO SIX INDIVIDUAL SWITCHES LOCATED NEAR WHERE THE SERVICE ENTERS THE BUILDING TO DISCONNECT ALL UNGROUNDED CONDUCTORS THAT SUPPLY A BUILDING. WHEN MORE THAN ONE SWITCH OR CIRCUIT BREAKER IS USED, EACH MUST SHOW WHETHER IT IS IN THE ON OR OFF POSITION AND MUST SIMULTANEOUSLY OPEN ALL UNGROUNDED CONDUCTORS OF THE CIRCUIT IT IS INTENDED TO OPEN.

(ii) Simultaneous opening of poles. Each service disconnecting means shall simultaneously disconnect all ungrounded conductors.

(2) Services over 600 volts, nominal. The following additional requirements apply to services over 600 volts, nominal.

(i) Guarding. Service-entrance conductors installed as open wires shall be guarded to make them accessible only to qualified persons.

(ii) Warning signs. Signs warning of high voltage shall be posted where other than qualified employees might come in contact with live parts.

(e) Overcurrent protection.

(1) 600 Volts, nominal, or less. The following requirements apply to overcurrent protection of circuits rated 600 volts, nominal, or less.

- (i) Protection of conductors and equipment. Conductors and equipment shall be protected from overcurrent in accordance with their ability to safely conduct current.

- ELECTRICAL CURRENT IS THE FLOW OF ELECTRONS THROUGH A CONDUCTOR. THE SIZE OF THE WIRE IS THE MAIN DETERMINING FACTOR AS TO HOW MUCH CURRENT CAN SAFELY FLOW THROUGH A CONDUCTOR. THE LARGER THE WIRE, THE MORE CURRENT CAN FLOW SAFELY. IF TOO MUCH CURRENT FLOWS THROUGH A CONDUCTOR, EXCESS HEAT IS PRODUCED. IF THE CIRCUIT IS NOT PROTECTED THE HEAT MAY CONTINUE TO BUILD AND REACH A TEMPERATURE HIGH ENOUGH TO DESTROY INSULATION AND CAUSE A FIRE.

CONDUCTORS AND EQUIPMENT ARE REQUIRED TO BE PROTECTED FROM OVERCURRENT CONDITIONS ACCORDING TO THEIR ABILITY TO SAFELY CONDUCT ELECTRIC CURRENT. CIRCUIT BREAKERS AND FUSES ARE PROTECTIVE DEVICES DESIGNED TO DISCONNECT A CIRCUIT FROM ITS SOURCE OF SUPPLY WHEN A MAXIMUM ALLOWABLE HEAT LEVEL IS REACHED. IN ADDITION, OVERCURRENT DEVICES MUST HAVE ADEQUATE INTERRUPTING RATINGS TO PREVENT HAZARDS TO EMPLOYEES DUE TO SHORT CIRCUIT CURRENTS. A FUSE FUNCTIONS TO DISCONNECT A CIRCUIT WHEN AN ELEMENT INSIDE THE FUSE BODY, A METAL RIBBON OR LINK, MELTS FROM THE HEAT PRODUCED WHEN TOO MUCH CURRENT PASSES THROUGH IT. WHEN THIS RIBBON MELTS THE CURRENT FLOW THROUGH THE CIRCUIT IS STOPPED (SEE FIGURE 21). A CIRCUIT BREAKER FUNCTIONS TO DISCONNECT A CIRCUIT WHEN

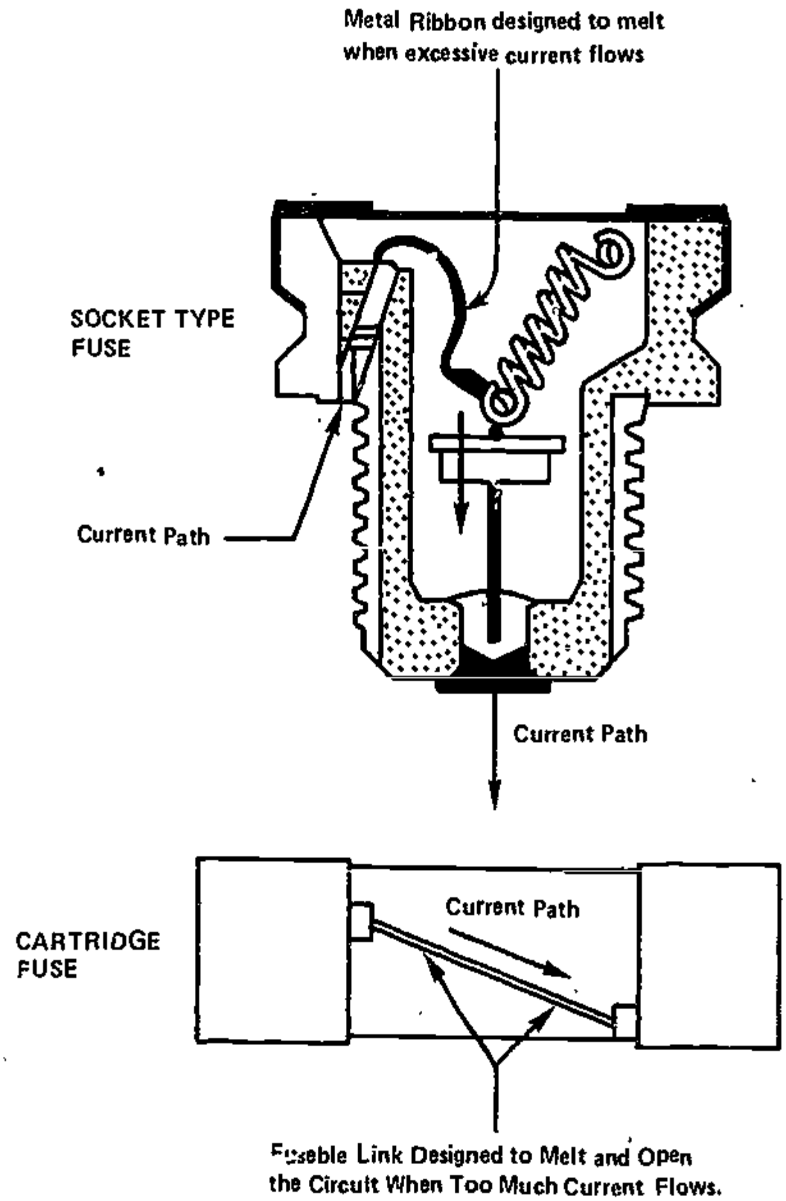


FIGURE 21. COMMON TYPES OF FUSES

EXCESSIVE CURRENT FLOWS. SOME BREAKERS SENSE OVERCURRENT BY MEANS OF A BI-METAL STRIP. WHEN EXCESSIVE CURRENT IS SENSED, THE BI-METAL STRIP MOVES AND RELEASES A SPRING-LOADED SWITCH THAT OPENS THE CIRCUIT, THUS STOPPING THE CURRENT FLOW. (SEE FIGURE 22). OTHER TYPES OF CIRCUIT BREAKERS USE DIFFERENT MEANS OF SENSING OVERCURRENT.

EITHER OF THESE METHODS OF CIRCUIT PROTECTION ARE ACCEPTABLE. CIRCUIT BREAKERS CAN BE RESET WHEN THE HANDLE IS MOVED FROM THE "TRIP" POSITION TO THE "OFF" POSITION AND THEN MOVED TO THE "ON" POSITION TO RESTORE CURRENT TO THE CIRCUIT. BY CONTRAST, FUSES MUST BE REPLACED, THUS REQUIRING

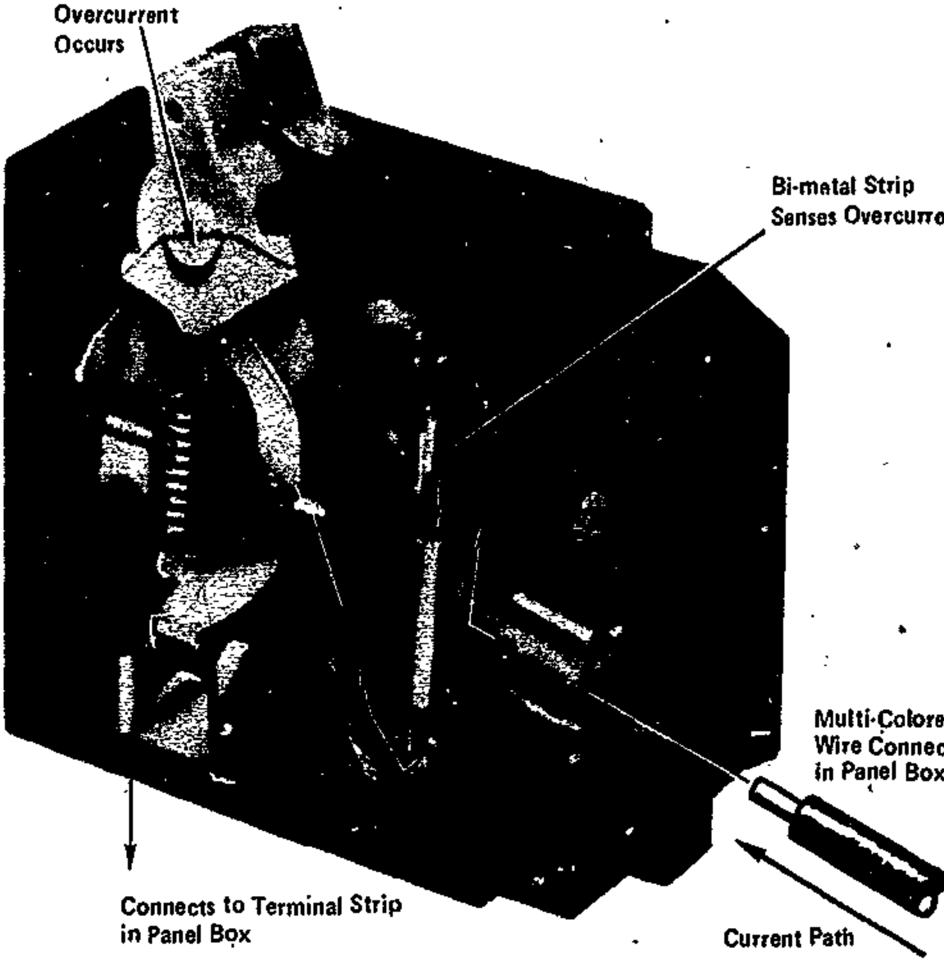


FIGURE 22. CUTAWAY VIEW OF A CIRCUIT BREAKER

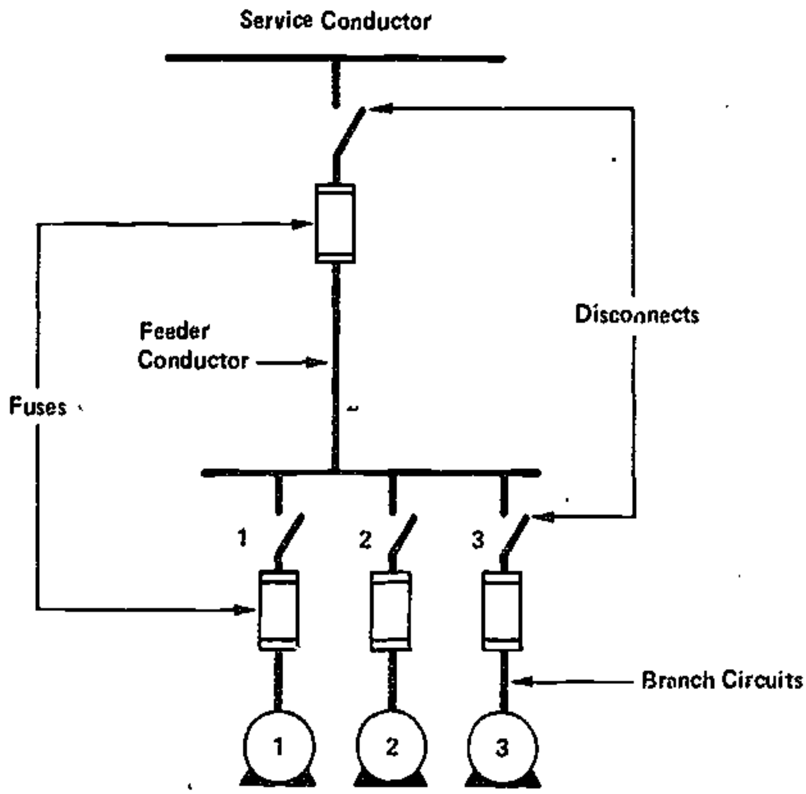
A SUPPLY OF REPLACEMENT FUSES TO BE ON HAND. IN CASES OF HIGH VOLTAGE (OVER 600 VOLTS), REPLACEMENT OF A FUSE MUST BE DONE ONLY BY QUALIFIED PERSONS.

THE NATIONAL ELECTRICAL CODE SPECIFIES THE ALLOWABLE CURRENT FLOW PERMITTED IN CERTAIN-SIZED CONDUCTORS. AMPACITY IS THE TERM USED TO DESCRIBE THE CURRENT-CARRYING CAPACITY OF A CONDUCTOR. THE SIZE OF THE CIRCUIT BREAKER OR FUSE REQUIRED TO PROVIDE PROTECTION IS DETERMINED BY THE AMPACITY OF THE CONDUCTOR IN THE CIRCUIT TO BE PROTECTED AND THE TYPE OF LOAD THAT IS ON THE CIRCUIT.

(ii) Grounded conductors. Except for motor running overload protection, overcurrent devices may not interrupt the continuity of the grounded conductor unless all conductors of the circuit are opened simultaneously.

- (iii) Disconnection of fuses and thermal cutouts. Except for service fuses, all cartridge fuses which are accessible to other than qualified persons and all fuses and thermal cutouts on circuits over 150 volts to ground shall be provided with disconnecting means. This disconnecting means shall be installed so that the fuse or thermal cutout can be disconnected from its supply without disrupting service to equipment and circuits unrelated to those protected by the overcurrent device.

- ALL CARTRIDGE-TYPE CIRCUIT FUSES THAT ARE ACCESSIBLE TO UNQUALIFIED EMPLOYEES MUST BE EQUIPPED WITH A DISCONNECTING MEANS TO ALLOW THE FUSE TO BE SERVICED SAFELY. IN ADDITION, WHERE CARTRIDGE-TYPE FUSES ARE LOCATED IN SYSTEMS THAT OPERATE OVER 150 VOLTS TO GROUND, A DISCONNECTING MEANS IS ALWAYS REQUIRED REGARDLESS OF THE QUALIFICATIONS OF THE PERSONS HAVING ACCESS TO THE FUSES. THE DISCONNECT SWITCHES MUST BE INSTALLED SO THAT ONLY THE CIRCUITS THAT ARE PROTECTED BY OR OTHERWISE RELATED TO THE OVERCURRENT DEVICE WILL BE SHUT OFF. IN THIS WAY POWER TO OTHER CIRCUITS AND EQUIPMENT IN A SYSTEM WILL NOT BE UNNECESSARILY DISRUPTED WHEN ONE OVERCURRENT DEVICE IN THE SYSTEM MUST BE SERVICED OR REPLACED (SEE FIGURE 23). THESE PROVISIONS DO NOT APPLY TO SERVICE FUSES.



IF PROCESS MOTOR NO. 3 DEVELOPED AN OVERCURRENT CONDITION AND BLEW A FUSE, THEN DISCONNECT NO. 3 WOULD BE THE ONLY SWITCH ACTUATED TO SERVICE THE FUSE

FIGURE 23. DISCONNECTS FOR OVERCURRENT DEVICES.

(iv) Location in or on premises. Overcurrent devices shall be readily accessible to each employee or authorized building management personnel. These overcurrent devices may not be located where they will be exposed to physical damage nor in the vicinity of easily ignitible material.

(v) Arcing or suddenly moving parts. Fuses and circuit breakers shall be so located or shielded that employees will not be burned or otherwise injured by their operation.

(vi) Circuit breakers.

(a) Circuit breakers shall clearly indicate whether they are in the open (off) or closed (on) position.

(b) Where circuit breaker handles on switchboards are operated vertically rather than horizontally or rotationally, the up position of the handle shall be the closed (on) position. (See §1910.302(b)(3).)

(c) If used as switches in 120-volt, fluorescent lighting circuits, circuit breakers shall be approved for the purpose and marked "SWD." (See §1910.302(b)(3).)

(2) Over 600 volts, nominal. Feeders and branch circuits over 600 volts, nominal, shall have short-circuit protection.

• (f) Grounding. Paragraphs (f)(1) through (f)(7) of this section contain grounding requirements for systems, circuits, and equipment.

• GROUNDING ELECTRICAL CIRCUITS AND ELECTRICAL EQUIPMENT IS REQUIRED TO PROTECT EMPLOYEES AGAINST ELECTRICAL SHOCK, SAFEGUARD AGAINST FIRE, AND PROTECT AGAINST DAMAGE TO ELECTRICAL EQUIPMENT. THERE ARE TWO KINDS OF GROUNDING. FIRST, ELECTRICAL CIRCUIT OR SYSTEM GROUNDING, AND SECOND, ELECTRICAL EQUIPMENT GROUNDING. ELECTRICAL SYSTEM GROUNDING IS ACCOMPLISHED WHEN ONE CONDUCTOR OF THE CIRCUIT IS INTENTIONALLY CONNECTED TO EARTH. THIS IS DONE TO PROTECT THE CIRCUIT SHOULD LIGHTNING STRIKE OR OTHER HIGH VOLTAGE CONTACT OCCUR. GROUNDING A SYSTEM ALSO STABILIZES THE VOLTAGE IN THE SYSTEM SO "EXPECTED VOLTAGE LEVELS" ARE NOT EXCEEDED UNDER NORMAL CONDITIONS. THE SECOND KIND OF GROUND IS EQUIPMENT GROUNDING. THIS IS ACCOMPLISHED WHEN ALL METAL FRAMES OF EQUIPMENT AND ENCLOSURES CONTAINING ELECTRICAL EQUIPMENT OR CONDUCTORS ARE GROUNDED BY MEANS OF A PERMANENT AND CONTINUOUS CONNECTION OR BOND. THE EQUIPMENT GROUNDING CONDUCTOR PROVIDES A PATH FOR DANGEROUS FAULT CURRENT TO RETURN TO THE SYSTEM GROUND AT THE SUPPLY SOURCE OF THE CIRCUIT SHOULD AN INSULATION FAILURE TAKE PLACE. IF INSTALLED PROPERLY, THE EQUIPMENT GROUNDING CONDUCTOR IS THE CURRENT PATH THAT ENABLES PROTECTIVE DEVICES, SUCH AS CIRCUIT BREAKERS AND FUSES, TO OPERATE WHEN A FAULT OCCURS. FIGURE 24 ILLUSTRATES BOTH TYPES OF GROUNDING.

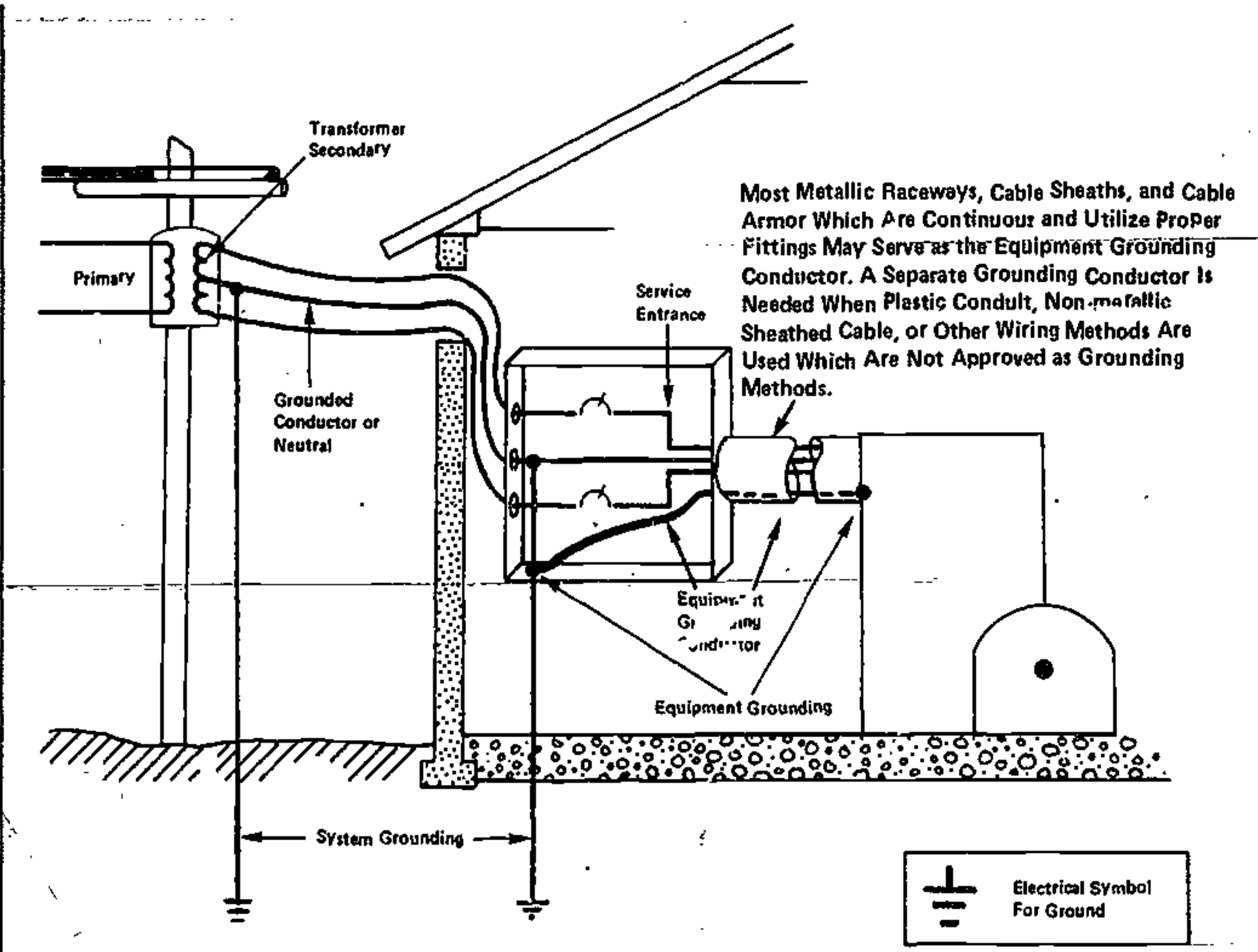


FIGURE 24. SYSTEM AND EQUIPMENT GROUNDING

(1) Systems to be grounded. The following systems which supply premises wiring shall be grounded:

- (i) All 3-wire DC systems shall have their neutral conductor grounded.

• A 3-WIRE DC SYSTEM IS GENERALLY USED IN HEAVY INDUSTRIAL APPLICATIONS TO PROVIDE FOR SMOOTH STARTING OF MOTORS AND SPEED CONTROL. THREE-WIRE DC MOTORS ARE COMMONLY USED TO OPERATE LARGE MILLS AND EXTRUSION MACHINES. WITH A 3-WIRE CIRCUIT, THEY CAN RUN AT HALF SPEED OR AT FULL SPEED, DEPENDING ON THE VOLTAGE SELECTED. A 250 VOLT DC 3-WIRE SYSTEM, FOR EXAMPLE, CAN SUPPLY BOTH 125 VOLTS DC AND 250 VOLTS DC TO A MOTOR. FIGURE 25 ILLUSTRATES A SCHEMATIC DIAGRAM OF A 3-WIRE DC SYSTEM THAT RUNS THREE MOTORS, TWO SINGLE SPEED MOTORS (ONE AT 125 VOLTS DC, THE OTHER AT 250 VOLTS DC) AND A MOTOR WITH TWO SPEED RANGES (A LOW SPEED AT 125 VOLTS DC,

ANO HIGH SPEEO AT 250 VOLTS DC). THE NEUTRAL CONDUCTOR IS THE CONDUCTOR WHICH REQUIRES A GROUNO CONNECTION TO EARTH. THIS CONNECTION MUST BE MADE AT A POINT NEAR THE DC SOURCE OF SUPPLY.

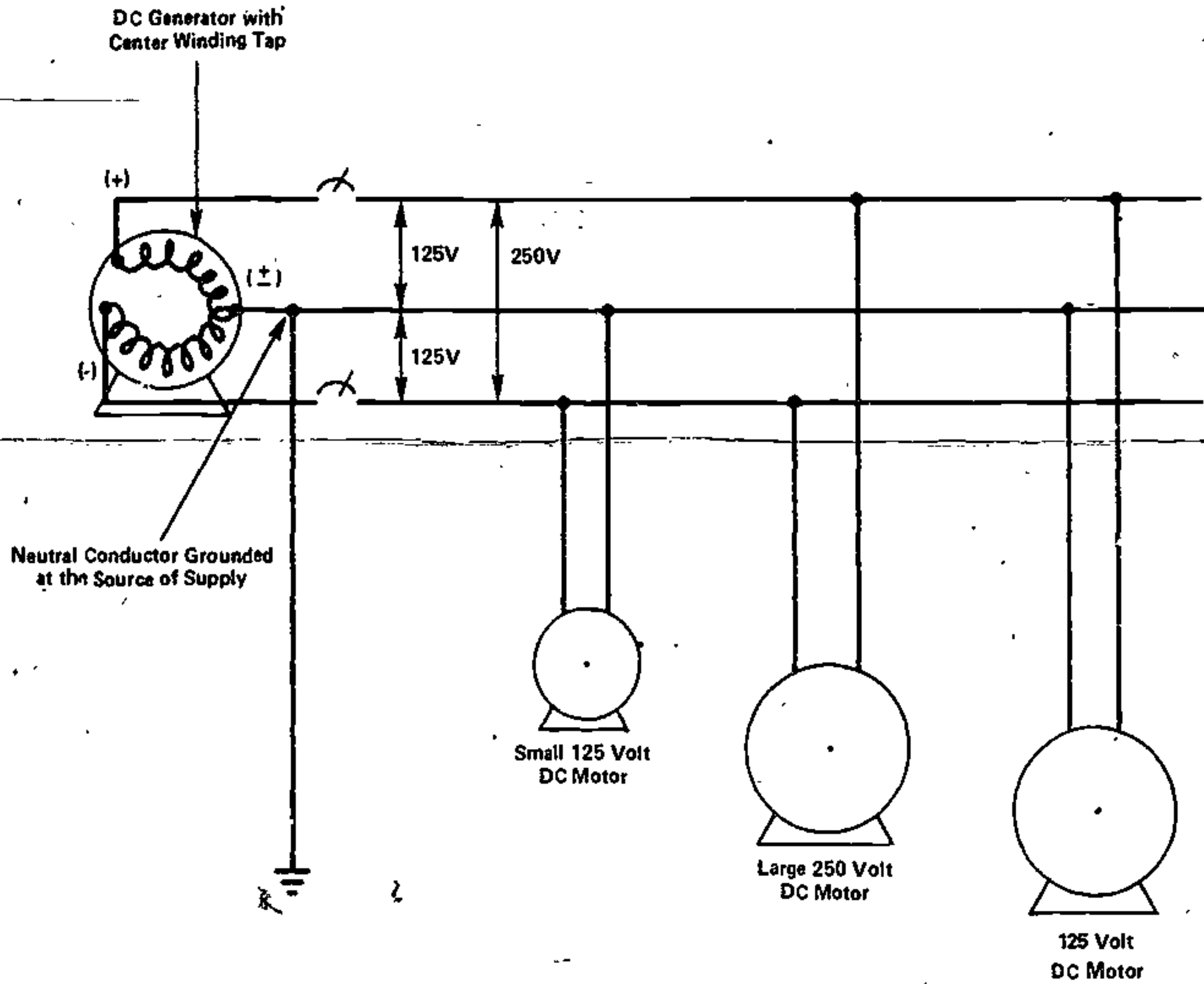


FIGURE 25. 250-VOLT THREE WIRE-OC SYSTEM. THE NEUTRAL CONOUCTOR IS GROUNDEO AT THE SOURCE

- (ii) Two-wire DC systems operating at over 50 volts through 300 volts between conductors shall be grounded unless:
  - (a) They supply only industrial equipment in limited areas and are equipped with a ground detector; or
  - (b) They are rectifier-derived from an AC system complying with paragraphs (f)(1)(iii), (f)(1)(iv), and (f)(1)(v) of this section; or
  - (c) They are fire-protective signaling circuits having a maximum current of 0.030 amperes.

- 2-WIRE DC SYSTEMS THAT OPERATE BETWEEN 50 VOLTS AND 300 VOLTS AND SERVICE PREMISES MUST BE GROUNDED. COMMON 2-WIRE DC SYSTEMS INCLUDE BATTERY CHARGING, ELECTROPLATING, AND SOME CRANE OPERATIONS. GROUNDING IS ACCOMPLISHED BY MAKING AN ELECTRICAL CONNECTION TO GROUND AT THE SOURCE AS SHOWN IN FIGURE 26.

THERE ARE THREE EXCEPTIONS TO THIS REQUIREMENT. FIRST, IF A DC SYSTEM POWERS ONLY INDUSTRIAL EQUIPMENT IN A LIMITED AREA AND IS EQUIPPED WITH A SENSOR TO DETECT ANY CURRENT LEAKS TO GROUND, THEN NO GROUNDING IS REQUIRED. IN SUCH CASES A GROUND FAULT, RESULTING FROM AN INSULATION FAILURE, CAN BE EASILY DETECTED, LOCATED, AND CORRECTED BEFORE SOMEONE IS INJURED. SECOND, IF A DC SYSTEM IS DERIVED FROM A RECTIFIER, THAT IS AN AC TO DC CONVERTER, AND THE AC SYSTEM COMPLIES WITH PARAGRAPHS (f)(1)(iii), (f)(1)(iv), AND (f)(1)(v), THEN NO GROUNDING IS REQUIRED IN THE DC SYSTEM. RECTIFIERS ALSO SERVICE LIMITED AREAS; WHEN THE AC SYSTEM WHICH SUPPLIES THE RECTIFIER IS PROPERLY GROUNDED, A GROUND FAULT CAN BE EASILY LOCATED AND CORRECTED. THESE SYSTEMS MUST BE PROPERLY MAINTAINED TO ASSURE THAT GROUND FAULTS DO NOT OCCUR. THIRD, FIRE PROTECTIVE SIGNALING CIRCUITS THAT OPERATE UNDER 30 MILLIAMPS DO NOT REQUIRE GROUNDING BECAUSE OF THE LOW CURRENT FLOW. THIS LOW CURRENT FLOW MEANS THAT NO SERIOUS SHOCK HAZARD EXISTS. FIGURE 26 ILLUSTRATES A DC POWERED ELECTROPLATING OPERATION WITH THE GROUNDING CONNECTION AT THE SOURCE.

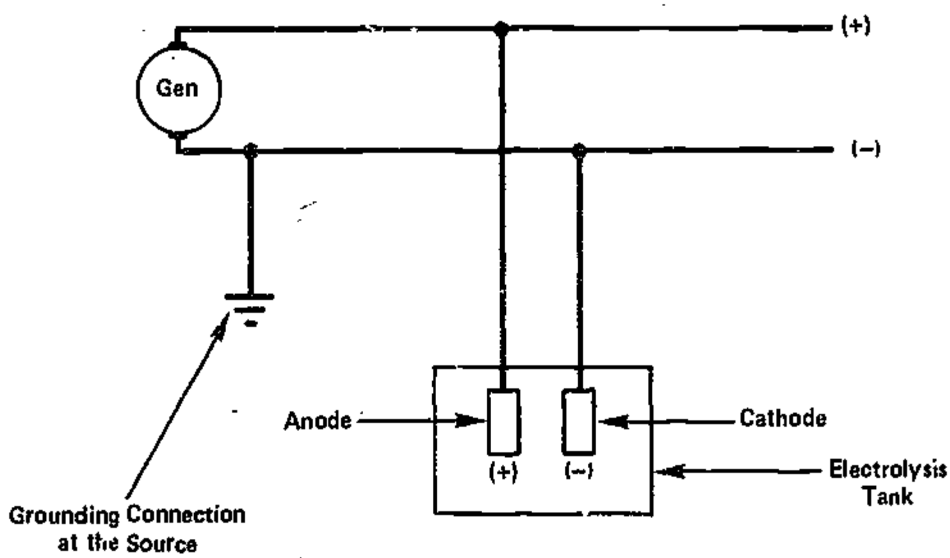


FIGURE 26. GROUNDED 2-WIRE DC SYSTEM SUPPLYING AN ELECTROPLATING OPERATION

- (iii) AC circuits of less than 50 volts shall be grounded if they are installed as overhead conductors outside of buildings or if they are supplied by transformers and the transformer primary supply system is ungrounded or exceeds 150 volts to ground.

• ONLY UNDER CERTAIN CONDITIONS ARE LOW VOLTAGE AC SYSTEMS REQUIRED TO BE GROUNDED. THESE ARE CONDITIONS WHERE THERE IS A LIKELIHOOD OF FOREIGN HIGHER VOLTAGE – SUCH AS LIGHTNING OR HIGHER PRIMARY VOLTAGES BEING CONDUCTED ACROSS DAMAGED TRANSFORMER WINDINGS CREATING A SERIOUS SHOCK HAZARD TO SOMEONE WORKING WITH THE LOW VOLTAGE SYSTEM. IN EACH CASE, GROUNDING IS REQUIRED AT THE SECONDARY SIDE OF THE LOW VOLTAGE TRANSFORMER.

THE FIRST CONDITION REQUIRES GROUNDING WHEN THE CONDUCTORS ARE RUN AS OVERHEAD CONDUCTORS OUTDOORS. IN THIS CASE, THE LOW VOLTAGE SYSTEM MUST BE PROTECTED AGAINST HIGH VOLTAGE SURGES RESULTING FROM LIGHTNING STRIKES AND AGAINST CONTACT WITH HIGH VOLTAGE OVERHEAD LINES. THE SECOND CONDITION REQUIRES GROUNDING WHEN LOW VOLTAGE SYSTEMS ARE SUPPLIED BY TRANSFORMERS THAT ARE SUPPLIED BY AN UNGROUNDED PRIMARY SYSTEM OF ANY VOLTAGE OR WHEN THE PRIMARY VOLTAGE TO GROUND EXCEEDS 150 VOLTS. FIGURE 27 ILLUSTRATES EXAMPLES OF CIRCUITS OPERATING AT LESS THAN 50 VOLTS THAT ARE REQUIRED TO BE GROUNDED BY THE SECOND CONDITION. GROUNDING OF THE LOW VOLTAGE SYSTEM ON THE SECONDARY SIDE OF THE TRANSFORMER WILL PREVENT ENERGIZING OF THE SECONDARY CIRCUIT WITH THE HIGHER PRIMARY VOLTAGES SHOULD THE TRANSFORMER WINDINGS BE DAMAGED.

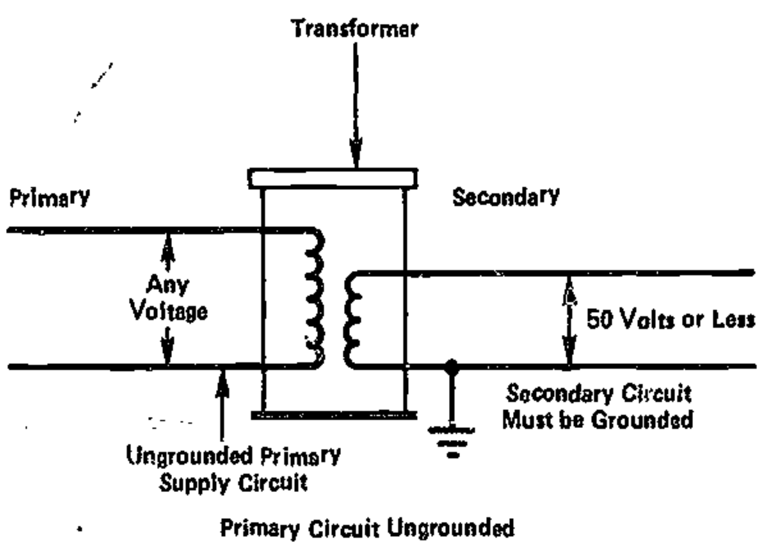


FIGURE 27. AC CIRCUITS UNDER 50 VOLTS REQUIRING GROUNDING

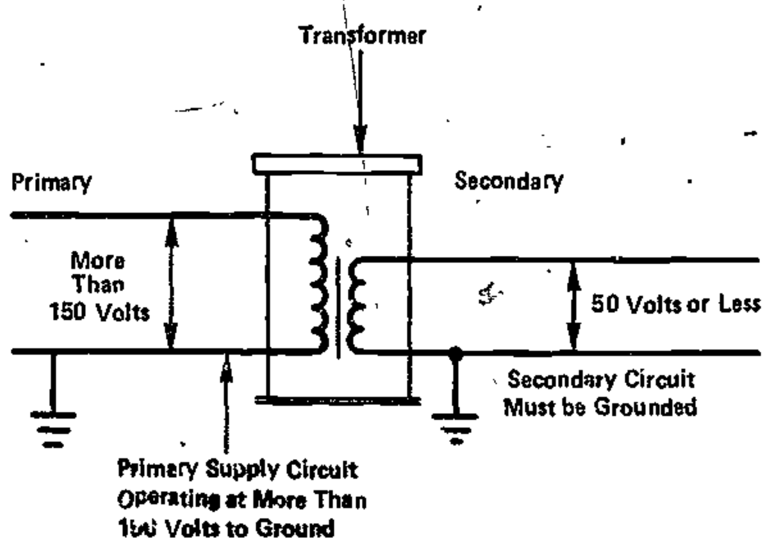


FIGURE 27. AC CIRCUITS UNDER 50 VOLTS REQUIRING GROUNDING (CONTINUED)

- (iv) AC systems of 50 volts to 1000 volts shall be grounded under any of the following conditions, unless exempted by paragraph (f)(1)(v) of this section:
  - (a) If the system can be so grounded that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts;
  - (b) If the system is nominally rated 480Y/277 volt, 3-phase, 4wire in which the neutral is used as a circuit conductor;
  - (c) If the system is nominally rated 240/120 volt, 3-phase, 4-wire in which the midpoint of one phase is used as a circuit conductor; or
  - (d) If a service conductor is uninsulated.

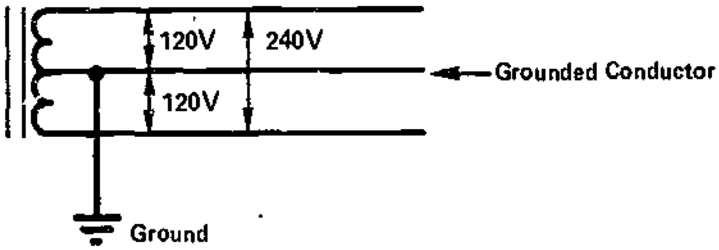
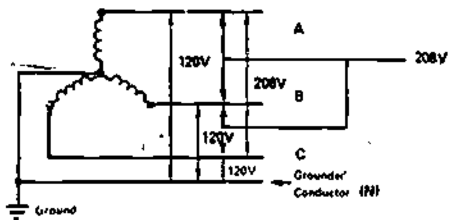
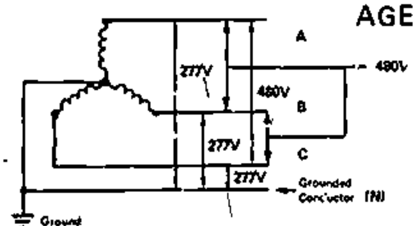
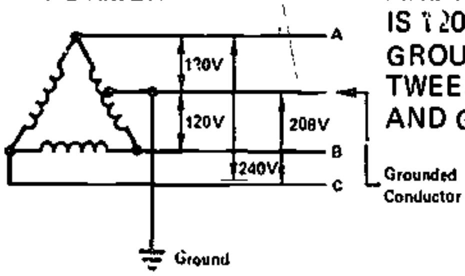
- THE MOST COMMON AC SYSTEMS IN USE IN INDUSTRY INCLUDE SEVERAL SINGLE AND THREE-PHASE SYSTEMS. GROUNDING OF THESE SYSTEMS IS REQUIRED TO PROVIDE FOR THE PROMPT OPERATION OF OVER-CURRENT DEVICES, TO ALLOW FOR THE QUICK ISOLATION OF FAULTS, TO PROVIDE FOR POSITIVE LIGHTNING PROTECTION, AND TO AFFORD PROTECTION FOR THE EQUIPMENT AND FOR PERSONNEL. TABLE 2 SUMMARIZES THE REQUIREMENTS FOR THE FOLLOWING SYSTEMS:

  (1) 240/120 VOLT SINGLE PHASE 3-WIRE SYSTEMS USED MOST OFTEN FOR GENERAL LIGHT AND POWER CIRCUITS;

  (2) 208Y/120 VOLT, 3-PHASE, 4-WIRE SYSTEM USED TO POWER INDUSTRIAL EQUIPMENT, LIGHTING, AND RECEPTACLES.

  (3) 480Y/277 VOLT, 3-PHASE, 4-WIRE SYSTEM WHICH IS USED IN HEAVY DUTY INDUSTRIAL AND OTHER APPLICATIONS; AND

TABLE 2 AC SYSTEMS 50 TO 1,000 VOLTS REQUIRING GROUNDING

SYSTEM SCHEMATIC	DESCRIPTION	COMMON USES
SINGLE PHASE TRANSORMER 	VOLTAGE BETWEEN UNGROUNDED CONDUCTORS IS 240 VOLTS VOLTAGE TO GROUND IS 120 VOLTS	GENERAL LIGHT AND POWER SYSTEMS. MEETS CONDITION (a)
1) 120/240 VOLT, SINGLE PHASE 3 WIRE SYSTEM		
WYE(Y) CONNECTED TRANSFORMER 	VOLTAGE BETWEEN UNGROUNDED CONDUCTORS IS 208 VOLTS; VOLTAGE TO GROUND IS 120 VOLTS	GENERAL LIGHTING, RECEPTACLES, SMALL MACHINES. MEETS CONDITION (a)
2) 208Y/120 VOLT, THREE PHASE, 4 WIRE SYSTEM		
WYE(Y) CONNECTED TRANSFORMER 	VOLTAGE BETWEEN UNGROUNDED CONDUCTORS IS 480 VOLTS; VOLTAGE TO GROUND IS 277 VOLTS	GENERAL LIGHTING AND HEAVY INDUSTRIAL APPLICATIONS. MEETS CONDITION (b)
3) 480Y/277 VOLT, THREE PHASE, 4 WIRE SYSTEM		
DELTA (Δ) CONNECTED TRANSFORMER 	VOLTAGE BETWEEN PHASE CONDUCTORS IS 240 VOLTS (A&B, B&C, AND A&C); VOLTAGE TO GROUND IS 120 VOLTS (BETWEEN A, B & GROUND) AND 208 VOLTS (BETWEEN PHASE CONDUCTOR C AND GROUND)	OLDER INDUSTRIAL APPLICATIONS SERVING MOSTLY 3-PHASE MOTORS. A CONDUCTOR IS CONNECTED TO THE MID-POINT OF ONE PHASE WINDING TO OBTAIN 120 VOLTS FOR GENERAL USE. MEETS CONDITION (c)
4) 240Δ/120 VOLT, 3 PHASE, 4 WIRE SYSTEM		

(4) 240/120 VOLT, 3-PHASE, 4-WIRE DELTA CONNECTED SYSTEM.

EACH OF THESE SYSTEMS MUST BE GROUNDED. THE 240/120 VOLT SYSTEM AND THE 208Y/120 VOLT SYSTEM ARE REQUIRED TO BE GROUNDED BECAUSE THEY ARE COVERED BY CONDITION (a). ITS VOLTAGE TO GROUND IS LESS THAN 150 VOLTS. THE 408Y/277 VOLT SYSTEM IS REQUIRED TO BE GROUNDED BECAUSE IT IS SPECIFICALLY MENTIONED IN CONDITION (b). THE 3-PHASE, 4-WIRE DELTA CONNECTED SYSTEM IS NOT AS COMMON AS THE OTHER SYSTEMS DESCRIBED BUT GROUNDING IS REQUIRED AS MENTIONED IN CONDITION (c). IN THIS SYSTEM THERE IS NO NEUTRAL CONDUCTOR AND THE CONDUCTOR THAT MUST BE GROUNDED IS THE CIRCUIT CONDUCTOR CONNECTED AT THE MID-POINT OF ONE OF THE PHASE WINDINGS IN THE TRANSFORMER.

IF THE SERVICE CONDUCTORS THAT PROVIDE POWER TO A BUILDING ARE LOCATED OVERHEAD AND ARE UNINSULATED, THE SYSTEM MUST BE GROUNDED. IN THIS CASE, GROUNDING IS REQUIRED TO PROTECT FROM FOREIGN HIGHER VOLTAGE CONDITIONS RESULTING FROM LIGHTNING OR ACCIDENTAL CONTACT WITH HIGHER VOLTAGE WIRES.

• (v) AC systems of 50 volts to 1000 volts are not required to be grounded under any of the following conditions:

(a) If the system is used exclusively to supply industrial electric furnaces for melting, refining, tempering, and the like.

(b) If the system is separately derived and is used exclusively for rectifiers supplying only adjustable speed industrial drives.

(c) If the system is separately derived and is supplied by a transformer that has a primary voltage rating less than 1000 volts, provided all of the following conditions are met:

(1) The system is used exclusively for control circuits,

(2) The conditions of maintenance and supervision assure that only qualified persons will service the installation,

(3) Continuity of control power is required, and

(4) Ground detectors are installed on the control system.

(d) If the system is an isolated power system that supplies circuits in health care facilities.

• UNDER CERTAIN CONDITIONS AC SYSTEMS THAT OPERATE BETWEEN 50 AND 1,000 VOLTS DO NOT REQUIRE GROUNDING. GROUNDING IS NOT REQUIRED BECAUSE THEY SERVE LIMITED AREAS OR ARE EASILY MONITORED FOR GROUND FAULTS. THEY ARE CLOSELY SUPERVISED AND ARE REQUIRED TO BE PROPERLY MAINTAINED. SHOULD A GROUND FAULT OCCUR IT CAN BE DETECTED RIGHT AWAY AND CORRECTED BEFORE A SECOND GROUND FAULT OCCURS THAT MAY INJURE AN EMPLOYEE.

• (2) Conductors to be grounded. For AC premises wiring systems the identified conductor shall be grounded.

• IN AC PREMISES WIRING (I.E., USED IN SERVICING BUILDINGS, PLANTS, AND OFFICES), IT IS REQUIRED THAT THE IDENTIFIED CIRCUIT CONDUCTOR (NEUTRAL) BE THE CONDUCTOR THAT IS GROUNDED ON SYSTEMS THAT ARE REQUIRED TO BE GROUNDED.

(3) Grounding connections.

• (i) For a grounded system, a grounding electrode conductor shall be used to connect both the equipment grounding conductor and the grounded circuit conductor to the grounding electrode. Both the equipment grounding conductor and the grounding electrode conductor shall be connected to the grounded circuit conductor on the supply side of the service disconnecting means, or on the supply side of the system disconnecting means or overcurrent devices if the system is separately derived.

• THE ELECTRICAL CONNECTION TO GROUND FOR SYSTEMS THAT REQUIRE GROUNDING, AS DISCUSSED IN PARAGRAPH (f)(1), MUST BE MADE AT THE SOURCE OF ELECTRICAL SUPPLY. FOR SYSTEMS SUPPLYING BUILDINGS, OFFICES, PLANTS, AND OTHER PREMISES, THE SOURCE IS AT THE SERVICE ENTRANCE. THE CONNECTION TO GROUND MUST BE MADE AT THE SUPPLY SIDE OF THE SERVICE DISCONNECTING MEANS. THE NATIONAL ELECTRICAL CODE PERMITS THIS CONNECTION TO BE MADE INSIDE THE SERVICE ENTRANCE EQUIPMENT THAT CONTAINS THE SERVICE DISCONNECTING MEANS, AS SHOWN IN FIGURE 28. TYPICALLY, A SYSTEM BONDING JUMPER (A) IS USED TO CONNECT THE GROUNDED CIRCUIT CONDUCTOR (B) (USUALLY THE NEUTRAL – THE WHITE WIRE) TO THE EQUIPMENT GROUNDING CONDUCTOR (C) (WHICH IS THE GREEN OR BARE WIRE AND CAN ALSO BE THE METAL EQUIPMENT ENCLOSURE). A GROUNDING ELECTRODE CONDUCTOR (D) IS USED TO MAKE THE CONNECTION TO THE GROUNDING ELECTRODE (E) WHICH MAY BE A METAL WATER PIPE, BUILDING STEEL, AND/OR ELECTRODE (GROUND ROD) DRIVEN INTO THE EARTH – DEPENDING WHEN THE BUILDING WAS CONSTRUCTED.

SEPARATELY DERIVED AC SYSTEMS ARE THOSE SUPPLIED BY AN ON-SITE GENERATOR, BATTERY-INVERTER, OR A TRANSFORMER ON THE PREMISES. IN THESE SITUATIONS, THE ELECTRICAL CONNECTION TO GROUND MUST BE MADE BOTH AT THE SOURCE AND AT THE SUPPLY SIDE OF THE SYSTEM DISCONNECTING MEANS. FIGURE 29 ILLUSTRATES A 120-208 VOLT, 3-PHASE, 4-WIRE SYSTEM DERIVED FROM AN INPLANT 480 VOLT 3-PHASE FEEDER. NOTE THAT IN THIS CASE, THE GROUNDING

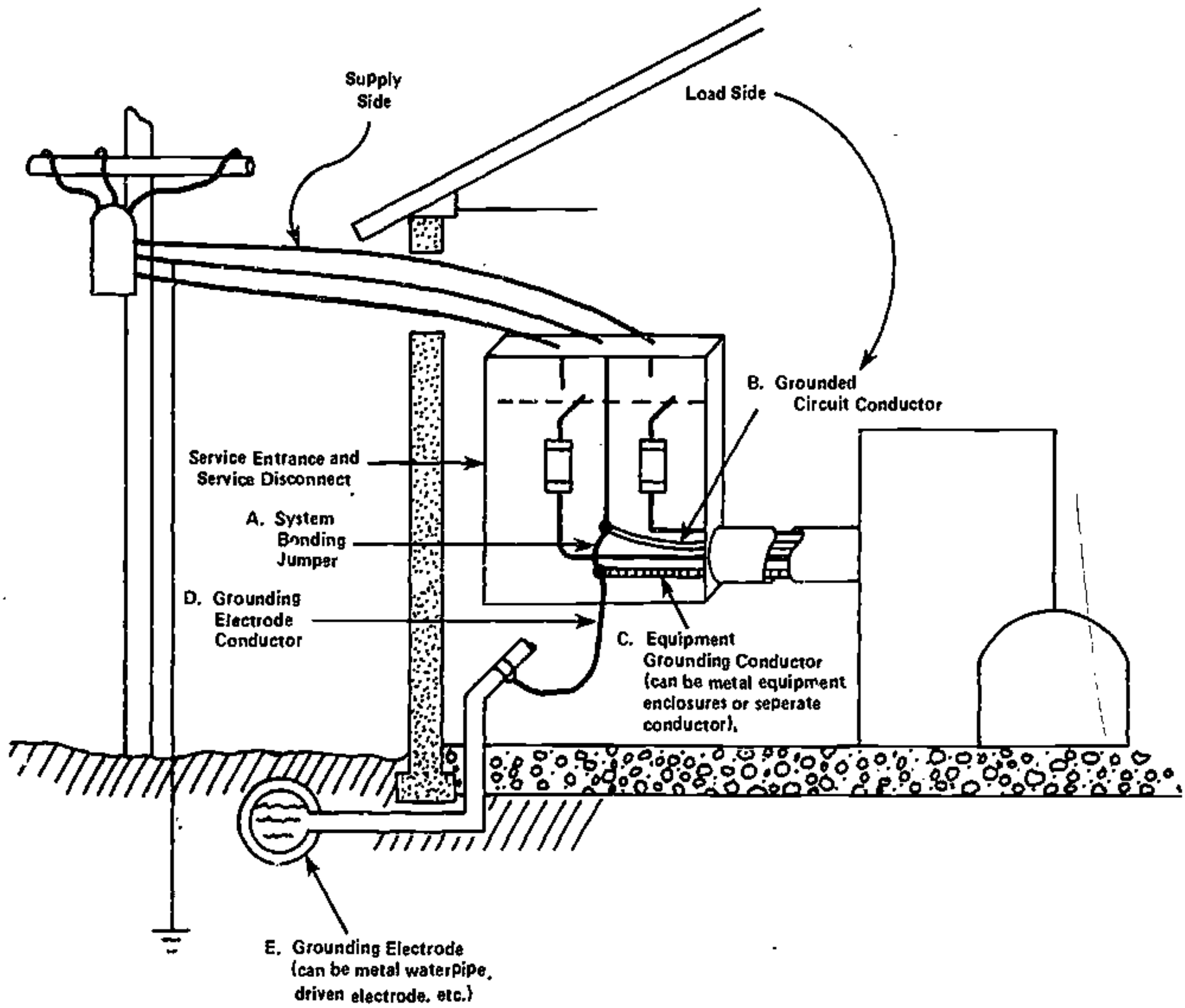


FIGURE 28. GROUNDING CONNECTIONS

ELECTRODE IS BUILDING STEEL. THE GROUNDED CIRCUIT CONDUCTOR (A) IS CONNECTED TO GROUND BY MEANS OF A SYSTEM BONDING JUMPER (B) CONNECTED TO THE EQUIPMENT GROUNDING CONDUCTOR (C), WHICH IN THIS CASE IS THE METAL EQUIPMENT ENCLOSURE. THE GROUNDING ELECTRODE CONDUCTOR (D) IS THEN CONNECTED TO BUILDING STEEL WHICH SERVES AS THE GROUNDING ELECTRODE (E). THE NEUTRAL IS ALSO CONNECTED TO THE EQUIPMENT GROUNDING CONDUCTOR WITHIN THE SERVICE DISCONNECT.

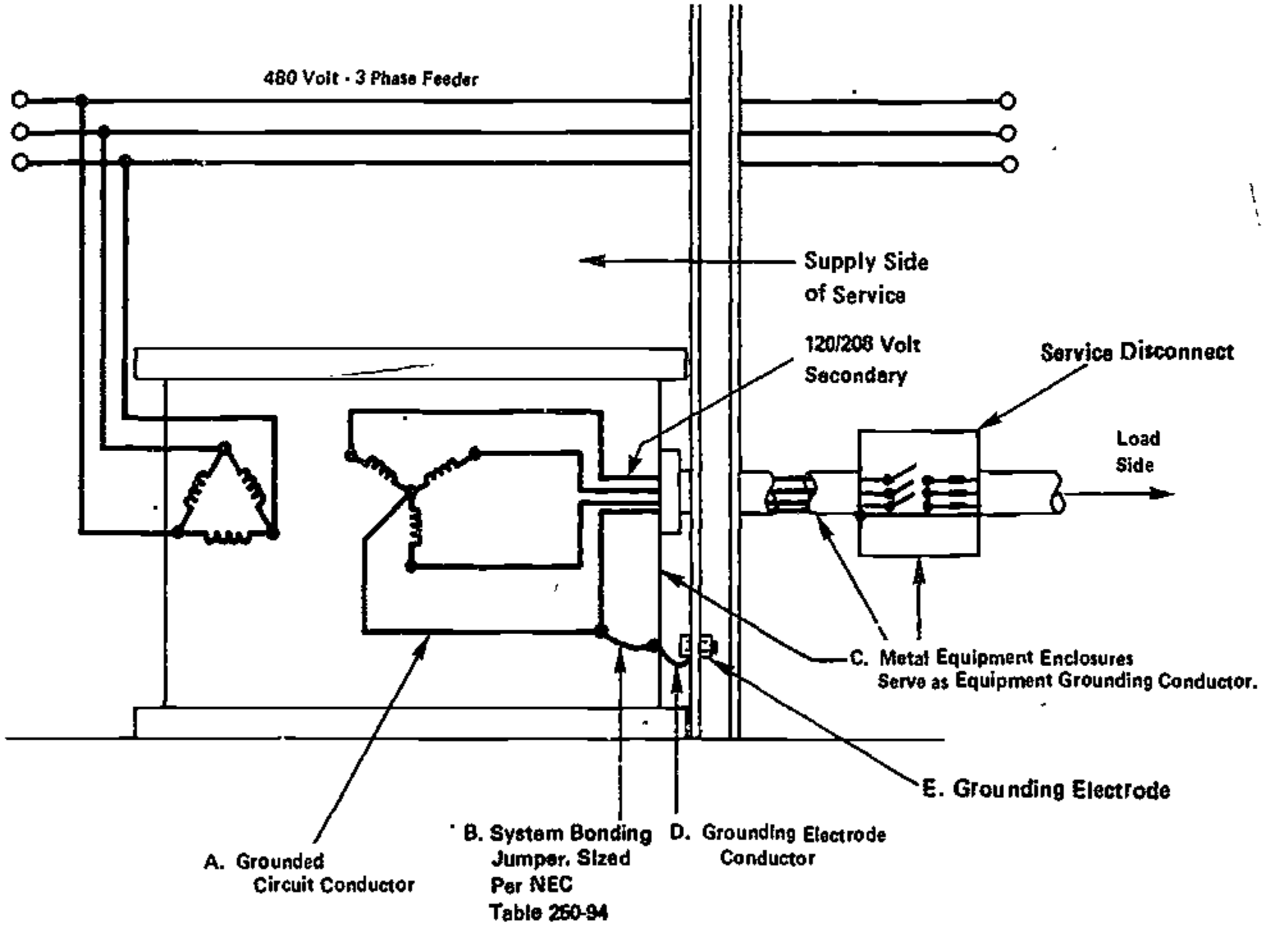


FIGURE 29. GROUNDING CONNECTION FOR A SEPARATELY DERIVED SYSTEM

(ii) For an ungrounded service-supplied system, the equipment grounding conductor shall be connected to the grounding electrode conductor at the service equipment. For an ungrounded separately derived system, the equipment grounding conductor shall be connected to the grounding electrode conductor at, or ahead of, the system disconnecting means or overcurrent devices.

- WHERE BUILDINGS, PLANTS, OFFICES AND OTHER PREMISES ARE SERVED BY AN UNGROUNDED SYSTEM THE CONNECTION FOR THE EQUIPMENT GROUNDING CONDUCTOR MUST BE MADE AT THE SOURCE OF ELECTRICAL SUPPLY. FIGURE 30 ILLUSTRATES WHERE THIS CONNECTION IS MADE. IN THIS CASE, THE SERVICE EQUIPMENT IS AT THE SERVICE ENTRANCE FOR THE PREMISES.

FOR UNGROUNDED SEPARATELY DERIVED SYSTEMS, I.E., SYSTEMS SUPPLIED BY A GENERATOR, A BATTERY-INVERTER OR AN ON-SITE TRANSFORMER, THE ELECTRICAL CONNECTION TO GROUND MUST BE MADE AT THE SUPPLY SIDE OF THE SYSTEM DISCONNECT. FIGURE 31 ILLUSTRATES THE GROUNDING CONNECTION MADE AHEAD OR UPSTREAM OF THE SYSTEM DISCONNECTING MEANS.

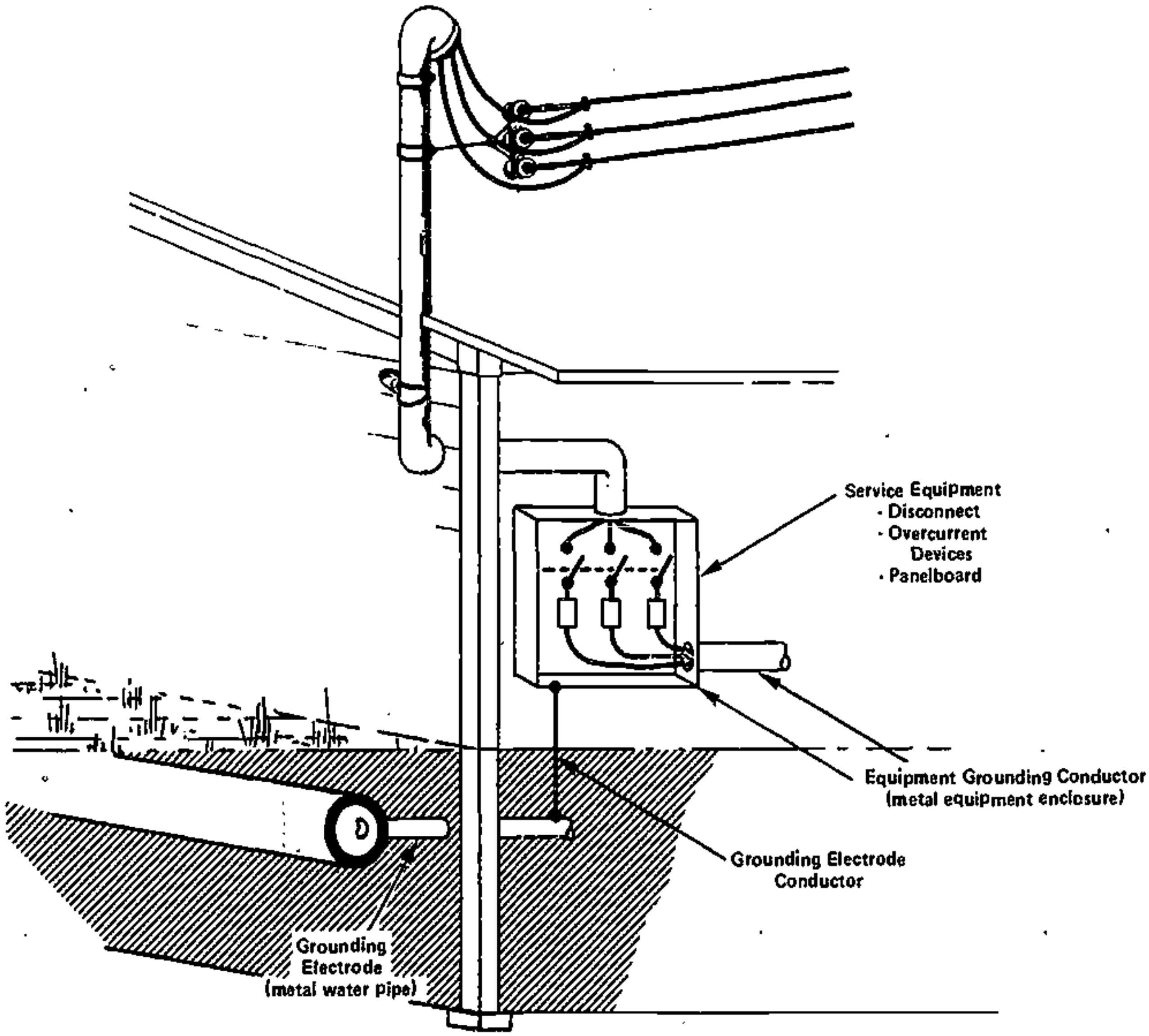


FIGURE 30. GROUNDING CONNECTION FOR AN UNGROUNDED SERVICE-SUPPLIED SYSTEM

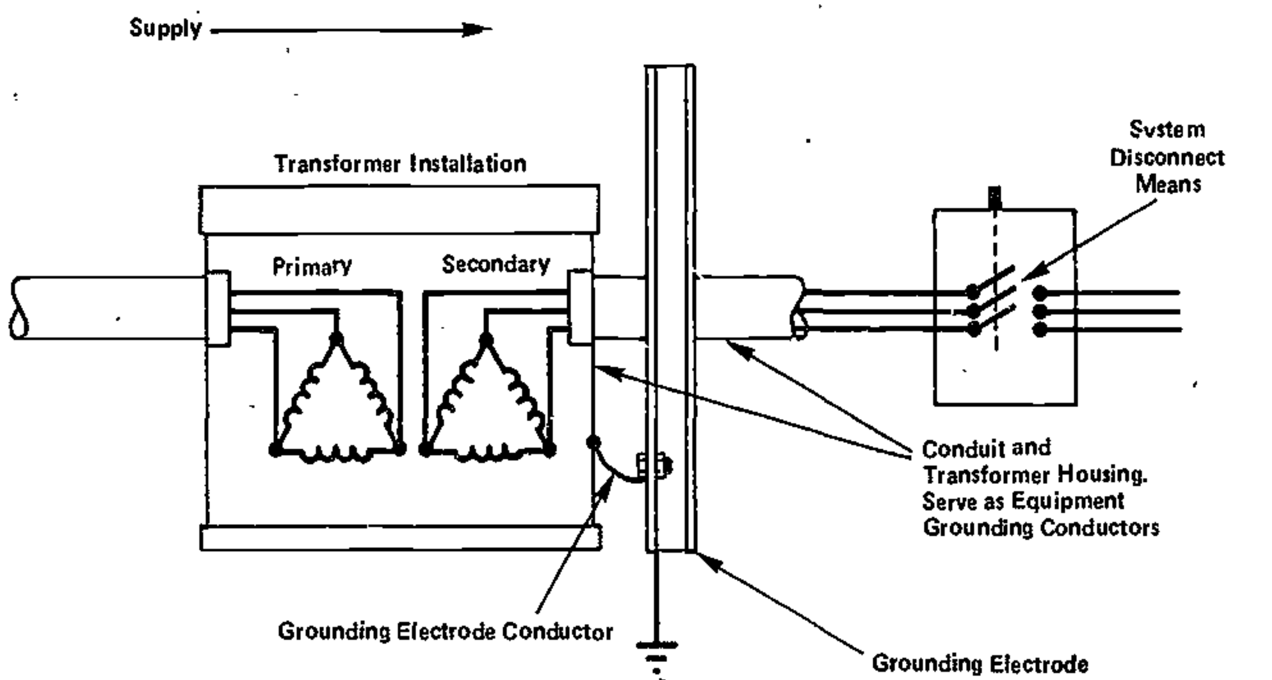


FIGURE 31. EQUIPMENT GROUNDING AHEAD OF SYSTEM DISCONNECT SWITCH FOR AN UNGROUNDED SYSTEM

(iii) On extensions of existing branch circuits which do not have an equipment grounding conductor, grounding-type receptacles may be grounded to a grounded cold water pipe near the equipment.

(4) Grounding path. The path to ground from circuits, equipment, and enclosures shall be permanent and continuous.

(5) Supports, enclosures, and equipment to be grounded.

(i) Supports and enclosures for conductors. Metal cable trays, metal raceways, and metal enclosures for conductors shall be grounded, except that:

(a) Metal enclosures such as sleeves that are used to protect cable assemblies from physical damage need not be grounded; or

(b) Metal enclosures for conductors added to existing installations of open wire, knob-and-tube wiring, and nonmetallic-sheathed cable need not be grounded if all of the following conditions are met:

(1) runs are less than 25 feet;

(2) enclosures are free from probable contact with ground, grounded metal, metal laths, or other conductive materials; and

(3) enclosures are guarded against employee contact.

(ii) Service equipment enclosures. Metal enclosures for service equipment shall be grounded.

(iii) Frames of ranges and clothes dryers. Frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and metal outlet or junction boxes which are part of the circuit for these appliances shall be grounded.

(iv) Fixed equipment. Exposed non-current carrying metal parts of fixed equipment which may become energized shall be grounded under any of the following conditions:

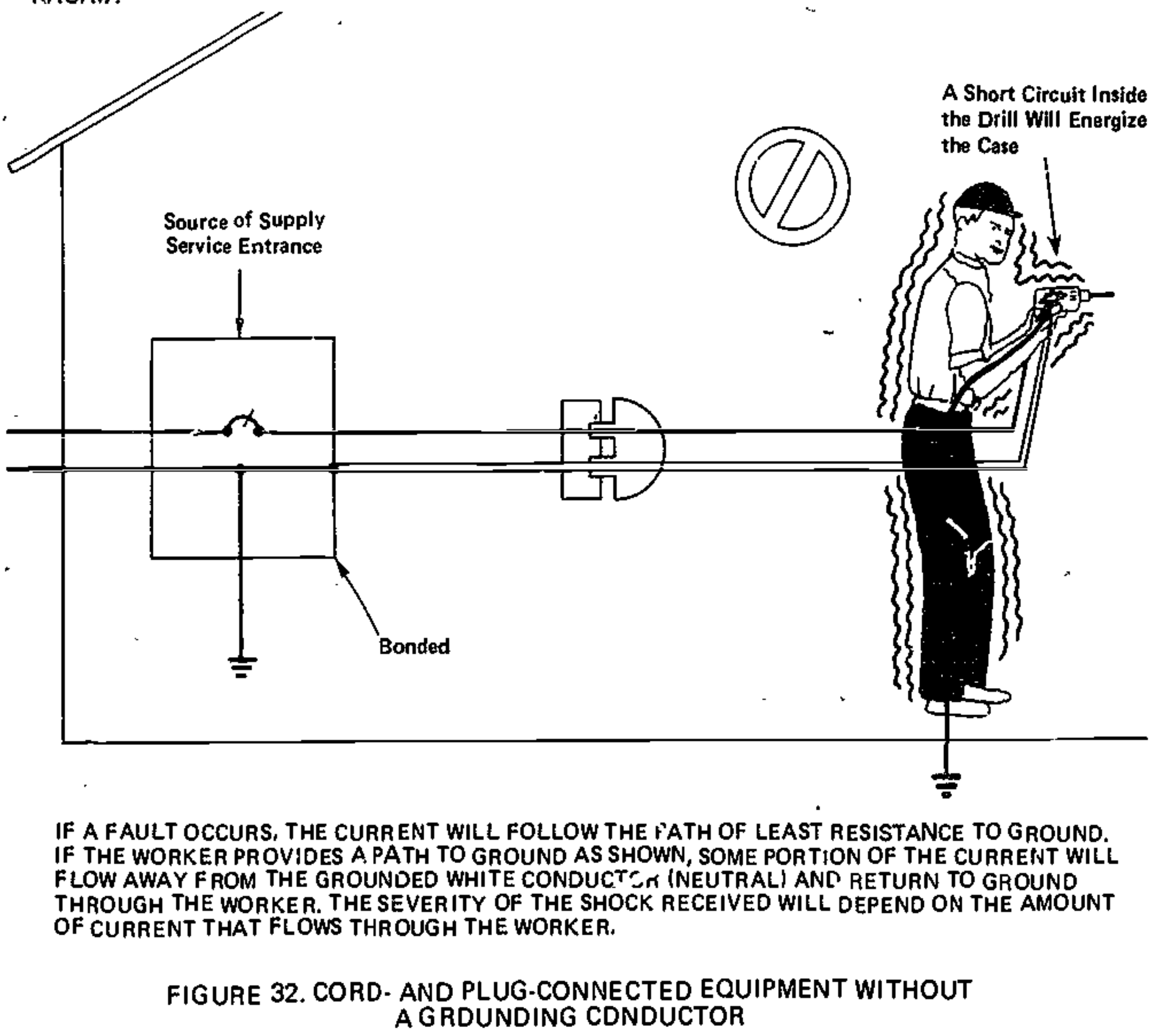
(a) If within 8 feet vertically or 5 feet horizontally of ground or grounded metal objects and subject to employee contact.

(b) If located in a wet or damp location and not isolated.
(c) If in electrical contact with metal.
(d) If in a hazardous (classified) location.
(e) If supplied by a metal-clad, metal-sheathed, or grounded metal raceway wiring method.
(f) If equipment operates with any terminal at over 150 volts to ground; however, the following need not be grounded:
(1) Enclosures for switches or circuit breakers used for other than service equipment and accessible to qualified persons only;
(2) Metal frames of electrically heated appliances which are permanently and effectively insulated from ground; and
(3) The cases of distribution apparatus such as transformers and capacitors mounted on wooden poles at a height exceeding 8 feet above ground or grade level.

• (v) Equipment connected by cord and plug. Under any of the conditions described in paragraphs (f)(5)(v) (a) through (f)(5)(v) (c) of this section, exposed non-current-carrying metal parts of cord- and plug-connected equipment which may become energized shall be grounded.
(a) If in hazardous (classified) locations (see §1910.307).
(b) If 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.
(c) If the equipment is of the following types:
(1) Refrigerators, freezers, and air conditioners;
(2) Clothes-washing, clothes-drying and dishwashing machines, sump pumps, and electrical aquarium equipment;
(3) Hand-held motor-operated tools;
(4) Motor-operated appliances of the following types: hedge clippers, lawn mowers, snow blowers, and wet scrubbers;
(5) Cord- and plug-connected appliances used in damp or wet locations or by employees standing on the ground or on metal floors or working inside of metal tanks or boilers;
(6) Portable and mobile X-ray and associated equipment;
(7) Tools likely to be used in wet and conductive locations; and
(8) Portable hand lamps.

• UNDER CONDITIONS DESCRIBED IN PARAGRAPHS (f)(5)(v)(A) THROUGH (C), EXPOSED NONCURRENT-CARRYING METAL PARTS OF CORD- AND PLUG-CONNECTED EQUIPMENT MUST BE GROUNDED. GROUNDING METAL PARTS IS NOT REQUIRED WHERE THE EQUIPMENT IS SUPPLIED THROUGH AN ISOLATING TRANSFORMER WITH AN UNGROUNDED SECONDARY OF NOT OVER 50 VOLTS OR IF PORTABLE TOOLS ARE PROTECTED BY AN APPROVED SYSTEM OF DOUBLE INSULATION. TO GROUND CORD- AND PLUG-CONNECTED EQUIPMENT, A THIRD WIRE IS COMMONLY PROVIDED IN THE CORD SET AND A THIRD PRONG IN THE PLUG. THE THIRD WIRE SERVES AS AN EQUIPMENT GROUNDING CONDUCTOR WHICH IS CONNECTED TO THE METAL HOUSING OF A PORTABLE TOOL AND A METAL GROUNDING BUS INSIDE THE SERVICE ENTRANCE EQUIPMENT. THE SERVICE ENTRANCE EQUIPMENT IS LOCATED AT THE ENTRANCE POINT OF THE ELECTRIC SUPPLY FOR A BUILDING OR PLANT AND

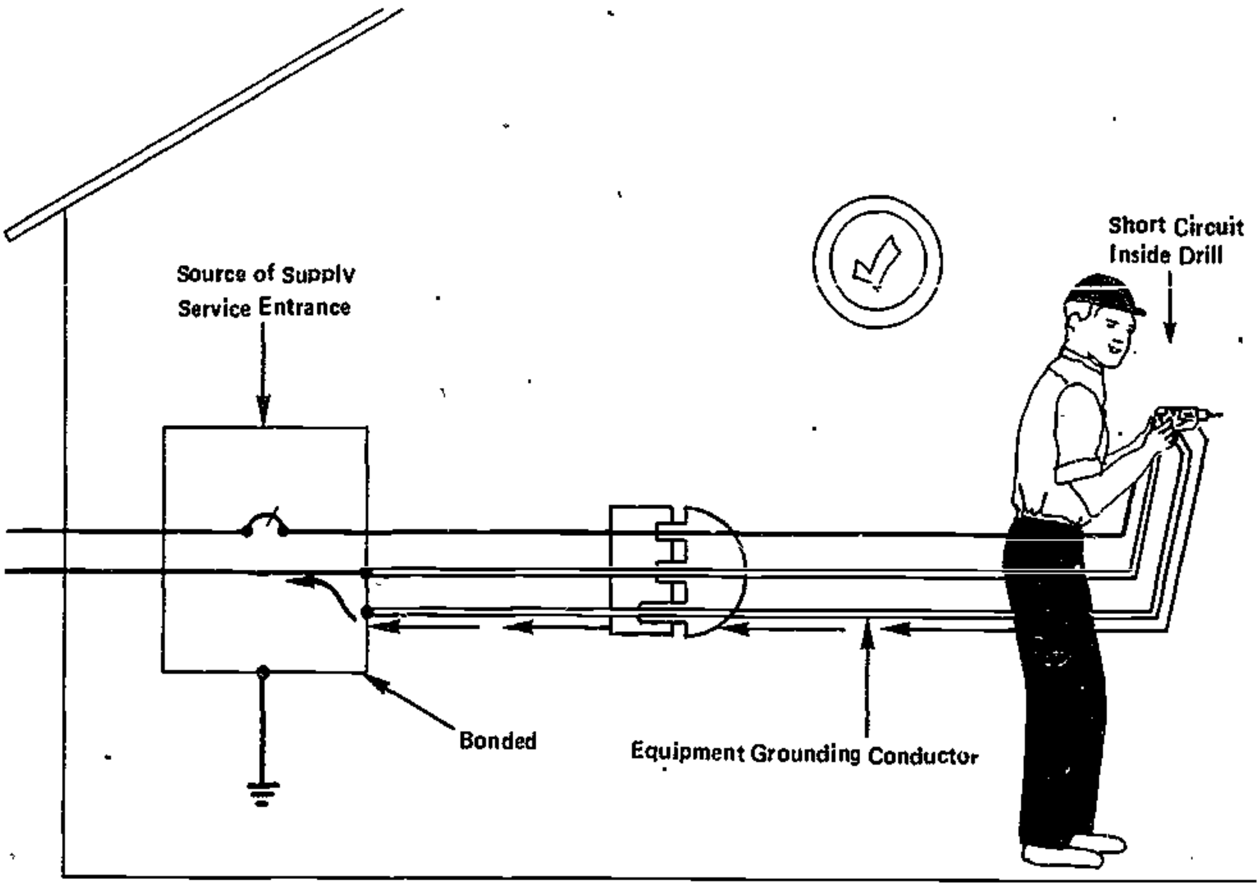
CONTAINS, OR SERVES OTHER PANELBOARDS WHICH CONTAIN, BRANCH CIRCUIT PROTECTIVE DEVICES SUCH AS FUSES AND CIRCUIT BREAKERS. THE THIRD WIRE PROVIDES A PATH FOR FAULT CURRENT SHOULD AN INSULATION FAILURE OCCUR. IN THIS MANNER DANGEROUS FAULT CURRENT WILL BE DIRECTED BACK TO THE SOURCE, THE SERVICE ENTRANCE, AND WILL ENABLE CIRCUIT BREAKERS OR FUSES TO OPERATE, THUS OPENING THE CIRCUIT AND STOPPING THE CURRENT FLOW. FIGURE 32 ILLUSTRATES THE POTENTIAL SHOCK HAZARD THAT EXISTS WHEN NO THIRD WIRE, GROUNDING CONDUCTOR, IS USED. FIGURE 33 ILLUSTRATES THE ADVANTAGE OF A PROPERLY CONNECTED GROUNDING CONDUCTOR. IT SHOULD BE NOTED THAT PROPERLY BONDED CONDUIT AND ASSOCIATED METAL ENCLOSURES CAN ALSO SERVE AS A GROUNDING CONDUCTOR AS DESCRIBED IN PARAGRAPH (f)(6)(i).



IF A FAULT OCCURS, THE CURRENT WILL FOLLOW THE PATH OF LEAST RESISTANCE TO GROUND. IF THE WORKER PROVIDES A PATH TO GROUND AS SHOWN, SOME PORTION OF THE CURRENT WILL FLOW AWAY FROM THE GROUNDED WHITE CONDUCTOR (NEUTRAL) AND RETURN TO GROUND THROUGH THE WORKER. THE SEVERITY OF THE SHOCK RECEIVED WILL DEPEND ON THE AMOUNT OF CURRENT THAT FLOWS THROUGH THE WORKER.

FIGURE 32. CORD- AND PLUG-CONNECTED EQUIPMENT WITHOUT A GROUNDING CONDUCTOR

SEVERITY OF THE SHOCK RECEIVED WILL DEPEND ON THE AMOUNT OF CURRENT THAT FLOWS THROUGH THE WORKER.



DANGEROUS FAULT CURRENT NOW IS REDIRECTED ALONG THE EQUIPMENT GROUNDING CONDUCTOR BACK TO THE SOURCE OF ELECTRICAL SUPPLY TO OPERATE OVERCURRENT DEVICE.

FIGURE 33. CORD- AND PLUG-CONNECTED EQUIPMENT WITH A GROUNDING CONDUCTOR

Tools likely to be used in wet and 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 an approved system of double insulation, or its equivalent, need not be grounded. If such a system is employed, the equipment shall be distinctively marked to indicate that the tool or appliance utilizes an approved system of double insulation.

(vi) Nonelectrical equipment. The metal parts of the following nonelectrical equipment shall be grounded: frames and tracks of electrically operated cranes; frames of nonelectrically driven elevator cars to which electric conductors are attached; hand operated metal shifting ropes or cables of electric elevators, and metal partitions, grill work, and similar metal enclosures around equipment of over 750 volts between conductors.

(6) Methods of grounding fixed equipment.

(i) Non-current-carrying metal parts of fixed equipment, if required to be grounded by this subpart, shall be grounded by an equipment grounding conductor which is contained within the same raceway, cable, or cord, or runs with or encloses the circuit conductors. For DC circuits only, the equipment grounding conductor may be run separately from the circuit conductors.

- THE NONCURRENT-CARRYING METAL PARTS OF FIXED ELECTRICAL EQUIPMENT, THAT REQUIRE GROUNDING, I.E., METAL ENCLOSURES, MUST BE GROUNDED BY ONE OF TWO METHODS WHICH ARE ACCEPTABLE FOR AC SYSTEMS. BOXES, CABINETS, AND OTHER METAL ENCLOSURES CAN BE GROUNDED BY AN EQUIPMENT GROUNDING CONDUCTOR THAT IS RUN WITH THE CIRCUIT CONDUCTORS SERVING THE EQUIPMENT OR BY USING THE METAL CABLE ARMOR, METAL SHEATH, OR THE METAL CONDUIT THAT CONTAINS THE POWER CONDUCTORS. PROPER FITTINGS MUST BE USED BETWEEN ENCLOSURES AND CONDUITS TO ASSURE THAT A GOOD ELECTRICAL CONNECTION IS MADE SO THE GROUNDING PATH IS CONTINUOUS.

FIGURE 34 ILLUSTRATES EXAMPLES OF HOW EQUIPMENT GROUNDING CONDUCTORS MAY BE RUN. FIGURE 35 SHOWS AN ACCEPTABLE ARRANGEMENT FOR EQUIPMENT GROUNDING USING EQUIPMENT ENCLOSURES WHICH ARE PROPERLY INTERCONNECTED AND FASTENED.

A SEPARATE EQUIPMENT GROUNDING CONDUCTOR MUST BE PROVIDED WHEN PLASTIC CONDUIT IS USED. IT MUST BE CONTAINED IN THE SAME RACEWAY OR CABLE

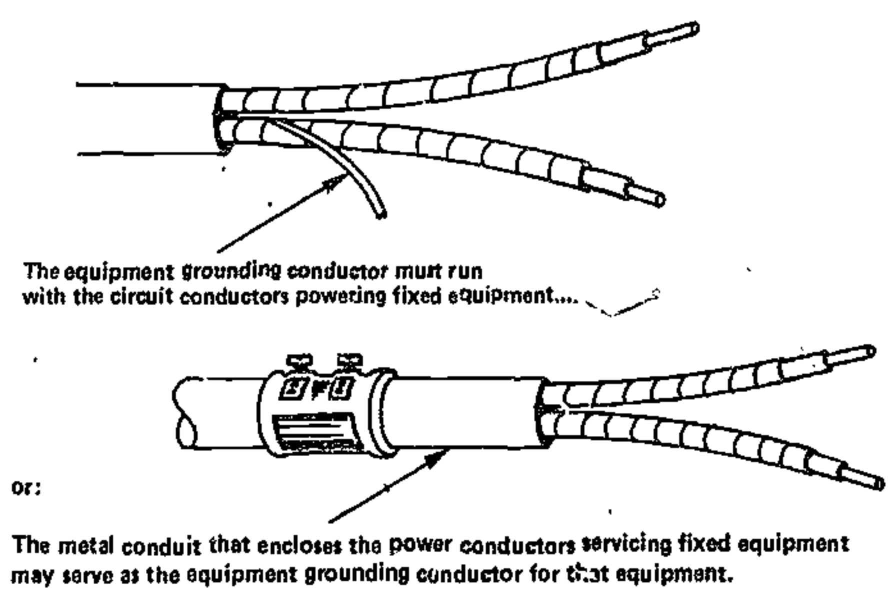
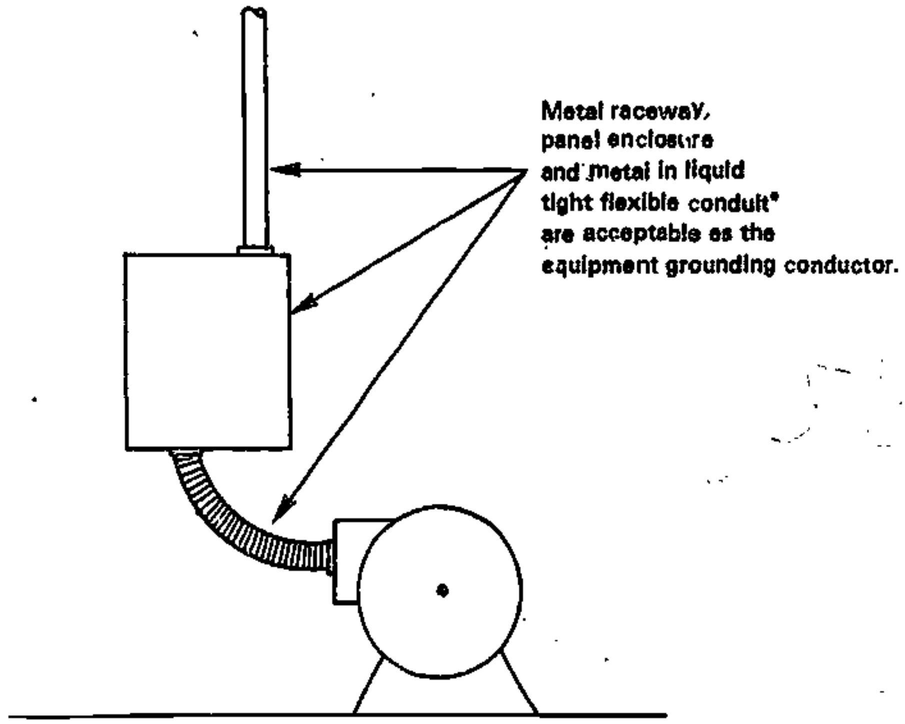


FIGURE 34. GROUNDING METHODS FOR FIXED EQUIPMENT USING A SEPARATE CONDUCTOR OR METAL ENCLOSURES AS THE EQUIPMENT GROUNDING CONDUCTOR

AS THE CIRCUIT OF WHICH IT IS PART AND PROPERLY CONNECTED TO TERMINALS AND GROUNDING BUSES INSIDE PANELS AND BOXES.

DC SYSTEMS ON THE OTHER HAND DO NOT REQUIRE THE EQUIPMENT GROUNDING CONDUCTOR TO BE IN THE SAME RACEWAY AS THE CIRCUIT CONDUCTORS.



*NOTE: THIS IS A SPECIAL CASE. WHEN LIQUID TIGHT FLEXIBLE CONDUIT IS USED THE LENGTH MUST NOT EXCEED 6 FEET AND THE DIAMETER MUST BE 1 1/4 INCHES OR LESS (NEC SECTION 250-91(B) EXCEPTION NO. 2)

FIGURE 35. GROUNDING METHOD FOR FIX EQUIPMENT USING CIRCUIT CONDUCTOR ENCLOSURES AS EQUIPMENT GROUNDING CONDUCTOR

- (ii) Electric equipment is considered to be effectively grounded if it is secured to, and in electrical contact with, a metal rack or structure that is provided for its support and the metal rack or structure is grounded by the method specified for the non-current-carrying metal parts of fixed equipment in paragraph (f)(6)(i) of this section. For installations made before April 16, 1981, only, electric equipment is also considered to be effectively grounded if it is secured to, and in metallic contact with, the grounded structural metal frame of a building. Metal car frames supported by metal hoisting cables attached to or running over metal sheaves or drums of grounded elevator machines are also considered to be effectively grounded.

- IF ELECTRICAL EQUIPMENT THAT MUST BE GROUNDED IS ATTACHED TO A METAL RACK OR STRUCTURE THAT IS GROUNDED, AND IF THERE IS A GOOD ELECTRICAL CONNECTION BETWEEN THE EQUIPMENT AND THE METAL RACK OR STRUCTURE, THEN THE EQUIPMENT IS CONSIDERED TO BE GROUNDED. THE STRUCTURE MUST BE EFFECTIVELY GROUNDED BY A GROUNDED RACEWAY OR EQUIPMENT GROUNDING CONDUCTOR RUN WITH THE CONDUCTOR SERVING THE EQUIPMENT ON THE STRUCTURE. FIGURE 36 SHOWS A MOTOR SUITABLY GROUNDED THROUGH ITS ATTACHMENTS TO A GROUNDED STRUCTURE.

METAL ELEVATOR CAR FRAMES ARE CONSIDERED TO BE EFFECTIVELY GROUNDED BECAUSE THERE IS CONTINUOUS METAL-TO-METAL CONTACT BETWEEN THE CAR AND THE GROUNDED ELEVATOR MACHINE THROUGH THE METAL HOISTING CABLES THAT ARE ATTACHED TO BOTH. FIGURE 37 SHOWS METAL HOISTING CABLES FOR AN ELEVATOR WHICH ARE CONSIDERED EFFECTIVELY GROUNDED.

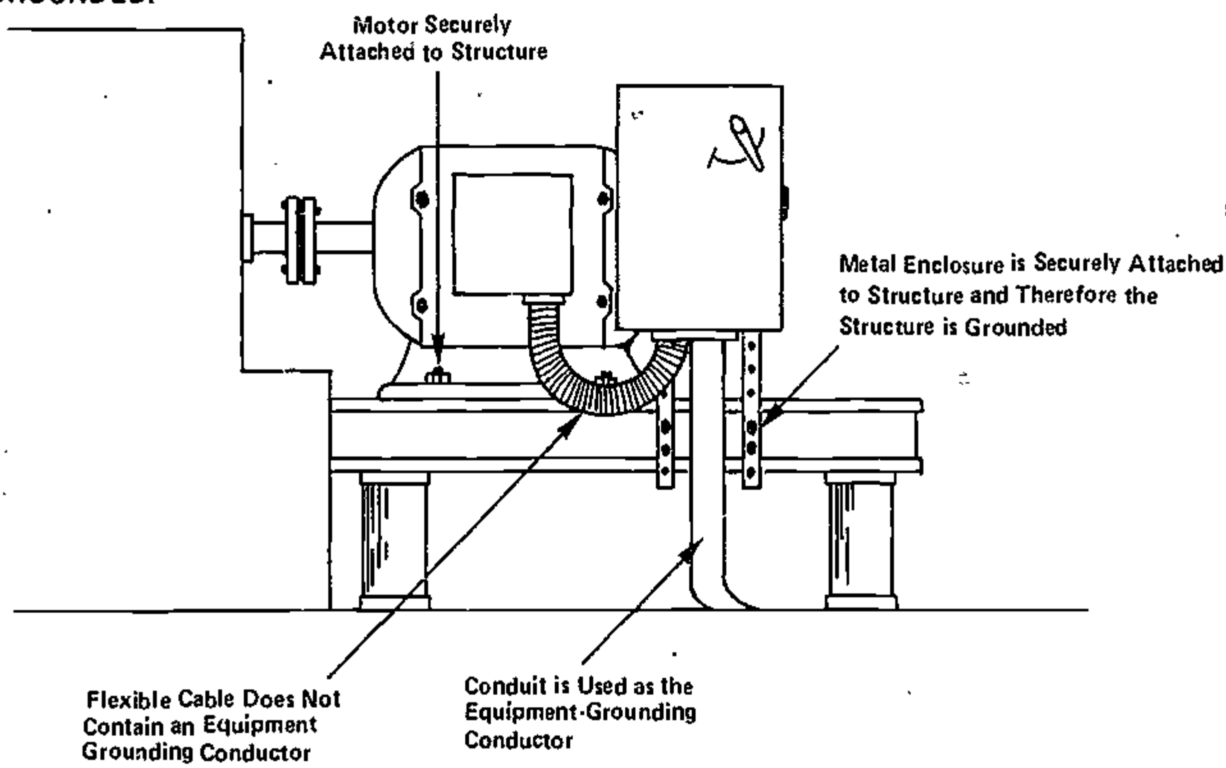


FIGURE 36. MOTOR SUITABLY GROUNDED BY ITS ATTACHMENT TO GROUNDED STRUCTURE

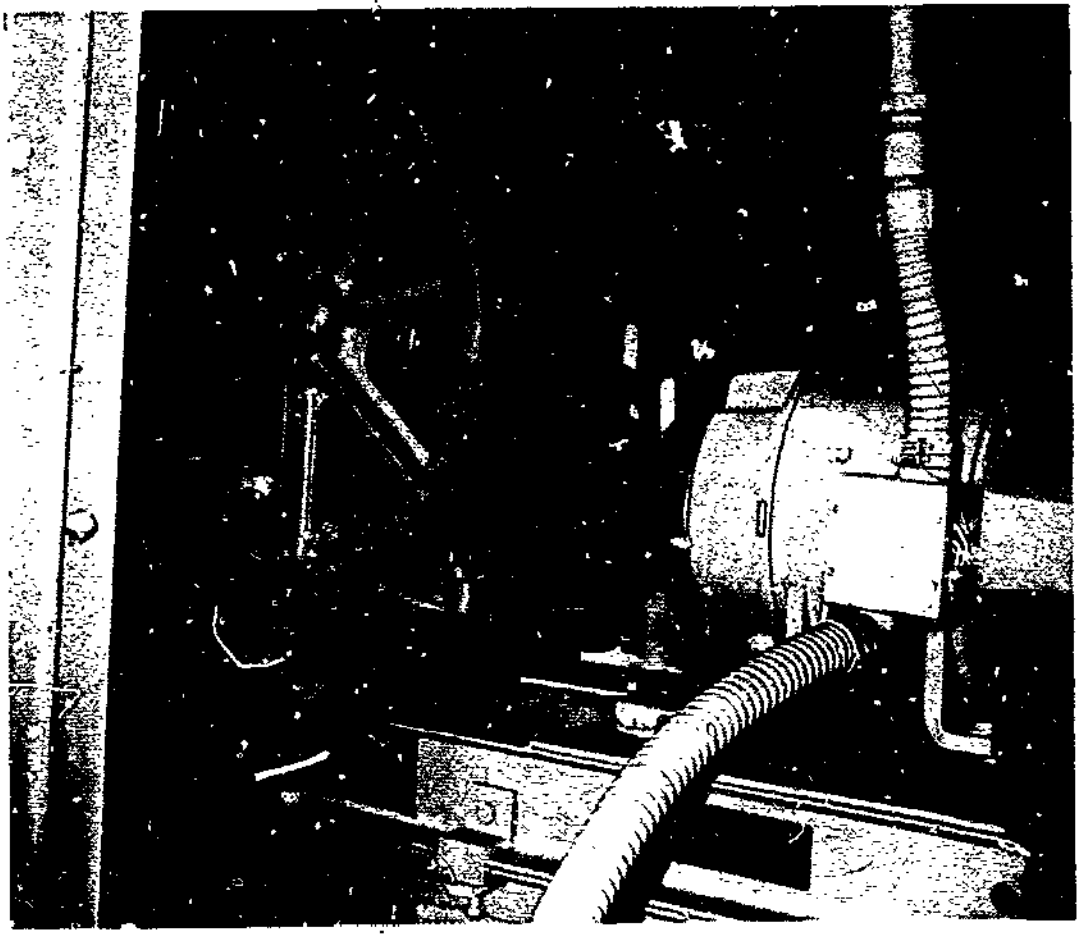


FIGURE 37. EQUIPMENT CONSIDERED EFFECTIVELY GROUNDED

METAL HOISTING CABLES ATTACHED TO OR RUNNING OVER METAL SHEAVES OR DRUMS OF GROUNDED ELEVATOR MACHINES ARE CONSIDERED GROUNDED.

(7) Grounding of systems and circuits of 1000 volts and over (high voltage).

(i) General. If high voltage systems are grounded, they shall comply with all applicable provisions of paragraphs (f)(1) through (f)(6) of this section as supplemented and modified by this paragraph (f)(7).

(ii) Grounding of systems supplying portable or mobile equipment. (See §1910.302(b)(3).) Systems supplying portable or mobile high voltage equipment, other than substations installed on a temporary basis, shall comply ... following:

Portable and mobile high voltage equipment shall be supplied from a system having its neutral grounded through an impedance. If a delta-connected high voltage system is used to supply the equipment, a system neutral shall be derived.

- BECAUSE OF THEIR LARGE CURRENT FLOWS, HIGH VOLTAGE SYSTEMS WHICH OPERATE AT 1,000 VOLTS OR MORE CANNOT BE GROUNDED USING LOW-IMPEDANCE GROUNDING CONDUCTORS AS IS DONE ON LOW VOLTAGE SYSTEMS. "IMPEDANCE" IN AN ALTERNATING CURRENT (AC) SYSTEM IS THE TOTAL OPPOSITION TO CURRENT FLOW. PORTABLE HIGH VOLTAGE EQUIPMENT MUST BE SUPPLIED WITH POWER FROM AN ELECTRICAL SYSTEM THAT HAS ITS NEUTRAL CONDUCTOR GROUNDED THROUGH AN IMPEDANCE. "AN IMPEDANCE" IS A DEVICE WHICH, WHEN IT IS PLACED IN A CIRCUIT, WILL OPPOSE CURRENT FLOW, THUS AIDING ITS CONTROL. THE IMPEDANCE CONTROLS THE FAULT CURRENT SO AS NOT TO DAMAGE THE SYSTEM. FIGURE 39 SHOWS THE LOCATION OF AN IMPEDANCE IN A GROUNDING CONNECTION.

A DELTA-CONNECTED AC CIRCUIT, BY ITS DESIGN, DOES NOT HAVE A NEUTRAL CONDUCTOR; THEREFORE, WHEN THIS TYPE OF HIGH VOLTAGE SYSTEM SUPPLIES POWER TO PORTABLE EQUIPMENT, A NEUTRAL IS DERIVED BY MEANS OF A GROUNDING TRANSFORMER. THIS GIVES THE SYSTEM THE ADVANTAGES OF A GROUNDED SYSTEM INCLUDING THE PROTECTION FROM ACCIDENTAL GROUNDING. THIS IS REQUIRED BECAUSE OF THE GREATER RISK OF ACCIDENTAL GROUNDING THAT EXISTS ON A PORTABLE SYSTEM. SEE FIGURE 38.

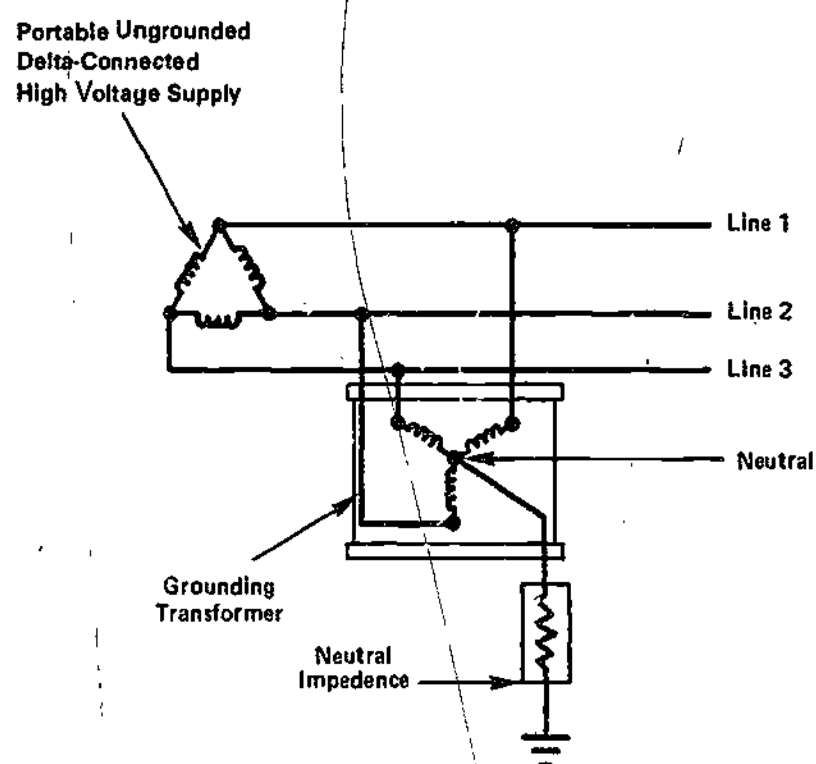


FIGURE 38. DERIVED NEUTRAL FOR AN UNGROUNDED DELTA-CONNECTED SYSTEM SHOWING THE NEUTRAL GROUNDED THROUGH AN IMPEDANCE

(b) Exposed non-current-carrying metal parts of portable and mobile equipment shall be connected by an equipment grounding conductor to the point at which the system neutral impedance is grounded.

ALL EXPOSED NONCURRENT-CARRYING METAL PARTS AND THE METAL ENCLOSURES, MUST BE ELECTRICALLY INTERCONNECTED WITH AN EQUIPMENT-GROUNDING CONDUCTOR. EITHER THE METAL RACEWAYS, METAL BOXES, AND OTHER METAL ENCLOSURES MUST BE BONDED TOGETHER, OR A SEPARATE CONDUCTOR MUST BE RUN WITH THE CIRCUIT CONDUCTORS AND IDENTIFIED AS THE EQUIPMENT-GROUNDING CONDUCTOR. FIGURE 39 ILLUSTRATES WHERE THE EQUIPMENT GROUNDING CONDUCTOR IS TO BE CONNECTED TO GROUND. IT SHOULD NOT BE CONNECTED AHEAD OF THE NEUTRAL IMPEDANCE. MAKING THE GROUNDING CONNECTION AT THE PROPER POINT FACILITATES THE OPERATION OF GROUND FAULT RELAYS AND PROTECTS THE REST OF THE SYSTEM FROM THE DAMAGING FAULT CURRENT.

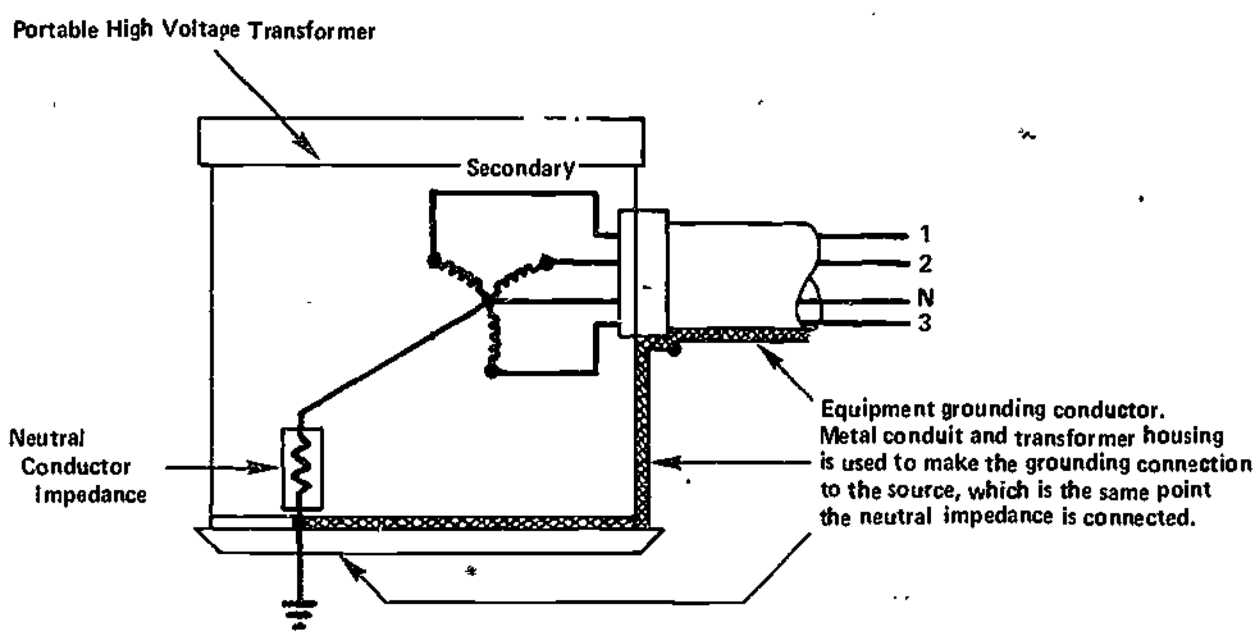


FIGURE 39. NONCURRENT-CARRYING METAL PARTS CONNECTED

(c) Ground-fault detection and relaying shall be provided to automatically de-energize any high voltage system component which has developed a ground fault. The continuity of the equipment grounding conductor shall be continuously monitored so as to de-energize automatically the high voltage feeder to the portable equipment upon loss of continuity of the equipment grounding conductor.

- PORTABLE HIGH-VOLTAGE EQUIPMENT MUST HAVE A MEANS OF DETECTING FAULTS AND AUTOMATICALLY DISCONNECTING THE POWER TO THE EQUIPMENT IF A GROUND FAULT DEVELOPS. THE DETECTION SYSTEM MUST CONTINUALLY MONITOR THE SYSTEM SO THAT POWER WILL BE DISCONNECTED AS SOON AS A FAULT OCCURS.

IN FIGURE 40, IF A GROUND FAULT OCCURS AT (A), THE FAULT CURRENT WILL TRAVEL ALONG THE PATH OF THE EQUIPMENT GROUNDING CONDUCTOR TO THE POINT WHERE THE NEUTRAL CONDUCTOR IMPEDANCE IS GROUNDED. IT WILL THEN RETURN TO THE CENTER POINT OF THE TRANSFORMER WINDINGS, TO THE NEUTRAL, PASSING THROUGH THE GROUND FAULT DETECTOR. ONCE THE GROUND FAULT DETECTOR SENSES FAULT CURRENT, A SIGNAL IS TRANSMITTED TO THE GROUND FAULT RELAY WHICH WILL OPERATE A DISCONNECT TO DE-ENERGIZE HIGH VOLTAGE SYSTEM COMPONENTS WHICH HAVE DEVELOPED A FAULT. IN ADDITION, THE CONTINUITY OF THE EQUIPMENT GROUNDING CONDUCTOR MUST BE CONTINUOUSLY MONITORED. SHOULD A BREAK OCCUR IN THE EQUIPMENT GROUNDING CONDUCTOR, THE CIRCUIT MUST AUTOMATICALLY BE DE-ENERGIZED.

FIGURE 41 IS A PHOTOGRAPH OF A GROUND DETECTOR WHICH MONITORS THREE LEGS OF A 3-PHASE SYSTEM.

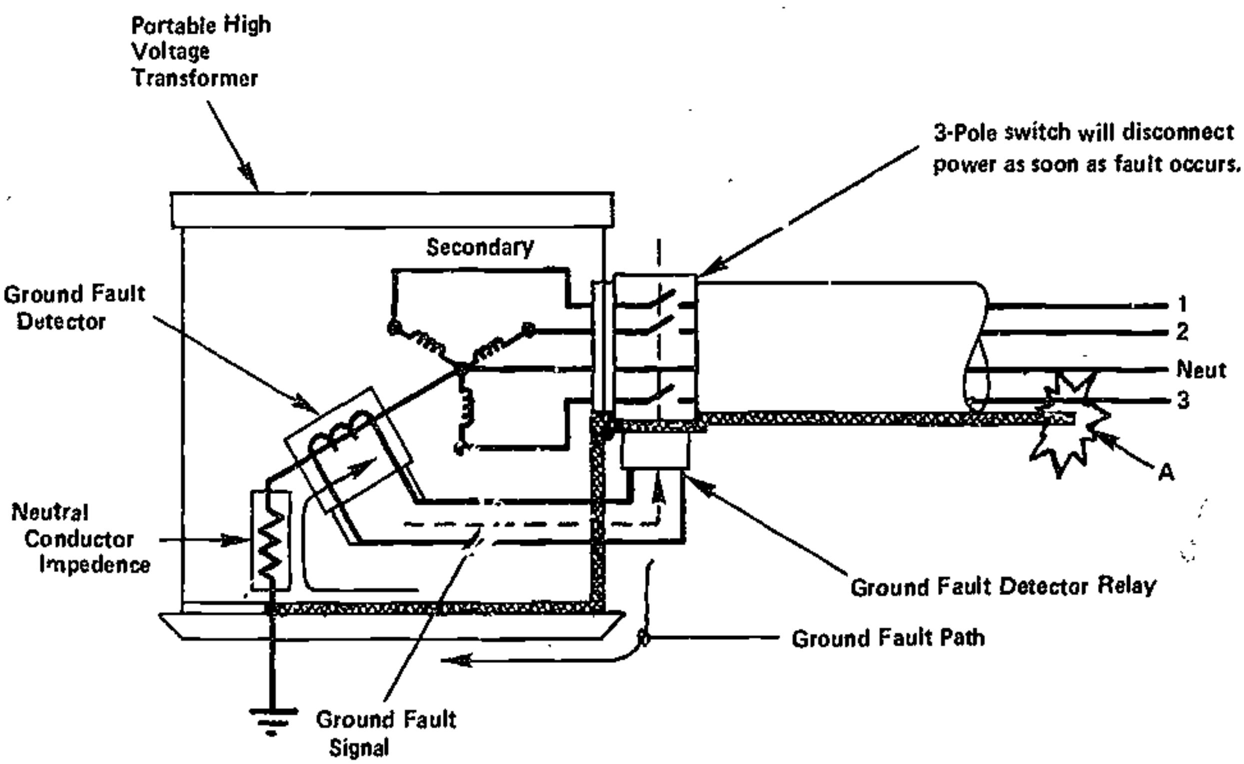


FIGURE 40. GROUND-FAULT DETECTION AND RELAYING

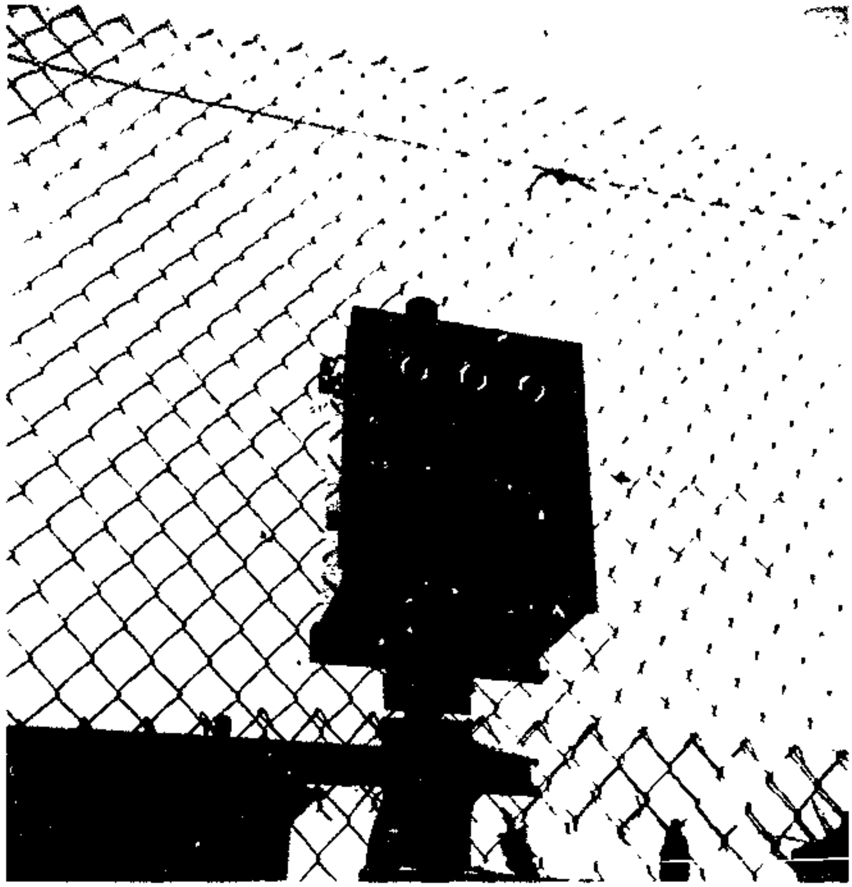


FIGURE 41. GROUND DETECTOR

(d) The grounding electrode to which the portable or mobile equipment system neutral impedance is connected shall be isolated from and separated in the ground by at least 20 feet from any other system or equipment grounding electrode, and there shall be no direct connection between the grounding electrodes, such as buried pipe, fence, etc.

• GROUNDING ELECTRODES OF SYSTEMS SUPPLYING PORTABLE OR MOBILE EQUIPMENT MUST BE ISOLATED FROM AND SEPARATED IN THE GROUND BY AT LEAST 20 FEET FROM ANY OTHER GROUNDING ELECTRODES. THERE MUST NOT BE ANY DIRECT ELECTRICAL CONNECTION BETWEEN THESE GROUNDING ELECTRODES AND OTHER OBJECTS SUCH AS BURIED PIPES, FENCES, ETC., TO PREVENT INTERFERENCE BETWEEN SYSTEMS. SEE FIGURE 42.

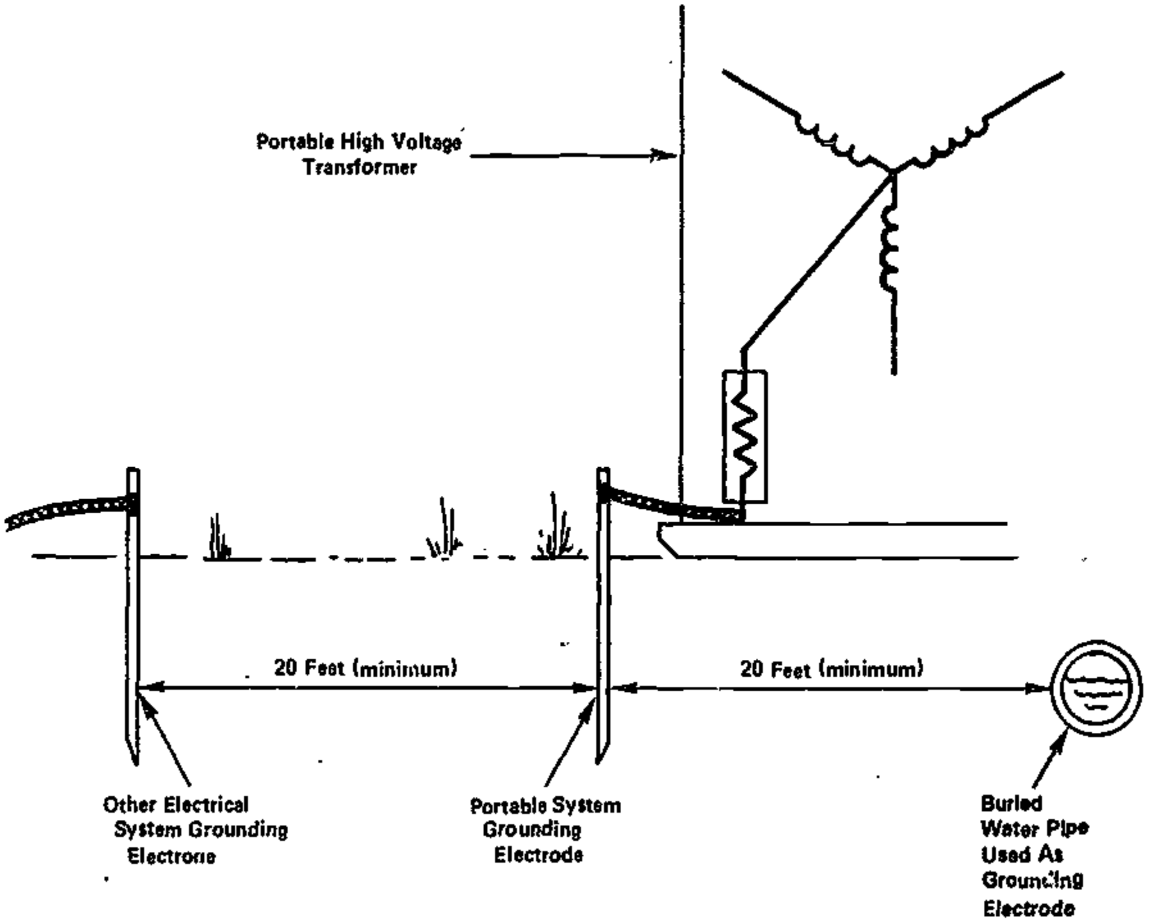


FIGURE 42. ISOLATED GROUNDING ELECTRODE

(iii) Grounding of equipment. All non-current-carrying metal parts of portable equipment and fixed equipment including their associated fences, housings, enclosures, and supporting structures shall be grounded. However, equipment which is guarded by location and isolated from ground need not be grounded. Additionally, pole-mounted distribution apparatus at a height exceeding 8 feet above ground or grade level need not be grounded.

§1910.305 WIRING METHODS

§1910.305 Wiring methods, components, and equipment for general use.

(a) Wiring methods. The provisions of this section do not apply to the conductors that are an integral part of factory-assembled equipment.

(1) General requirements.

(i) Electrical continuity of metal raceways and enclosures. Metal raceways, cable armor, and other metal enclosures for conductors shall be metallically joined together into a continuous electric conductor and shall be so connected to all boxes, fittings, and cabinets as to provide effective electrical continuity.

(ii) Wiring in ducts. No wiring systems of any type shall be installed in ducts used to transport dust, loose stock or flammable vapors. No wiring system of any type may be installed in any duct used for vapor removal or for ventilation of commercial-type cooking equipment, or in any shaft containing only such ducts.

- (2) Temporary wiring. Temporary electrical power and lighting wiring methods may be of a class less than would be required for a permanent installation. Except as specifically modified in this paragraph, all other requirements of this subpart for permanent wiring shall apply to temporary wiring installations.

- TEMPORARY WIRING

THE REQUIREMENTS FOR TEMPORARY WIRING FOR POWER AND LIGHTING PURPOSES INCLUDE PROVISIONS FOR WIRE CONNECTIONS, JUNCTION BOXES, AND OVERCURRENT PROTECTION AS WELL AS THE USE OF CONDUCTORS. TEMPORARY WIRING DOES NOT HAVE TO MEET ALL OF THE REQUIREMENTS THAT PERMANENT WIRING MUST MEET. FOR EXAMPLE, AN ELECTRICAL METER ON A CONSTRUCTION SITE CAN BE MOUNTED ON A POLE OR OTHER TEMPORARY SUPPORT, WITH OPEN INSULATED CONDUCTORS USED TO CONNECT IT. IF THE METER WERE PART OF A PERMANENT INSTALLATION, IT WOULD HAVE TO BE MOUNTED ON A PERMANENT STRUCTURE, SUCH AS A BUILDING, AND THE CONDUCTORS WOULD NORMALLY BE PLACED IN CONDUIT FOR PERMANENT PROTECTION. FIGURE 43 SHOWS A PERMISSIBLE TEMPORARY WIRING ARRANGEMENT.

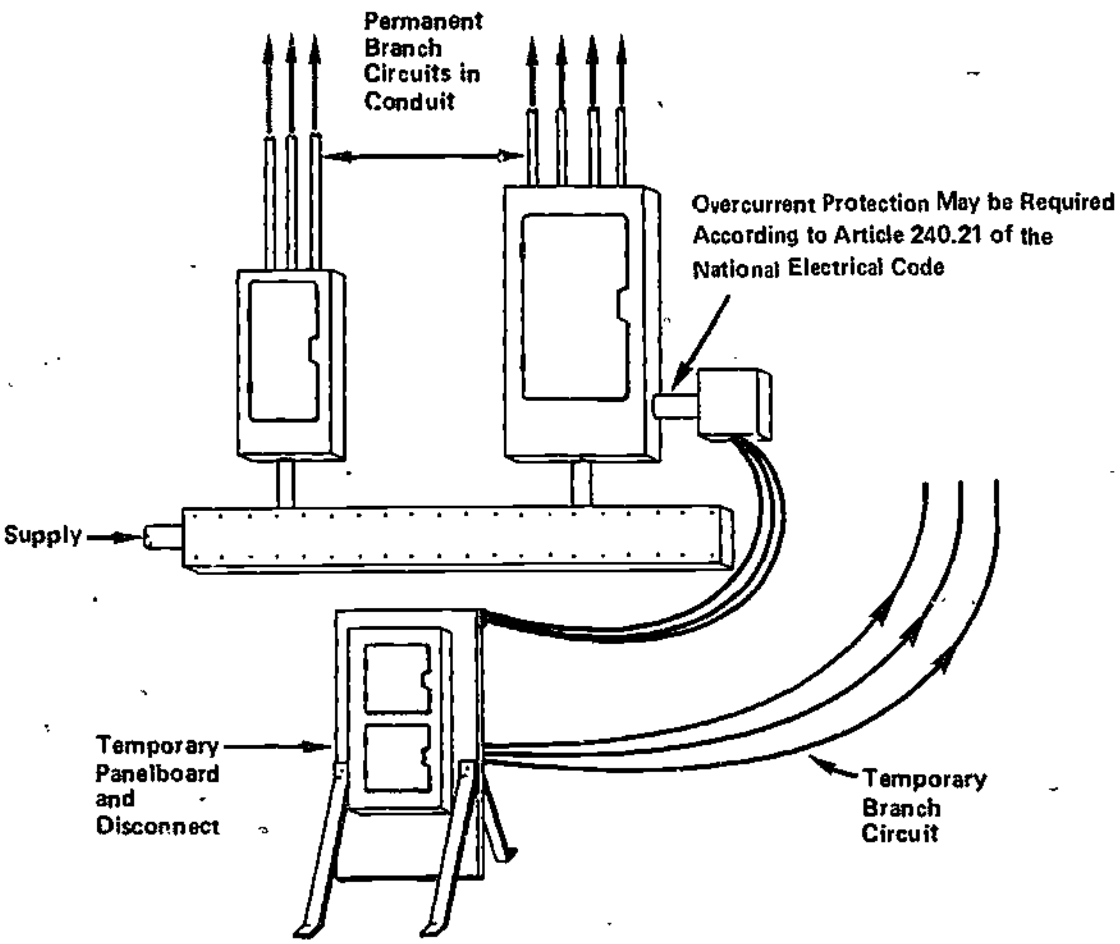


FIGURE 43. TEMPORARY WIRING ARRANGEMENT PERMISSIBLE FOR DURATION OF CONSTRUCTION, REMODELING, MAINTENANCE, REPAIR, OR DEMOLITION OF STRUCTURES

(i) Uses permitted, 600 volts, nominal, or less. Temporary electrical power and lighting installations 600 volts, nominal, or less may be used only:

(a) During and for remodeling, maintenance, repair, or demolition of buildings, structures, or equipment, and similar activities;
(b) For experimental or development work, and
(c) For a period not to exceed 90 days for Christmas decorative lighting, carnivals, and similar purposes.

(ii) Uses permitted, over 600 volts, nominal. Temporary wiring over 600 volts, nominal, may be used only during periods of tests, experiments, or emergencies.

(iii) General requirements for temporary wiring.

(a) Feeders shall originate in an approved distribution center. The conductors shall be run as multiconductor cord or cable assemblies, or, where not subject to physical damage, they may be run as open conductors on insulators not more than 10 feet apart.

- FEEDER CIRCUITS

FEEDERS ARE THE CONDUCTORS THAT TRANSMIT POWER FROM THE SERVICE DROP TO THE DISTRIBUTION PANELBOARD, OR BETWEEN THE MAIN DISCONNECT AND THE BRANCH CIRCUIT OVERCURRENT DEVICES (CIRCUIT BREAKERS, FUSES). FEEDERS FOR TEMPORARY WIRING MUST ORIGINATE INSIDE AN APPROVED DISTRIBUTION CENTER, SUCH AS A PANELBOARD, THAT IS RATED FOR THE VOLTAGES AND CURRENTS THE SYSTEM IS EXPECTED TO CARRY. SOME EQUIPMENT IS MANUFACTURED SPECIFICALLY FOR TEMPORARY USE.

FEEDERS MAY BE RUN AS MULTI-CONDUCTOR CORDS OR CABLES, I.E., TWO OR MORE CONDUCTORS, EACH WITH THEIR OWN INSULATION, RUN TOGETHER IN THE SAME CORD. ONE TYPE OF CABLE ASSEMBLY HAS THE HOT CONDUCTORS JACKETED TOGETHER AND THE NEUTRAL WRAPPED AROUND THEM. THE NEUTRAL IS A SPECIAL CABLE THAT IS REINFORCED WITH STEEL TO PROVIDE THE NECESSARY SUPPORT FOR THE ENTIRE ASSEMBLY.

WHEN FEEDER CONDUCTORS WILL NOT BE SUBJECTED TO PHYSICAL DAMAGE, THEY CAN BE INSTALLED AS OPEN CONDUCTORS. HOWEVER, THEY MUST BE INSTALLED ON INSULATING SUPPORTS THAT ARE NO MORE THAN 10 FEET APART (SEE FIGURE 44).

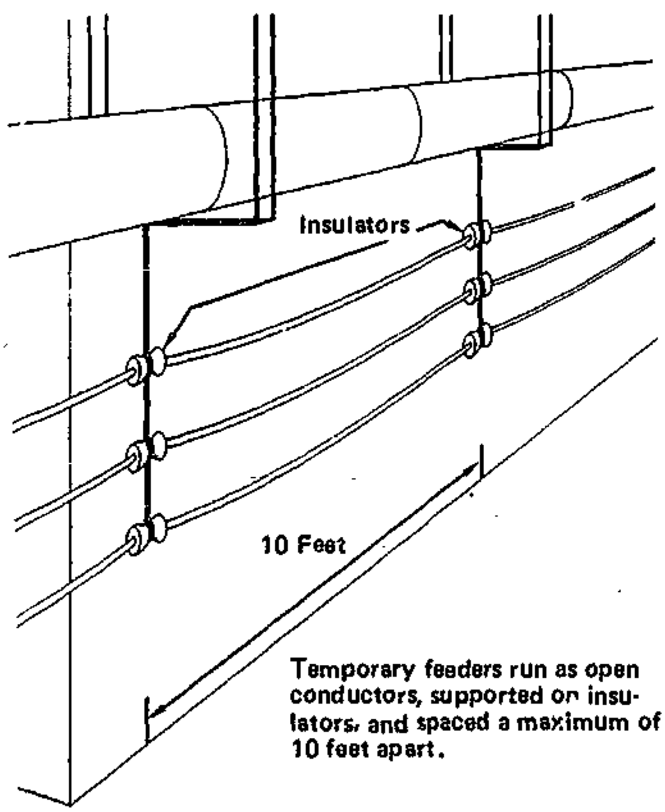


FIGURE 44. TEMPORARY FEEDERS RUN AS OPEN CONDUCTORS

(b) Branch circuits shall originate in an approved power outlet or panelboard. Conductors shall be multiconductor cord or cable assemblies or open conductors. If run as open conductors they shall be fastened at ceiling height every 10 feet. No branch-circuit conductor may be laid on the floor. Each branch circuit that supplies receptacles or fixed equipment shall contain a separate equipment grounding conductor if run as open conductors.

- BRANCH CIRCUITS

BRANCH CIRCUITS ARE THE CONDUCTORS BETWEEN THE LAST OVERCURRENT DEVICE IN AN ELECTRICAL SYSTEM AND THE OUTLETS, SUCH AS RECEPTACLES, LIGHTING OUTLETS, AND OUTLETS FOR ELECTRICAL EQUIPMENT WIRED DIRECTLY INTO A CIRCUIT. BRANCH CIRCUITS FOR TEMPORARY WIRING MUST ORIGINATE INSIDE AN APPROVED PANELBOARD OR POWER OUTLET THAT IS RATED FOR THE VOLTAGES AND CURRENTS THE SYSTEM IS EXPECTED TO CARRY. AS WITH FEEDERS, BRANCH CIRCUIT CONDUCTORS CAN BE CONTAINED WITHIN MULTI-CONDUCTOR CORD OR CABLE ASSEMBLIES, OR THEY CAN BE RUN AS OPEN CONDUCTORS. IF THE CONDUCTORS ARE RUN AS OPEN CONDUCTORS, THEY MUST BE SECURELY ATTACHED EVERY 10 FEET AT CEILING HEIGHT. TO AVOID PHYSICAL DAMAGE, BRANCH CIRCUIT CONDUCTORS MUST NEVER BE PLACED ON THE FLOOR (SEE FIGURE 45).

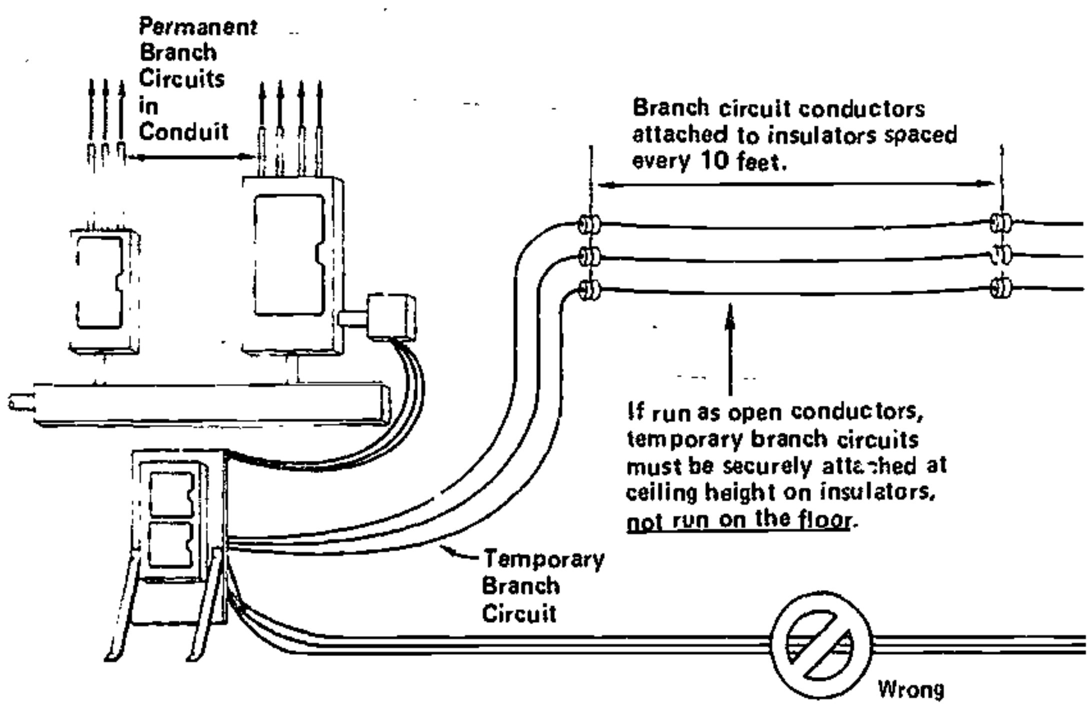


FIGURE 45. TEMPORARY BRANCH CIRCUIT

IF A BRANCH CIRCUIT SUPPLIES POWER TO A RECEPTACLE OR TO FIXED EQUIPMENT THROUGH A SYSTEM OF OPEN CONDUCTORS, AN ADDITIONAL CONDUCTOR MUST BE RUN WITH THE CIRCUIT CONDUCTORS TO GROUND EQUIPMENT.

- (c) Receptacles shall be of the grounding type. Unless installed in a complete metallic raceway, each branch circuit shall contain a separate equipment grounding conductor and all receptacles shall be electrically connected to the grounding conductor.

- RECEPTACLES

RECEPTACLES USED IN TEMPORARY WIRING CIRCUITS MUST PROVIDE A CONNECTION FOR AN EQUIPMENT GROUNDING CONDUCTOR. UNLESS THE RECEPTACLE IS SUPPLIED BY A METALLIC RACEWAY THAT PROVIDES A CONTINUOUS GROUNDING PATH BACK TO THE SOURCE, A SEPARATE EQUIPMENT GROUNDING CONDUCTOR MUST BE PLACED IN THE BRANCH CIRCUIT. THERE MUST BE A GOOD ELECTRICAL CONNECTION BETWEEN THE RECEPTACLE GROUNDING TERMINAL AND THE EQUIPMENT GROUNDING CONDUCTOR (SEE FIGURE 46).

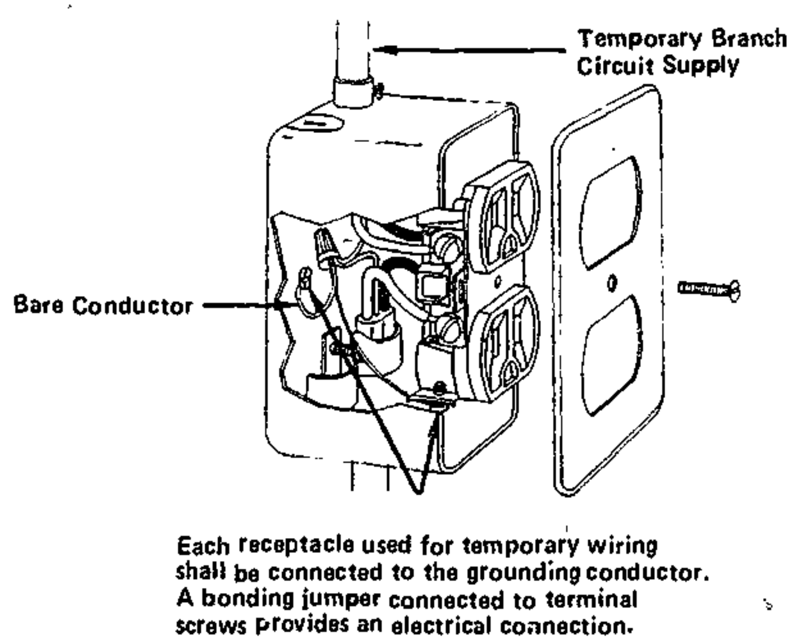


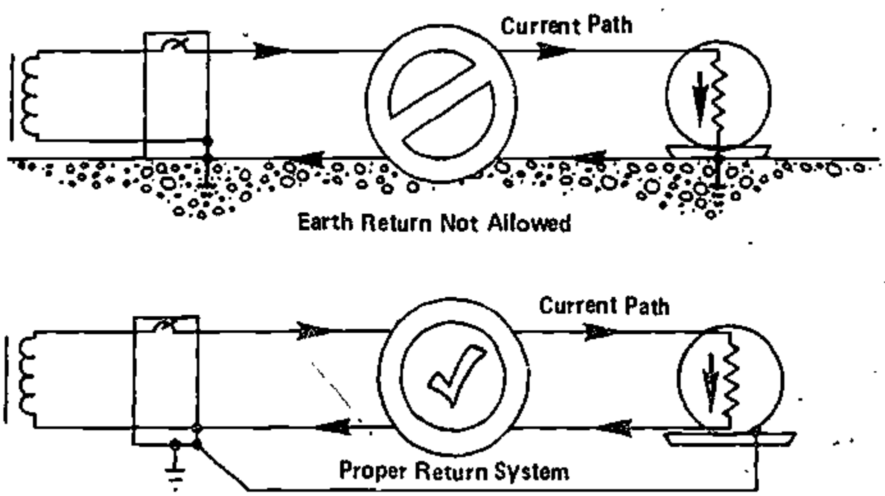
FIGURE 46. RECEPTACLE USED FOR TEMPORARY WIRING

(d) No bare conductors nor earth returns may be used for the wiring of any temporary circuit.

- EARTH RETURNS

BARE CONDUCTORS ARE CONDUCTORS THAT DO NOT HAVE ANY COVERINGS WHATSOEVER. BARE CONDUCTORS MUST NOT BE USED FOR WIRING TEMPORARY CIRCUITS.

EARTH RETURNS USE THE EARTH ITSELF TO PROVIDE A CURRENT PATH BACK TO THE SUPPLY SOURCE. THIS IS DONE BY IMPLANTING A GROUNDING ELECTRODE AT THE EQUIPMENT BEING SERVED AND CONNECTING THE EQUIPMENT TO THE UNGROUNDED CONDUCTOR AND TO THE GROUNDING ELECTRODE. SINCE ONE SIDE OF THE SUPPLY SOURCE IS ALSO CONNECTED TO GROUND THROUGH A GROUNDING ELECTRODE, A RETURN PATH EXISTS; HOWEVER, ITS EFFECTIVENESS IS DEPENDENT ON VARYING SOIL CONDITIONS. EARTH RETURNS MUST NOT BE USED FOR WIRING TEMPORARY CIRCUITS BECAUSE THEY ARE NOT ALWAYS EFFECTIVE AND MAY PRESENT A SERIOUS HAZARD ON TEMPORARY WORK SITES. FIGURE 47 SHOWS AN EARTH RETURN, WHICH IS NOT ALLOWED, IN CONTRAST TO A PROPER RETURN SYSTEM.



In addition, a separate equipment grounding conductor must be used to provide a low-impedance path to the source. This path will allow sufficient current to flow to operate the circuit breaker when a fault occurs.

FIGURE 47. EARTH RETURNS

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(e) Suitable disconnecting switches or plug connectors shall be installed to permit the disconnection of all ungrounded conductors of each temporary circuit.

- DISCONNECTING MEANS

SUITABLE SWITCHES OR PLUG CONNECTORS, SUCH AS THOSE APPROVED FOR USE IN DAMP LOCATIONS, MUST BE INSTALLED IN ALL UNGROUNDED, OR HOT, CONDUCTORS USED IN TEMPORARY CIRCUITS. THESE SWITCHES ALLOW POWER TO THE CONDUCTORS TO BE QUICKLY AND SAFELY DISCONNECTED IN EMERGENCIES OR FOR MAINTENANCE PURPOSES. FIGURE 4B SHOWS A PLUG CONNECTOR THAT IS ACCEPTABLE FOR USE WITH TEMPORARY CIRCUITS.

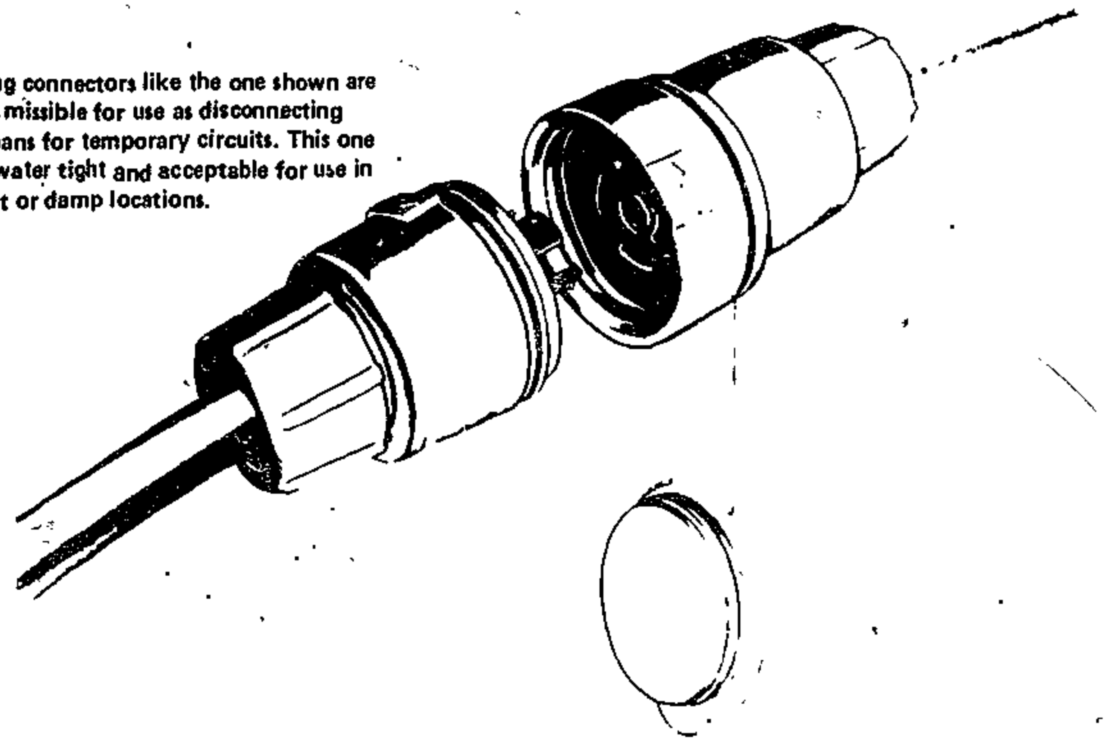

FIGURE 48. PLUG CONNECTOR FOR USE WITH TEMPORARY CIRCUITS

(f) Lamps for general illumination shall be protected from accidental contact or breakage. Protection shall be provided by elevation of at least 7 feet from normal working surface or by a suitable fixture or lampholder with a guard.

(g) Flexible cords and cables shall be protected from accidental damage. Sharp corners and projections shall be avoided. Where passing through doorways or other pinch points, flexible cords and cables shall be provided with protection to avoid damage.

(3) Cable trays.

(i) Uses permitted.

(a) Only the following may be installed in cable tray systems:

(1) Mineral-insulated metal-sheathed cable (Type MI);

(2) Armored cable (Type AC);

(3) Metal-clad cable (Type MC);
(4) Power-limited tray cable (Type PLTC);
(5) Nonmetallic-sheathed cable (Type NM or NMC);
(6) Shielded nonmetallic-sheathed cable (Type SNM);
(7) Multiconductor service-entrance cable (Type SE or USE);
(8) Multiconductor underground feeder and branch-circuit cable (Type UF);
(9) Power and control tray cable (Type TC);
(10) Other factory-assembled, multiconductor control, signal, or power cables which are specifically approved for installation in cable trays; or
(11) Any approved conduit or raceway with its contained conductors.

(b) In industrial establishments only, where conditions of maintenance and supervision assure that only qualified persons will service the installed cable tray system, the following cables may also be installed in ladder, ventilated trough, or 4 inch ventilated channel-type cable trays:
(1) Single conductor cables which are 250 MCM or larger and are Types RHH, RHW, MV, USE, or THW, and other 250 MCM or larger single conductor cables if specifically approved for installation in cable trays. Where exposed to direct rays of the sun, cables shall be sunlight-resistant.
(2) Type MV cables, where exposed to direct rays of the sun, shall be sunlight-resistant.

(c) Cable trays in hazardous (classified) locations shall contain only the cable types permitted in such locations.

(ii) Uses not permitted. Cable tray systems may not be used in hoistways or where subjected to severe physical damage.

(4) Open wiring on insulators.

(i) Uses permitted. Open wiring on insulators is only permitted on systems of 600 volts, nominal, or less for industrial or agricultural establishments and for services.

(ii) Conductor supports. Conductors shall be rigidly supported on noncombustible, nonabsorbent insulating materials and may not contact any other objects.

(iii) Flexible nonmetallic tubing. In dry locations where not exposed to severe physical damage, conductors may be separately enclosed in flexible nonmetallic tubing. The tubing shall be in continuous lengths not exceeding 15 feet and secured to the surface by straps at intervals not exceeding 4 feet 6 inches.

(iv) Through walls, floors, wood cross members, etc. Open conductors shall be separated from contact with walls, floors, wood cross members, or partitions through which they pass by tubes or bushings of noncombustible, nonabsorbent insulating material. If the bushing is shorter than the hole, a waterproof sleeve of nonconductive material shall be inserted in the hole and an insulating bushing slipped into the sleeve at each end in such a manner as to keep the conductors absolutely out of contact with the sleeve. Each conductor shall be carried through a separate tube or sleeve.

(v) Protection from physical damage. Conductors within 7 feet from the floor are considered exposed to physical damage. Where open conductors cross ceiling joists and wall studs and are exposed to physical damage, they shall be protected.

(b) Cabinets, boxes, and fittings.

(1) Conductors entering boxes, cabinets, or fittings. Conductors entering boxes, cabinets, or fittings shall be protected from abrasion, and openings through which conductors enter shall be effectively closed. Unused openings in cabinets, boxes, and fittings shall also be effectively closed.

- CONDUCTORS ENTERING BOXES, CABINETS, OR FITTINGS

SINCE CONDUCTORS CAN BE DAMAGED IF THEY RUB AGAINST THE SHARP EDGES OF CABINETS, BOXES, OR FITTINGS, THEY MUST BE PROTECTED FROM DAMAGE WHERE THEY ENTER. TO PROTECT THE CONDUCTORS, SOME TYPE OF CLAMP OR RUBBER GROMMET MUST BE USED. THE DEVICE USED MUST CLOSE THE HOLE THROUGH WHICH THE CONDUCTOR PASSES AS WELL AS PROVIDE PROTECTION FROM ABRASION. IF THE CONDUCTOR IS IN A CONDUIT AND THE CONDUIT FITS TIGHTLY IN THE OPENING, ADDITIONAL SEALING IS NOT REQUIRED.

THE KNOCKOUTS IN CABINETS, BOXES, AND FITTINGS SHOULD BE REMOVED ONLY IF CONDUCTORS ARE TO BE RUN THROUGH THEM. HOWEVER, IF A KNOCKOUT IS MISSING OR IF THERE IS ANOTHER HOLE IN THE BOX, THE HOLE OR OPENING MUST BE CLOSED.

Cable clamps protect conductors from abrasion and effectively close the opening.

FIGURE 49. CONDUCTOR ENTERING BOX OR CABINET

(2) Covers and canopies. All pull boxes, junction boxes, and fittings shall be provided with covers approved for the purpose. If metal covers are used they shall be grounded. In completed installations each outlet box shall have a cover, faceplate, or fixture canopy. Covers of outlet boxes having holes through which flexible cord pendants pass shall be provided with bushings designed for the purpose or shall have smooth, well-rounded surfaces on which the cords may bear.

(3) Pull and junction boxes for systems over 600 volts, nominal. In addition to other requirements in this section for pull and junction boxes, the following shall apply to these boxes for systems over 600 volts, nominal:

(i) Boxes shall provide a complete enclosure for the contained conductors or cables.

(ii) Boxes shall be closed by suitable covers securely fastened in place. Underground box covers that weigh over 100 pounds meet this requirement. Covers for boxes shall be permanently marked "HIGH VOLTAGE." The marking shall be on the outside of the box cover and shall be readily visible and legible.

(c) Switches.

- (1) Knife switches. Single-throw knife switches shall be so connected that the blades are dead when the switch is in the open position. Single-throw knife switches shall be so placed that gravity will not tend to close them. Single-throw knife switches approved for use in the inverted position shall be provided with a locking device that will ensure that the blades remain in the open position when so set.

- KNIFE SWITCHES

SINGLE-THROW KNIFE SWITCHES HAVE ONE ENERGIZED (CLOSED OR "ON") POSITION AND ONE OPEN (DEAD OR "OFF") POSITION. THE SWITCH MUST BE DESIGNED SO THAT WHEN IT IS IN THE OPEN POSITION, THE BLADES ARE NOT ENERGIZED (I.E., THE BLADES MUST BE CONNECTED TO THE LOAD SIDE, NOT THE SUPPLY SIDE OF THE CIRCUIT). THE SWITCHES MUST ALSO BE INSTALLED SO THAT IF THE SWITCH FALLS DOWNWARD, IT WILL NOT FALL INTO ITS ENERGIZED POSITION. HOWEVER, SOME SINGLE-THROW KNIFE SWITCHES ARE DESIGNED TO BE INSTALLED SO THAT THEY OPEN UPWARD. TO BE APPROVED FOR THIS TYPE OF INSTALLATION, THEY MUST HAVE A LATCH OR OTHER LOCKING DEVICE (SUCH AS A SPRING-LOADED DEVICE) USED TO SECURE THE SWITCH IN THE OPEN POSITION. THE ILLUSTRATION IN FIGURE 50A SHOWS A SINGLE-THROW KNIFE SWITCH CONNECTED SO THAT THE BLADES ARE DEAD WHEN THE SWITCH IS OPEN. ADDITIONALLY, FIGURE 50B SHOWS A LATCH ARRANGEMENT THAT HOLDS THE BLADE IN THE OPEN POSITION AND WILL PREVENT GRAVITY FROM PULLING THE SWITCH CLOSED.

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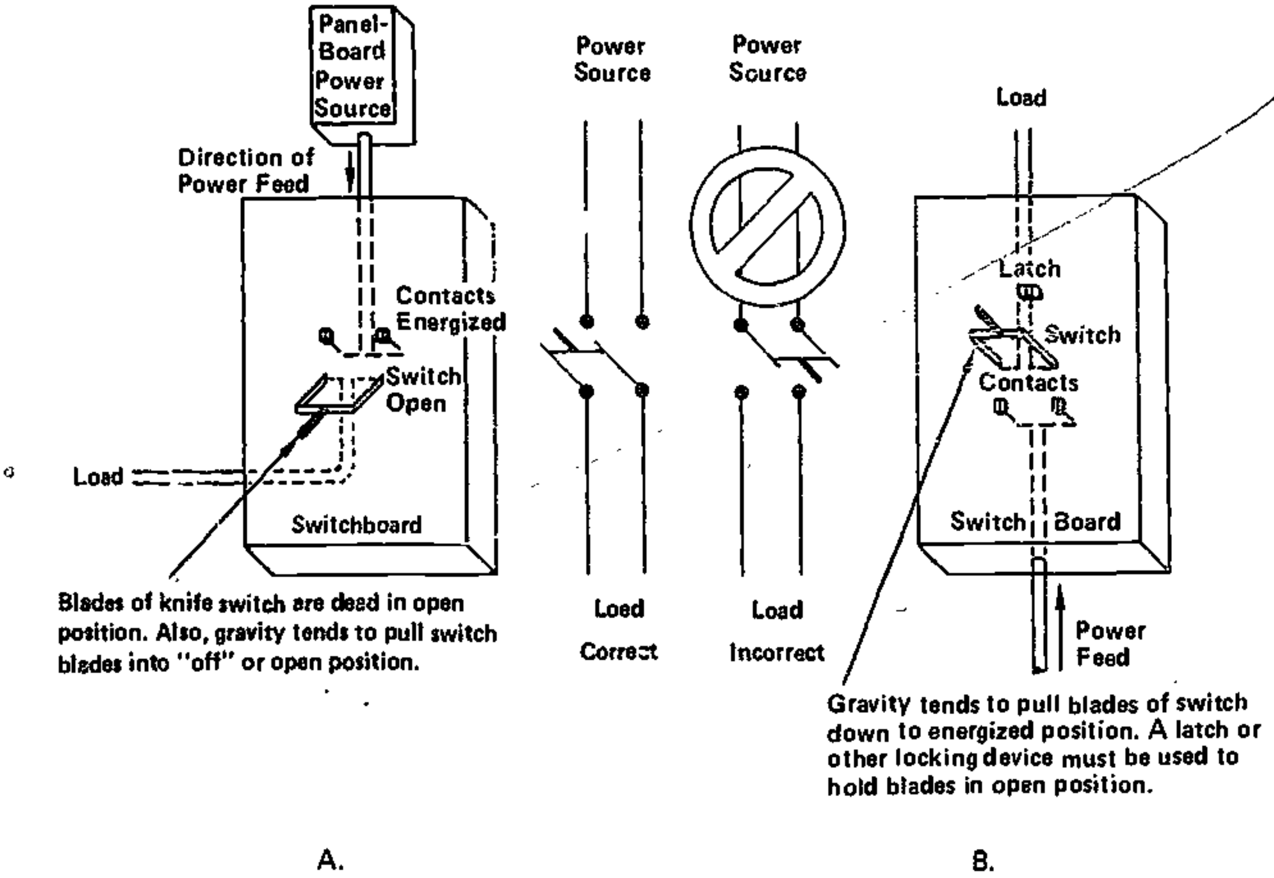

FIGURE 50. KNIFE SWITCHES

- Double-throw knife switches may be mounted so that the throw will be either vertical or horizontal. However, if the throw is vertical a locking device shall be provided to ensure that the blades remain in the open position when so set.

- DOUBLE-THROW KNIFE SWITCHES

DOUBLE-THROW KNIFE SWITCHES ARE KNIFE SWITCHES THAT HAVE TWO ENERGIZED (CLOSED OR "ON") POSITIONS AND ONE OPEN (DEAD OR "OFF") POSITION. THESE SWITCHES CAN BE MOUNTED VERTICALLY SO THAT THEY ARE MOVED UP AND DOWN, OR HORIZONTALLY SO THAT THEY ARE MOVED BACK AND FORTH. IF SWITCHES ARE MOUNTED VERTICALLY, THEY MUST HAVE A LOCKING DEVICE (SUCH AS A SPRING-LOADED DEVICE) THAT WILL HOLD THE SWITCH BLADES IN THE OPEN POSITION (SEE FIGURE 51).

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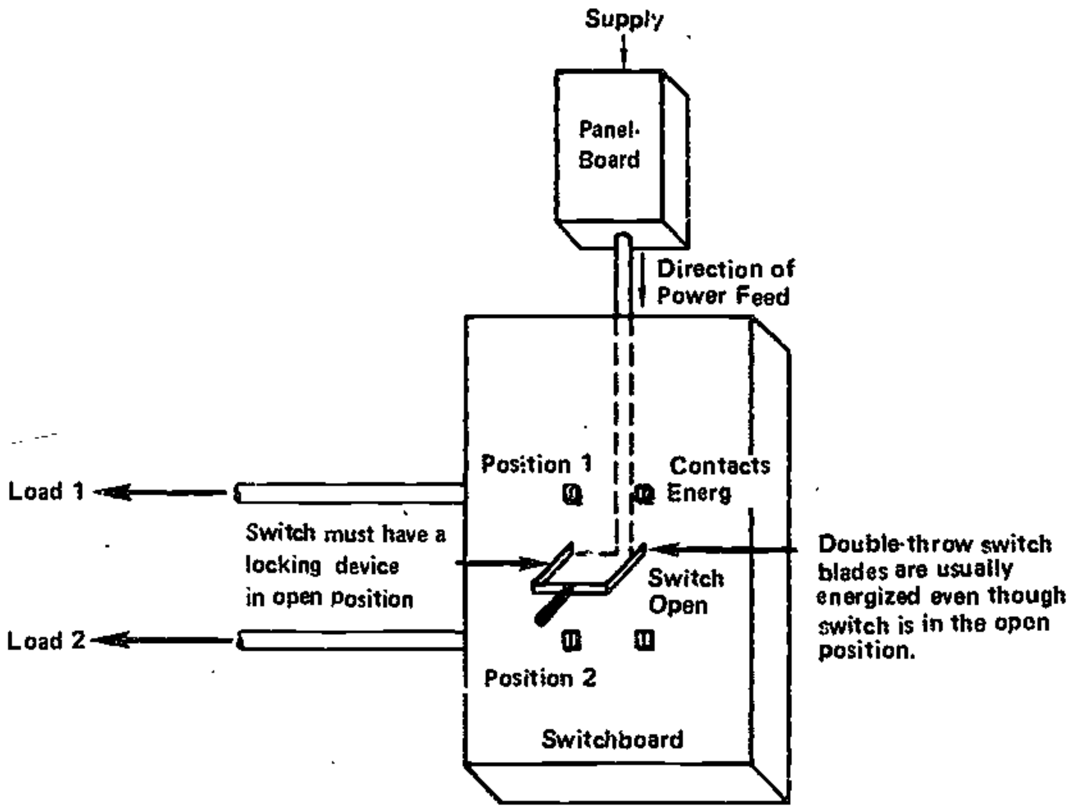

FIGURE 51. DOUBLE-THROW KNIFE SWITCHES WITH LOCKING DEVICE

(2) Faceplates for flush-mounted snap switches. Flush snap switches that are mounted in ungrounded metal boxes and located within reach of conducting floors or other conducting surfaces shall be provided with faceplates of nonconducting, noncombustible material.

• (d) Switchboards and panelboards. Switchboards that have any exposed live parts shall be located in permanently dry locations and accessible only to qualified persons. Panelboards shall be mounted in cabinets, cutout boxes, or enclosures approved for the purpose and shall be dead front. However, panelboards other than the dead front externally-operable type are permitted where accessible only to qualified persons. Exposed blades of knife switches shall be dead when open.

• SWITCHBOARDS AND PANELBOARDS

A SWITCHBOARD THAT HAS EXPOSED LIVE PARTS MUST BE LOCATED IN AN AREA THAT IS NOT SUBJECT TO WETNESS OR DAMPNESS. ONE PURPOSE OF THIS REGULATION IS TO LESSEN THE CHANCE OF SEVERE SHOCK IF A WORKER ACCIDENTALLY CAME INTO CONTACT WITH THE LIVE PARTS. ADDITIONALLY, ONLY QUALIFIED PERSONS MAY HAVE ACCESS TO SWITCHBOARDS WITH EXPOSED LIVE PARTS. TO LIMIT ACCESS, THE SWITCHBOARD SHOULD BE LOCATED IN A LOCKED ROOM OR WITHIN A LOCKED CAGE OR FENCED AREA. KEYS TO THE LOCKS SHOULD BE CONTROLLED TO ENSURE THAT ONLY PROPERLY TRAINED PERSONNEL ARE ALLOWED TO ENTER THE AREA.

PANELBOARDS MUST BE MOUNTED IN ENCLOSURES AND MUST BE RATED FOR THE VOLTAGES AND CURRENTS INVOLVED. PANELBOARDS, LIKE SWITCHBOARDS, MAY HAVE EXPOSED LIVE PARTS IF ONLY PROPERLY TRAINED PERSONNEL WILL HAVE ACCESS TO THEM. IF THE PANELBOARD HAS AN EXPOSED KNIFE SWITCH, THE BLADES MUST BE DE-ENERGIZED WHEN THE SWITCH IS OPEN. (SEE ALSO DISCUSSION OF KNIFE SWITCHES, PAGE 68.

(e) Enclosures for damp or wet locations.

(1) Cabinets, cutout boxes, fittings, boxes, and panelboard enclosures in damp or wet locations shall be installed so as to prevent moisture or water from entering and accumulating within the enclosures. In wet locations the enclosures shall be weatherproof.

(2) Switches, circuit breakers, and switchboards installed in wet locations shall be enclosed in weatherproof enclosures.

• (f) Conductors for general wiring. All conductors used for general wiring shall be insulated unless otherwise permitted in this Subpart. The conductor insulation shall be of a type that is approved for the voltage, operating temperature, and location of use. Insulated conductors shall be distinguishable by appropriate color or other suitable means as being grounded conductors, ungrounded conductors, or equipment grounding conductors.

• CONDUCTOR INSULATION

TO PROVIDE ADEQUATE PROTECTION AGAINST SHOCK AND FIRE HAZARDS, CONDUCTORS MUST BE INSULATED WITH APPROVED MATERIALS. INSULATING MATERIAL SHOULD BE THE APPROPRIATE COMPOSITION AND THICKNESS FOR THE VOLTAGE AND CURRENT THE CONDUCTOR WILL CARRY, FOR THE TEMPERATURE EXTREMES AND OTHER ENVIRONMENTAL FACTORS TO WHICH IT WILL BE SUBJECTED, AND FOR THE LOCATION IN WHICH IT IS TO BE PLACED.

INSULATED CONDUCTORS MUST ALSO BE EASILY IDENTIFIABLE, AND COLOR CODING IS MOST OFTEN USED. NEUTRAL, OR GROUNDED, CONDUCTORS SHOULD BE WHITE OR NATURAL GRAY. GROUNDING CONDUCTORS SUCH AS EQUIPMENT GROUNDING CONDUCTORS SHOULD BE GREEN OR GREEN WITH YELLOW STRIPES. GROUNDING CONDUCTORS ARE PERMITTED TO BE BARE WIRES. OTHER TYPES OF CIRCUIT WIRES MAY BE ANY COLORS EXCEPT THESE. FIGURE 52 SHOWS THE CONSTRUCTION OF A TYPICAL MULTICONDUCTOR CABLE. INCLUDING THE INSULATION ON THE INDIVIDUAL CONDUCTORS.

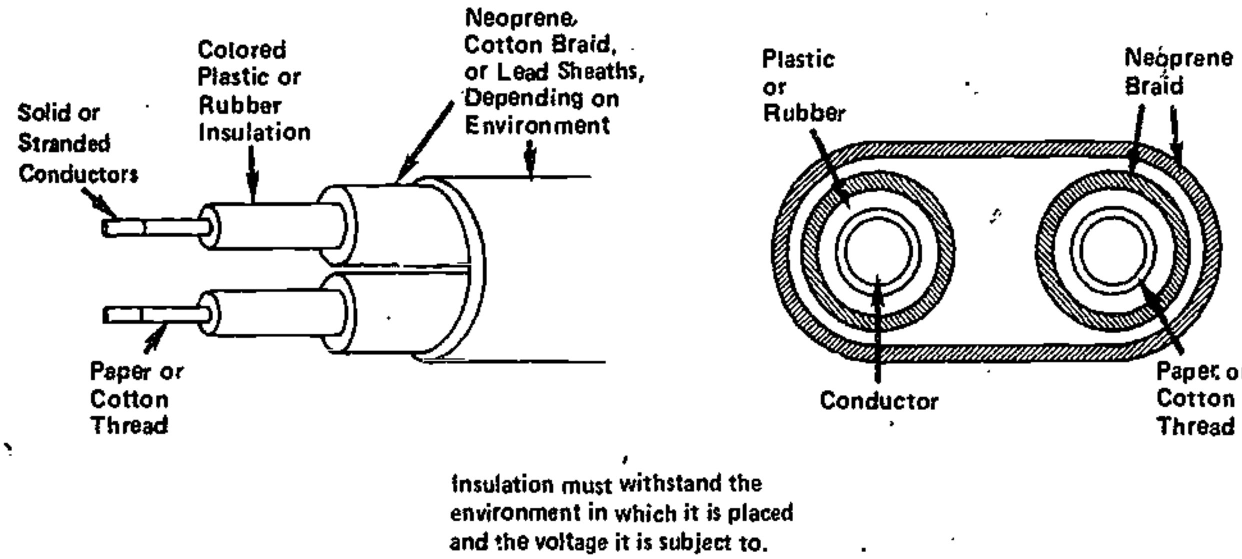

FIGURE 52. TYPICAL MULTICONDUCTOR INSULATION

(g) Flexible cords and cables.

(1) Use of flexible cords and cables.

(i) Flexible cords and cables shall be approved and suitable for conditions of use and location. Flexible cords and cables shall be used only for:

(a) Pendants;
(b) Wiring of fixtures;
(c) Connection of portable lamps or appliances;
(d) Elevator cables;
(e) Wiring of cranes and hoists;
(f) Connection of stationary equipment to facilitate their frequent interchange;
(g) Prevention of the transmission of noise or vibration;
(h) Appliances where the fastening means and mechanical connections are designed to permit removal for maintenance and repair; or
(i) Data processing cables approved as a part of the data processing system.

(ii) If used as permitted in paragraphs (g)(1)(i)(c), (g)(1)(i)(f), or (g)(1)(i)(h) of this section, the flexible cord shall be equipped with an attachment plug and shall be energized from an approved receptacle outlet.

(iii) Unless specifically permitted in paragraph (g)(1)(i) of this section, flexible cords and cables may not be used:

(a) As a substitute for the fixed wiring of a structure;
(b) Where run through holes in walls, ceilings, or floors;
(c) Where run through doorways, windows, or similar openings;
(d) Where attached to building surfaces; or
(e) Where concealed behind building walls, ceilings, or floors.

(iv) Flexible cords used in show windows and showcases shall be Type S, SO, SJ, SJO, ST, STO, SJT, SJTO, or AFS except for the wiring of chain-supported lighting fixtures and supply cords for portable lamps and other merchandise being displayed or exhibited.

(2) Identification, splices, and terminations.

(i) A conductor of a flexible cord or cable that is used as a grounded conductor or an equipment grounding conductor shall be distinguishable from other conductors. Types SJ, SJO, SJT, SJTO, S, SO, ST, and STO shall be durably marked on the surface with the type designation, size, and number of conductors.

(ii) Flexible cords shall be used only in continuous lengths without splice or tap. Hard service flexible cords No. 12 or larger may be repaired if spliced so that the splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced.

(iii) Flexible cords shall be connected to devices and fittings so that strain relief is provided which will prevent pull from being directly transmitted to joints or terminal screws.

(h) Portable cables over 600 volts, nominal. Multiconductor portable cable for use in supplying power to portable or mobile equipment at over 600 volts, nominal, shall consist of No. 8 or larger conductors employing flexible stranding. Cables operated at over 2000 volts shall be shielded for the purpose of confining the voltage stresses to the insulation. Grounding conductors shall be provided. Connectors for these cables shall be of a locking type with provisions to prevent their opening or closing while energized. Strain relief shall be provided at connections and terminations. Portable cables may not be operated with splices unless the splices are of the permanent molded, vulcanized, or other approved type. Termination enclosures shall be suitably marked with a high voltage hazard warning, and terminations shall be accessible only to authorized and qualified personnel.

(i) Fixture wires.

(1) General. Fixture wires shall be approved for the voltage, temperature, and location of use. A fixture wire which is used as a grounded conductor shall be identified.

(2) Uses permitted. Fixture wires may be used:

(i) For installation in lighting fixtures and in similar equipment where enclosed or protected and not subject to bending or twisting in use; or

(ii) For connecting lighting fixtures to the branch-circuit conductors supplying the fixtures.

(3) Uses not permitted. Fixture wires may not be used as branch-circuit conductors except as permitted for Class 1 power limited circuits.

(j) Equipment for general use.

(1) Lighting fixtures, lampholders, lamps, and receptacles.

(i) Fixtures, lampholders, lamps, rosettes, and receptacles may have no live parts normally exposed to employee contact. However, rosettes and cleat-type lampholders and receptacles located at least 8 feet above the floor may have exposed parts.

(ii) Handlamps of the portable type supplied through flexible cords shall be equipped with a handle of molded composition or other material approved for the purpose, and a substantial guard shall be attached to the lampholder or the handle.

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(iii) Lampholders of the screw-shell type shall be installed for use as lampholders only. Lampholders installed in wet or damp locations shall be of the weatherproof type.

- LAMPHOLDERS

SCREW-SHELL TYPE LAMPHOLDERS MUST BE USED ONLY AS LAMPHOLDERS AND MUST NOT BE USED WITH SCREW-BASE SOCKET ADAPTERS. THESE ADAPTERS SCREW INTO THE EXISTING LAMP SOCKET AND CONVERT LAMPHOLDERS INTO RECEPTACLES. THESE ADAPTERS ARE NOT PERMISSIBLE BECAUSE EQUIPMENT GROUNDING CONNECTIONS CANNOT BE MADE THROUGH THE TWO-BLADE ADAPTERS AND BECAUSE THE FIXTURE HAS BEEN DESIGNED ONLY FOR LIGHTING. ONLY WEATHERPROOF LAMPHOLDERS MAY BE INSTALLED IN WET OR DAMP AREAS (SEE FIGURE 53). UNPROTECTED LAMPHOLDERS MIGHT ALLOW MOISTURE TO ENTER THE LAMPHOLDER SOCKET, CREATING AN ELECTRICAL SHOCK HAZARD.

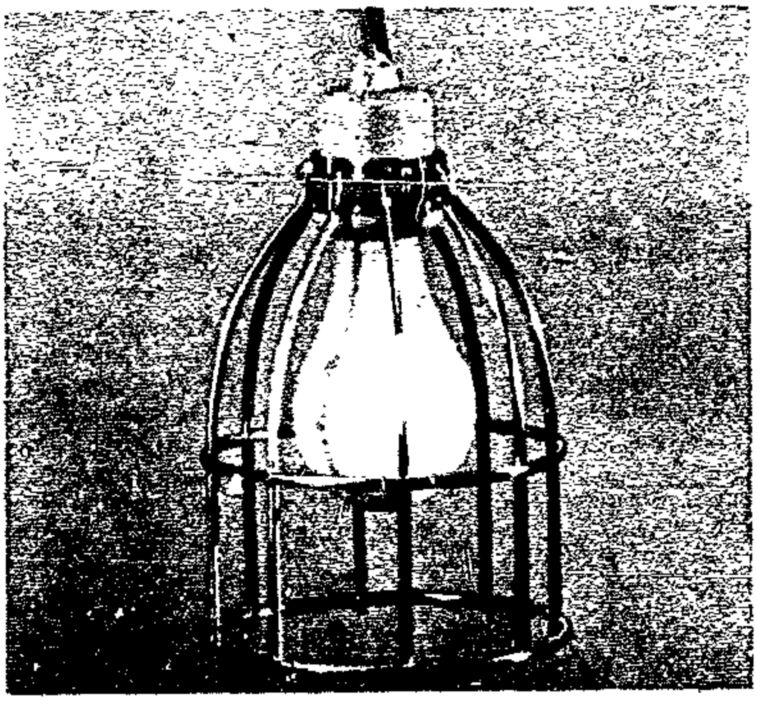

FIGURE 53. A COMMERCIALLY AVAILABLE WEATHERPROOF LAMPHOLDER

(iv) Fixtures installed in wet or damp locations shall be approved for the purpose and shall be so constructed or installed that water cannot enter or accumulate in wireways, lampholders, or other electrical parts.

(2) Receptacles, cord connectors, and attachment plugs (caps).

(i) Receptacles, cord connectors, and attachment plugs shall be constructed so that no receptacle or cord connector will accept an attachment plug with a different voltage or current rating than that for which the device is intended. However, a 20-ampere T-slot receptacle or cord connector may accept a 15-ampere attachment plug of the same voltage rating.

- RECEPTACLES, CORD CONNECTORS, AND ATTACHMENT PLUGS (CAPS)

CORD CONNECTORS ARE DEVICES THAT JOIN TWO SECTIONS OF ELECTRICAL CORD TOGETHER. ATTACHMENT PLUGS ARE DEVICES THAT ARE FASTENED ONTO THE END OF A CORD SO THAT ELECTRICAL CONTACT CAN BE MADE BETWEEN THE CONDUCTORS IN THE CORD AND THE CONDUCTORS IN A RECEPTACLE. CONNECTORS, PLUGS, AND RECEPTACLES ARE UNIQUELY DESIGNED FOR DIFFERENT VOLTAGES AND CURRENTS, SO THAT ONLY MATCHING PLUGS WILL FIT INTO THE CORRECT RECEPTACLE OR CORD CONNECTOR. IN THIS WAY, A PIECE OF EQUIPMENT RATED FOR ONE VOLTAGE/CURRENT COMBINATION CANNOT BE PLUGGED INTO A POWER SYSTEM THAT IS OF A DIFFERENT VOLTAGE OR CURRENT CAPACITY.

THE ONLY EXCEPTIONS TO THIS ARE 125-VOLT AND 250-VOLT, 20-AMPERE, T-SLOT RECEPTACLES. ONE OF THESE IS ILLUSTRATED IN FIGURE 54. A 125-VOLT AND A

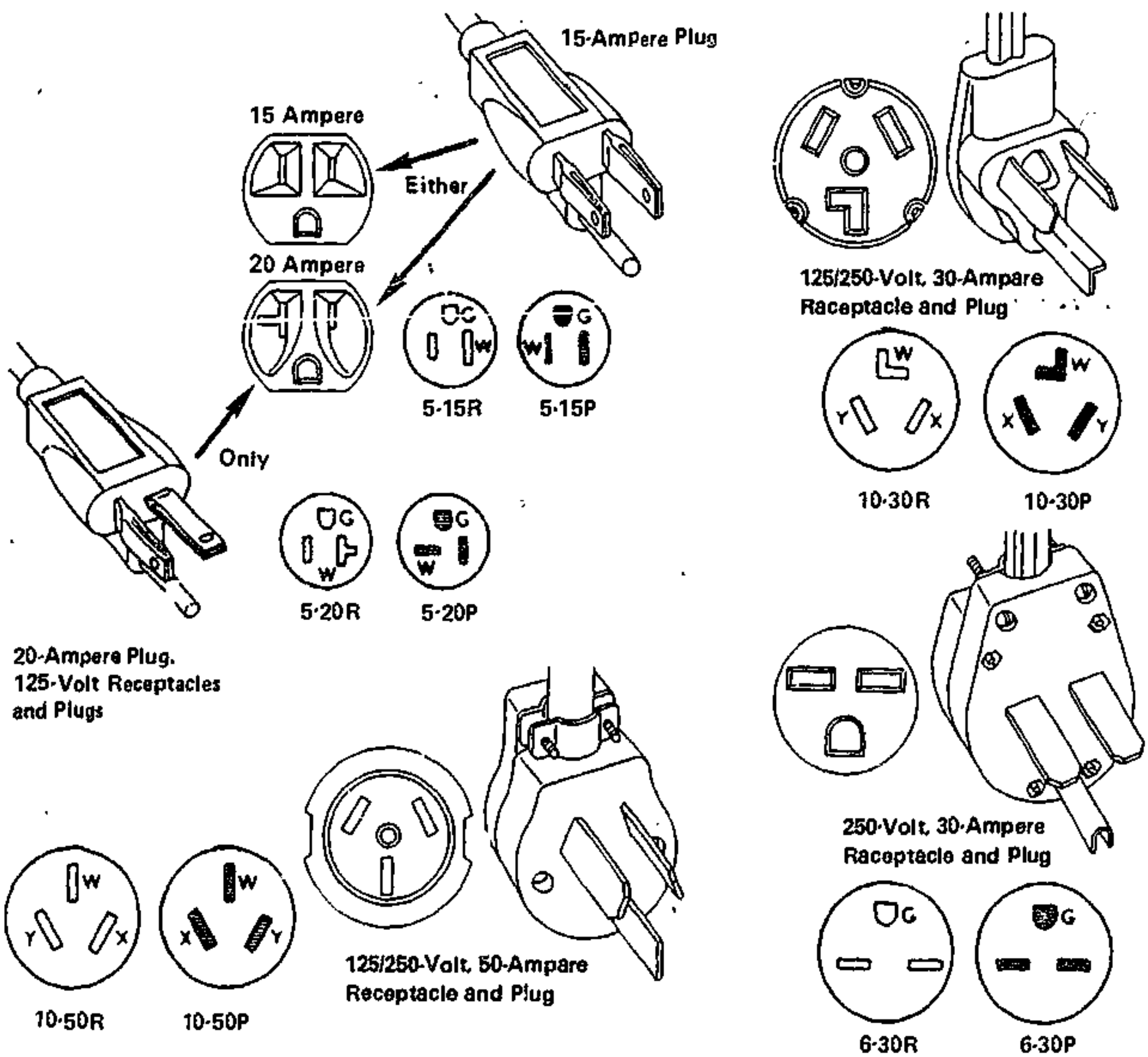

FIGURE 54. RECEPTACLES AND PLUGS WITH NEMA CONFIGURATIONS

250-VOLT, 15-AMPERE PLUG WILL FIT INTD A 20-AMPERE T-SLOT RECEPTACLE OR CONNECTDR OF THE SAME VDLTAGE RATING AS WELL AS IN A 120-VOLT, 15-AMPERE GROUNDING TYPE RECEPTACLE DR CONNECTOR OF THE SAME VOLTAGE RATING. AN ELECTRICAL APPLIANCE THAT IS RATED FOR 15 AMPERES WILL NOT OVERLOAD A 20-AMPERE CIRCUIT, AND THE 20-AMPERE BREAKER WILL STILL PROVIDE OVERCURRENT PROTECTION FOR 15-AMPERE EQUIPMENT. NOTE THAT THE OPPOSITE IS NOT NECESSARILY TRUE AND THAT A 20-AMPERE PLUG WILL NDT FIT INTO A 15-AMPERE RECEPTACLE OR CORD CONNECTOR.

THE NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA) HAS STANDARD PLUG AND RECEPTACLE CDNNECTOR BLADE CDNFIGURATION. EACH HAS BEEN DEVELOPED TO STANDARDIZE THE USE OF PLUGS AND RECEPTACLES FOR DIFFERENT VOLTAGES, AMPERAGES, AND PHASES FROM 115 VOLTS THROUGH 600, FROM 15 AMPERES THROUGH 60, AND FOR SINGLE- AND THREE-PHASE SYSTEMS.

(ii) A receptacle installed in a wet or damp location shall be suitable for the location.

(3) Appliances.

- (i) Appliances, other than those in which the current-carrying parts at high temperatures are necessarily exposed, may have no live parts normally exposed to employee contact.

- APPLIANCES

ELECTRICAL APPLIANCES SUCH AS PORTABLE AIR CONDITIONING UNITS, COFFEEMAKERS, AND FANS MUST NOT HAVE ANY EXPOSED LIVE WIRES OR ELECTRICAL PARTS THAT MIGHT CREATE AN ELECTRICAL SHOCK HAZARD.

EXCEPTIONS TD THIS ARE APPLIANCES SUCH AS HEATERS OR TOASTERS THAT MUST HAVE EXPDSED CURRENT-CARRYING PARTS THAT OPERATE AT HIGH TEMPERATURES TO TRANSFER HEAT (SEE FIGURE 55). THE HEAT GENERATED BY THESE PARTS MINIMIZES THE POSSIBILITY OF DIRECT CONTACT AND RESULTANT ELECTRIC SHOCK.

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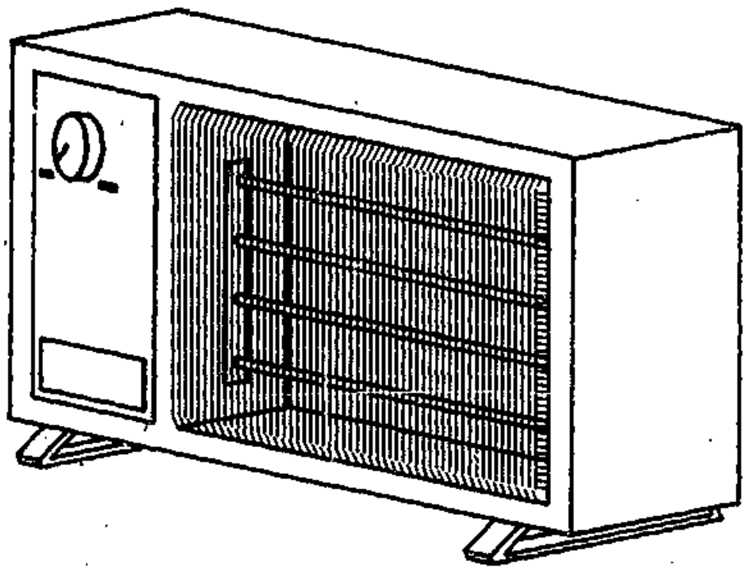


Energized Heating Elements Inside the Heater Are Guarded

FIGURE 55. ELECTRIC SPACE HEATER
WITH ELEMENTS EXPOSED

- (ii) A means shall be provided to disconnect each appliance.

- APPLIANCE DISCONNECTING MEANS

A DISCONNECTING MEANS IS A SWITCH OR PLUG THAT CAN OPEN AN ELECTRIC CIRCUIT UNDER LOAD AND SAFELY STOP THE FLOW OF CURRENT. ALL APPLIANCES MUST HAVE A DISCONNECTING MEANS. IN SOME CASES, THE DISCONNECTING MEANS MAY BE A UNIT SWITCH OR AN ATTACHMENT PLUG. ON PERMANENTLY CONNECTED APPLIANCES THAT OPERATE AT LESS THAN 300 VOLT-AMPERES, THE BRANCH CIRCUIT OVERCURRENT DEVICE (CIRCUIT BREAKER OR FUSE) MAY BE USED AS THE DISCONNECTING MEANS.

(iii) Each appliance shall be marked with its rating in volts and amperes or volts and watts.

(4) Motors. This paragraph applies to motors, motor circuits, and controllers.

(i) In sight from. If specified that one piece of equipment shall be "in sight from" another piece of equipment, one shall be visible and not more than 50 feet from the other.

(ii) Disconnecting means.

(a) A disconnecting means shall be located in sight from the controller location. However, a single disconnecting means may be located adjacent to a group of coordinated controllers mounted adjacent to each other on a multi-motor continuous process machine. The controller disconnecting means for motor branch circuits over 600 volts, nominal, may be out of sight of the controller, if the controller is marked with a warning label giving the location and identification of the disconnecting means which is to be locked in the open position.

- MOTOR DISCONNECTING MEANS

A MOTOR CONTROLLER IS A DEVICE, SUCH AS A SWITCH OR CIRCUIT BREAKER, THAT CONTROLS POWER TO A MOTOR. THE CONTROLLER TURNS THE POWER OFF AND ON AND LIMITS THE CURRENT FLOW. A DISCONNECTING MEANS FOR THE CONTROLLER MUST BE WITHIN SIGHT FROM THE CONTROLLER (I.E., VISIBLE FROM THE CONTROLLER AND LOCATED WITHIN 50 FEET OF THE CONTROLLER) (SEE FIGURE 56). IF A GROUP OF CONTROLLERS ARE LOCATED TOGETHER AND ARE USED TO CONTROL POWER TO MORE THAN ONE MOTOR ON A SINGLE CONTINUOUS PROCESS MACHINE, A SINGLE DISCONNECT SWITCH, LOCATED WITH THE CONTROLLERS, CAN BE USED. IT SHOULD BE NOTED THAT IT IS POSSIBLE FOR A SWITCH OR CIRCUIT BREAKER TO SERVE AS BOTH A CONTROLLER AND A DISCONNECT. THIS DEPENDS ON WHERE THE SWITCH IS LOCATED AND THE RATING OF BOTH THE MOTOR AND THE SWITCH. DETAILED SPECIFICATIONS ON MOTOR DISCONNECTING MEANS ARE GIVEN IN ARTICLE 430 OF THE NEC.

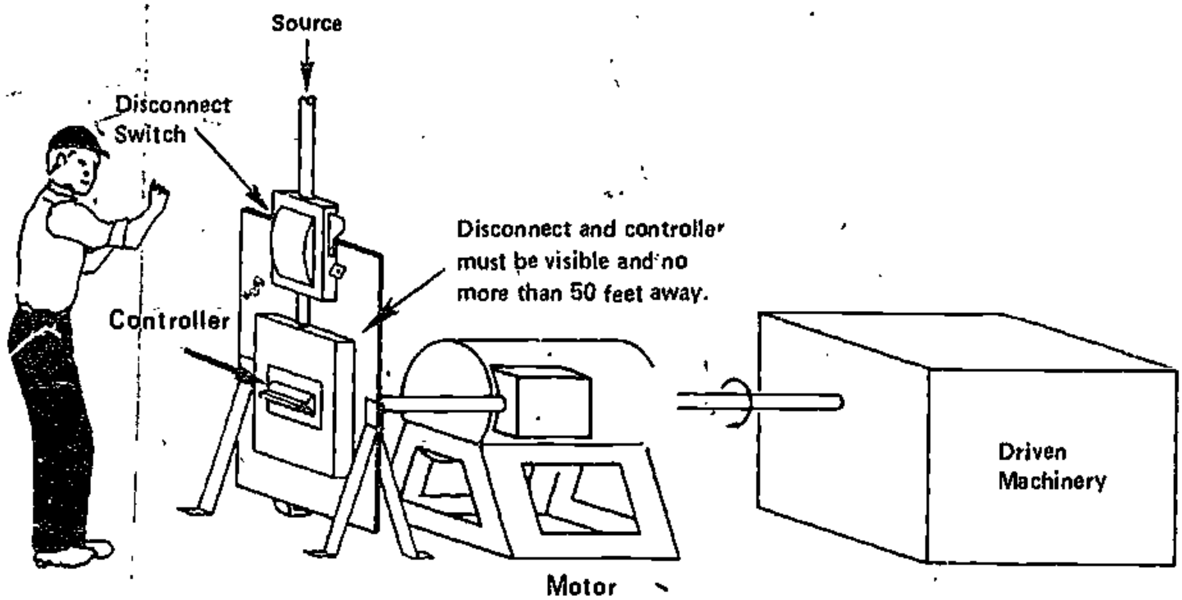


FIGURE 56. MOTOR DISCONNECTING MEANS

FOR LARGER CAPACITY MOTORS OPERATING AT VOLTAGES GREATER THAN 600 VOLTS, THE DISCONNECT CAN BE OUT OF SIGHT OF THE CONTROLLER IF THE CONTROLLER AND THE DISCONNECT ARE LABELED. WARNING LABELS ON THE CONTROLLER SHOULD INDICATE WHERE THE DISCONNECT IS LOCATED AND THAT IT IS TO BE LOCKED OUT FOR MAINTENANCE. THE DISCONNECT MUST BE LABELED WITH IDENTIFICATION SUCH AS A NUMBER TO ENSURE THAT THE CORRECT DISCONNECT IS OPENED OR DE-ENERGIZED. SEE FIGURE 57.

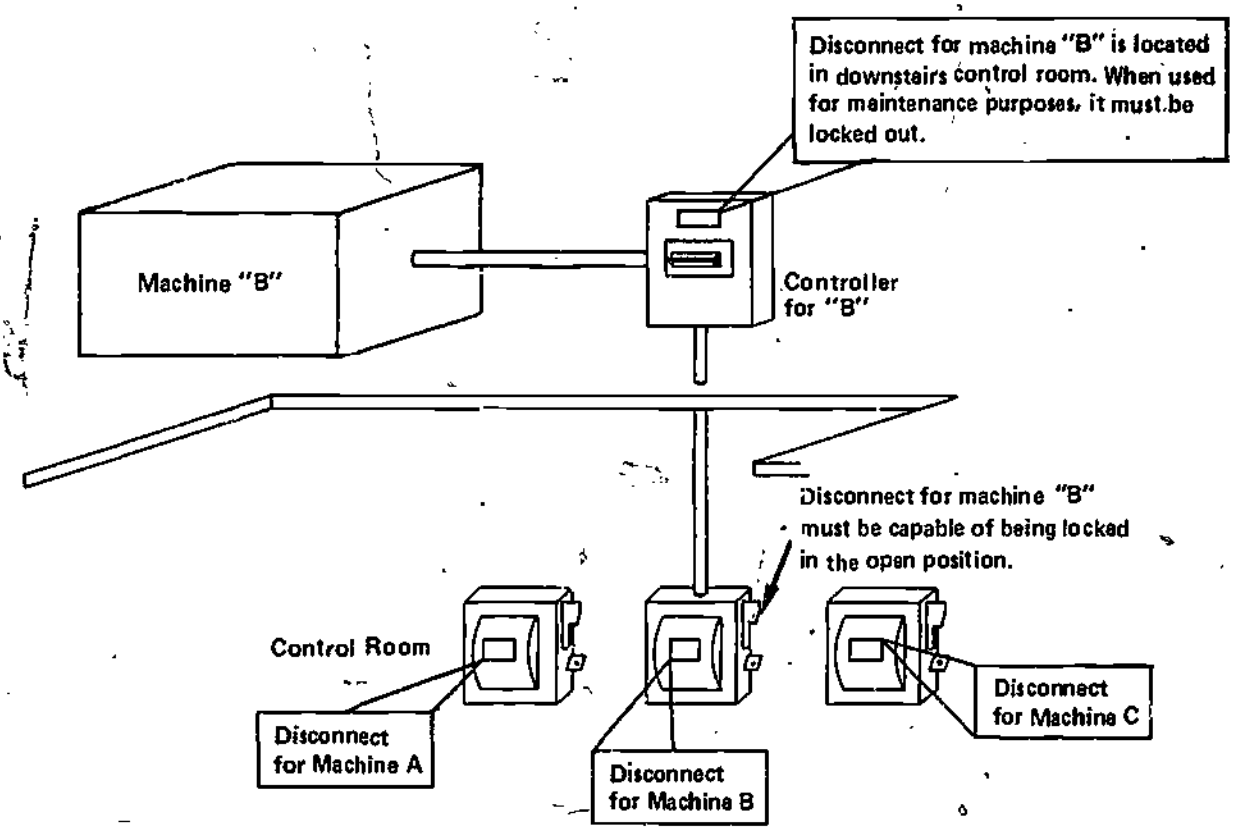


FIGURE 57. LABELING REQUIRED WHEN DISCONNECTS ARE OUT OF SIGHT

(b) The disconnecting means shall disconnect the motor and the controller from all ungrounded supply conductors and shall be so designed that no pole can be operated independently.

(c) If a motor and the driven machinery are not in sight from the controller location, the installation shall comply with one of the following conditions:

(1) The controller disconnecting means shall be capable of being locked in the open position.

(2) A manually operable switch that will disconnect the motor from its source of supply shall be placed in sight from the motor location.

- MOTOR AND DRIVEN MACHINERY NOT WITHIN SIGHT OF CONTROLLER

USUALLY, A MOTOR AND THE EQUIPMENT IT DRIVES SHOULD BE WITHIN SIGHT OF THE CONTROLLER. IF THEY ARE NOT WITHIN SIGHT OF THE CONTROLLER, ONE OF TWO CONDITIONS MUST BE MET: (1) THE CONTROLLER DISCONNECT MUST BE DESIGNED SO THAT IT CAN BE LOCKED IN THE OPEN, OR DE-ENERGIZED, POSITION TO PROTECT PERSONS WORKING ON THE MOTOR OR EQUIPMENT (SEE FIGURE 58), OR (2) A SWITCH THAT CAN BE MANUALLY (NOT MAGNETICALLY) OPERATED MUST BE LOCATED WITHIN 50 FEET OF, AND MUST BE VISIBLE FROM, THE MOTOR (SEE FIGURE 59).

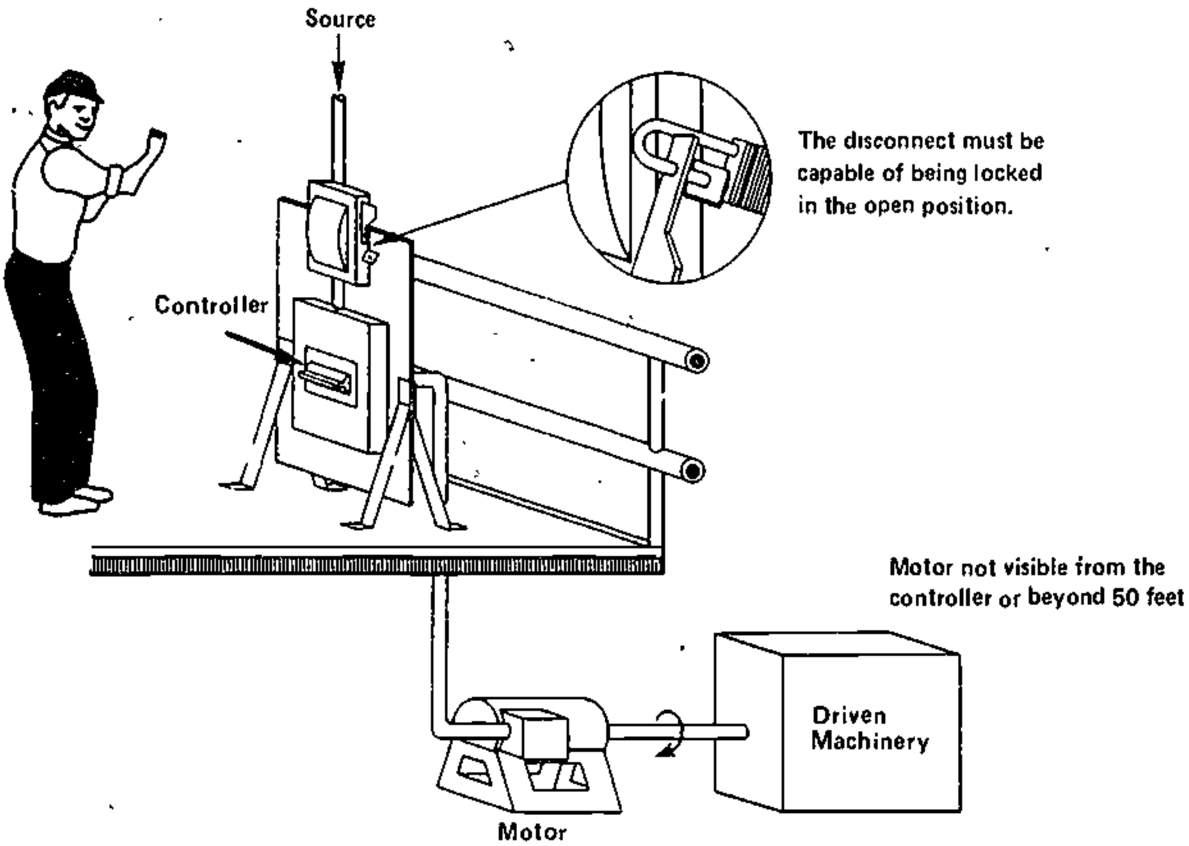


FIGURE 58. LOCKING CONTROLLER DISCONNECTING MEANS

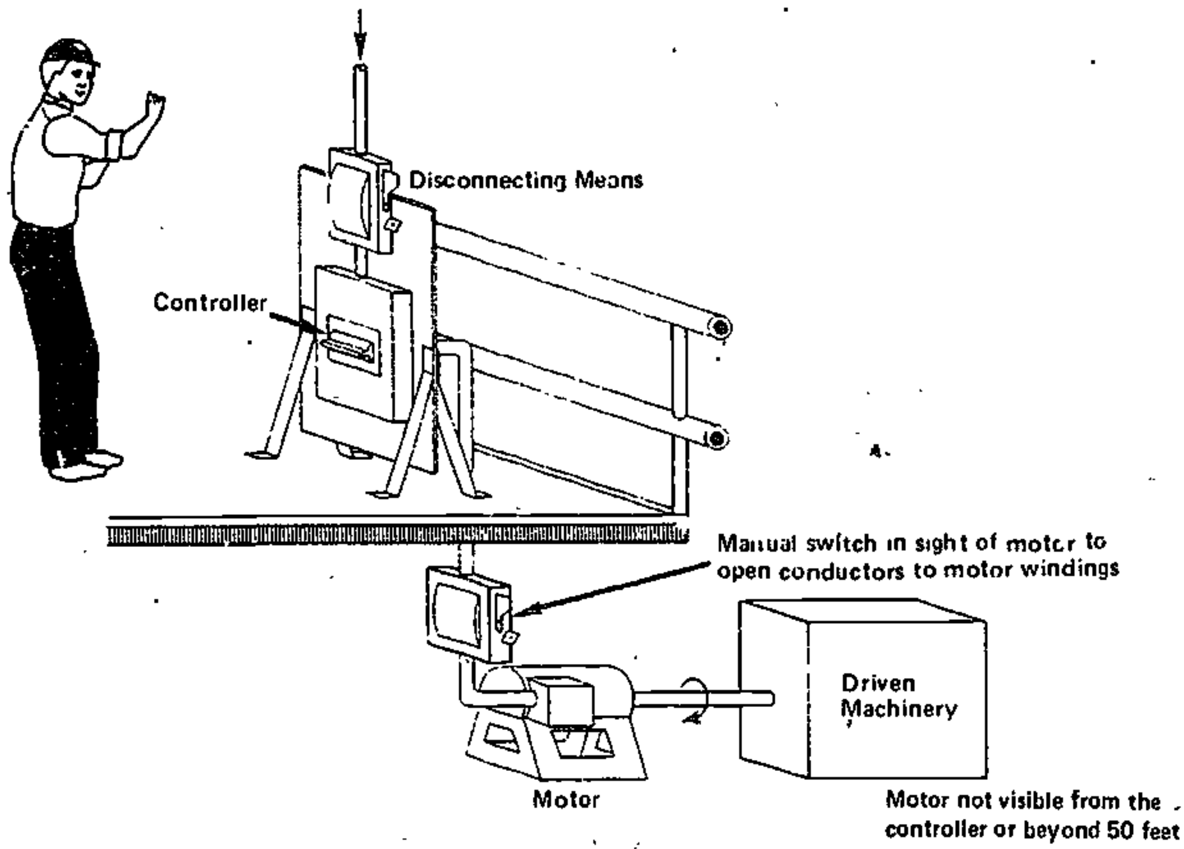


FIGURE 59. MANUALLY OPERABLE SWITCH WITHIN SIGHT

(d) The disconnecting means shall plainly indicate whether it is in the open (off) or closed (on) position.
(e) The disconnecting means shall be readily accessible. If more than one disconnect is provided for the same equipment, only one need be readily accessible.
(f) An individual disconnecting means shall be provided for each motor, but a single disconnecting means may be used for a group of motors under any one of the following conditions:
(1) If a number of motors drive special parts of a single machine or piece of apparatus, such as a metal or woodworking machine, crane, or hoist;
(2) If a group of motors is under the protection of one set of branch-circuit protective devices; or
(3) If a group of motors is in a single room in sight from the location of the disconnecting means.

(iii) Motor overload, short-circuit, and ground-fault protection. Motors, motor-control apparatus, and motor branch-circuit conductors shall be protected against overheating due to motor overloads or failure to start, and against short-circuits or ground faults. These provisions shall not require overload protection that will stop a motor where a shutdown is likely to introduce additional or increased hazards, as in the case of fire pumps, or where continued operation of a motor is necessary for a safe shutdown of equipment or process and motor overload sensing devices are connected to a supervised alarm.

- MOTOR OVERLOAD, SHORT-CIRCUIT, AND GROUND-FAULT PROTECTION

ALL MOTORS, MOTOR CONTROLLERS, AND CONDUCTORS THAT FEED MOTORS MUST BE PROTECTED FROM OVERCURRENT. FOR EXAMPLE, DAMAGE MIGHT OCCUR WHEN OVERHEATING RESULTS FROM AN OVERLOAD (EXCESSIVE CURRENT FLOW) OR FROM THE FAILURE OF THE MOTOR TO START. DAMAGE AND HAZARDS MIGHT ALSO RESULT FROM SHORT-CIRCUITS AND GROUND FAULTS. FIGURE 60 ILLUSTRATES METHODS OF MOTOR PROTECTION.

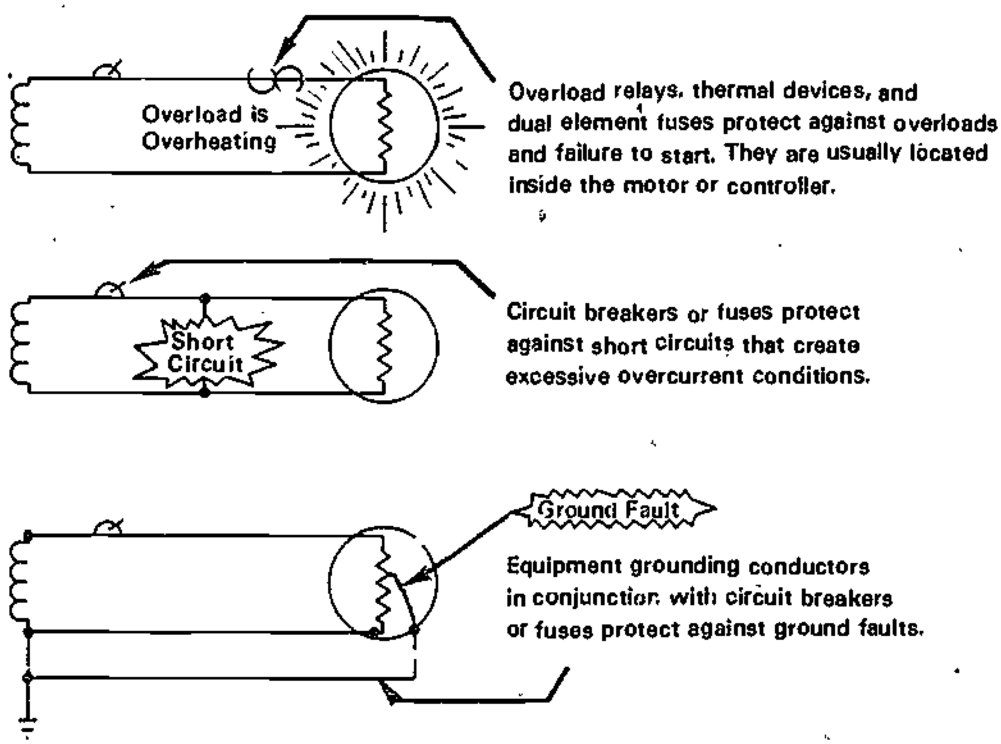


FIGURE 60. MOTOR PROTECTION METHODS

HOWEVER, PROTECTION TO SHUT DOWN THE MOTOR IS NOT REQUIRED IF IT WOULD PRODUCE A MORE HAZARDOUS SITUATION. AN EXAMPLE IS A FIRE PUMP THAT IF OVERHEATED AND SHUT DOWN IS OF NO HELP IN FIGHTING A FIRE THAT MIGHT DESTROY A LARGE BUILDING OR OTHER VALUABLE PROPERTY. THE DAMAGE TO THE MOTOR, CONTROLLER, OR CONDUCTORS AND ANY HAZARDS THAT MIGHT RESULT ARE INSIGNIFICANT WHEN COMPARED TO THE RESULTS OF SHUTTING OFF THE POWER TO THIS TYPE OF EQUIPMENT.

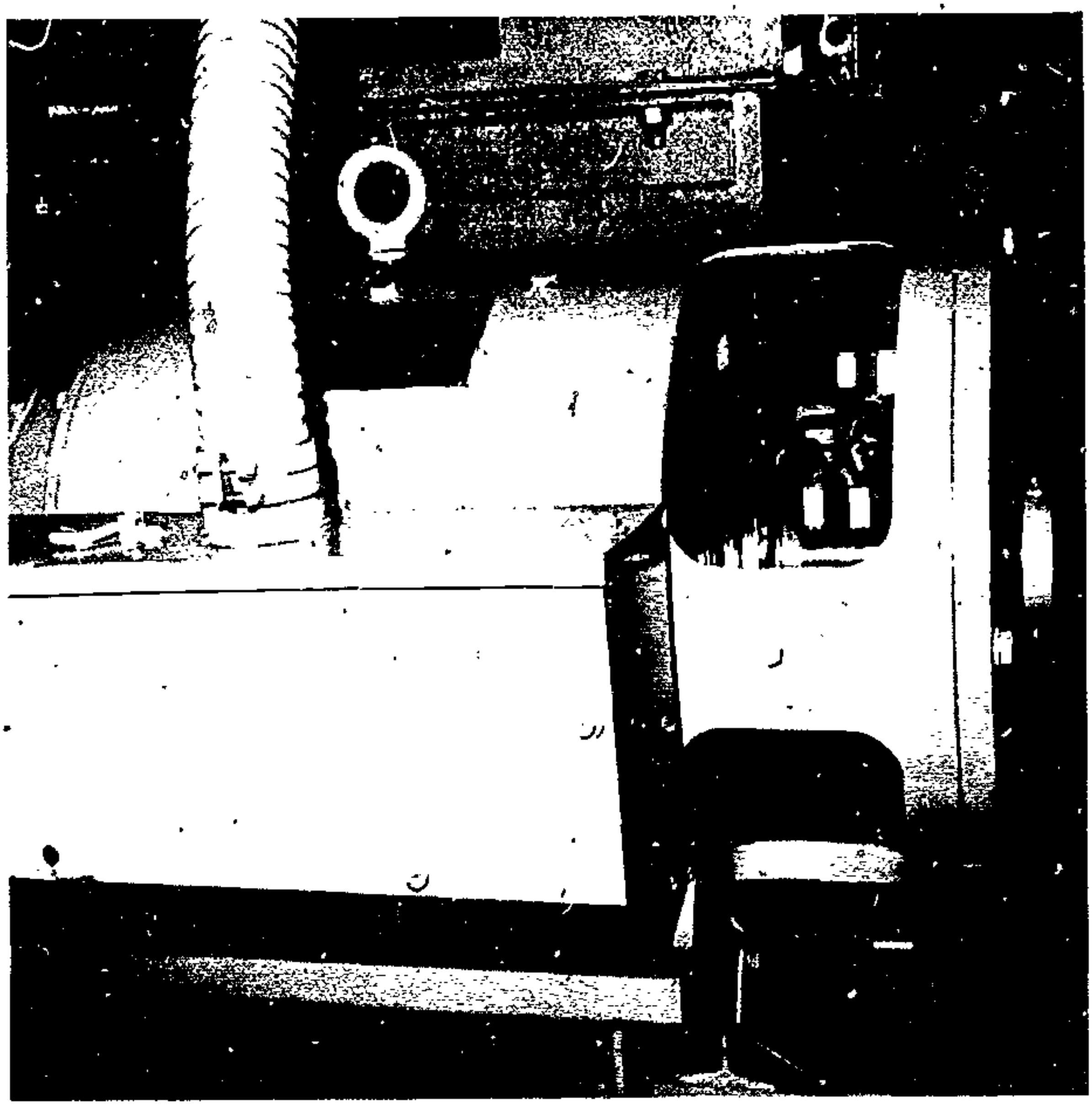
IN SITUATIONS WHERE A MOTOR DOES NOT HAVE OVERLOAD PROTECTION, IT MUST BE DESIGNED SO THAT AN AUTOMATIC SENSING DEVICE WITHIN THE MOTOR WILL TRIGGER AN ALARM. THIS ALARM IS USUALLY LOCATED IN A CONTROL LOCATION AND MUST BE MONITORED.

(iv) Protection of live parts—all voltages.

(a) Stationary motors having commutators, collectors, and brush rigging located inside of motor end brackets and not conductively connected to supply circuits operating at more than 150 volts to ground need not have such parts guarded.

- PROTECTION OF LIVE PARTS, ALL VOLTAGES

MOTORS THAT ARE FIXED IN PLACE NEED NOT HAVE THEIR INTERNAL LIVE PARTS GUARDED IF THEY MEET THE FOLLOWING TWO CONDITIONS: (1) IF THE COMMUTATORS (CONDUCTING MEMBERS, INSULATED FROM ONE ANOTHER, AGAINST WHICH THE BRUSHES BEAR), THE BRUSH RIGGINGS (PARTS WHICH SUPPORT AND POSITION THE BRUSHES), AND THE COLLECTORS (METAL RINGS WHICH, THROUGH CONTACT WITH THE BRUSHES, CONDUCTS CURRENT INTO OR OUT OF MACHINES) ARE ALL LOCATED INSIDE THE MOTOR END BRACKETS, AND (2) IF THE COMMUTATORS, BRUSH RIGGINGS, AND COLLECTORS ARE NOT IN ELECTRICAL CONTACT WITH ANY SUPPLY CIRCUIT THAT OPERATES AT MORE THAN 150 VOLTS TO GROUND (SEE FIGURE 61).



Motors having commutators, collectors, and brushes housed within the motor do not require guarding unless there are exposed rotating parts, or there is electrical contact with voltage in supply circuits operating at over 150 volts to ground.

FIGURE 61. UNGUARDED COMMUTATORS, COLLECTORS, AND BRUSHES HOUSED WITHIN MOTOR

Exposed live parts of motors and controllers operating at 50 volts or more between terminals shall be guarded against accidental contact by any of the following:
(1) By installation in a room or enclosure that is accessible only to qualified persons;
(2) By installation on a suitable balcony, gallery, or platform, so elevated and arranged as to exclude unqualified persons; or
(3) By elevation 8 feet or more above the floor.

(b) Where live parts of motors or controllers operating at over 150 volts to ground are guarded against accidental contact only by location, and where adjustment or other attendance may be necessary during the operation of the apparatus, suitable insulating mats or platforms shall be provided so that the attendant cannot readily touch live parts unless standing on the mats or platforms.

(5) Transformers.

(i) The following paragraphs cover the installation of all transformers except the following:
(a) Current transformers;
(b) Dry-type transformers installed as a component part of other apparatus;
(c) Transformers which are an integral part of an X-ray, high frequency, or electrostatic-coating apparatus;
(d) Transformers used with Class 2 and Class 3 circuits, sign and outline lighting, electric discharge lighting, and power-limited fire-protective signaling circuits; and

- TRANSFORMERS EXCLUDED FROM THE STANDARD

THE REQUIREMENTS OF THE STANDARD FOR TRANSFORMERS APPLY TO MOST TRANSFORMERS. EXCEPTIONS INCLUDE TRANSFORMERS USED WITH: (1) CLASS 2 AND CLASS 3 POWER-LIMITED, SIGNALING OR REMOTE-CONTROL CIRCUITS, WHICH HAVE CURRENT LIMITED BY THE SUPPLY TRANSFORMER SO THAT ONLY RELATIVELY SMALL CURRENTS WILL FLOW — THESE CIRCUITS ARE USED WHEN THE CURRENT AND VOLTAGE REQUIRED ARE NOT AS GREAT AS THAT REQUIRED FOR NORMAL LIGHT AND POWER SYSTEMS, AS WITH A DOORBELL OR AN OIL-BURNER THERMOSTAT CONTROL CIRCUIT (SEE FIGURE 62); (2) SIGN AND OUTLINE LIGHTING, SUCH AS NEON LIGHTING; (3) ELECTRIC DISCHARGE LIGHTING, SUCH AS FLUORESCENT LAMPS; (4) POWER-LIMITED, FIRE-PROTECTIVE SIGNALING CIRCUITS, WHICH HAVE LOW VOLTAGE AND CURRENT NEEDS, SUCH AS SMOKE DETECTORS THAT ARE TIED INTO AN ALARM STATION IN A BUILDING (SEE FIGURE 63).

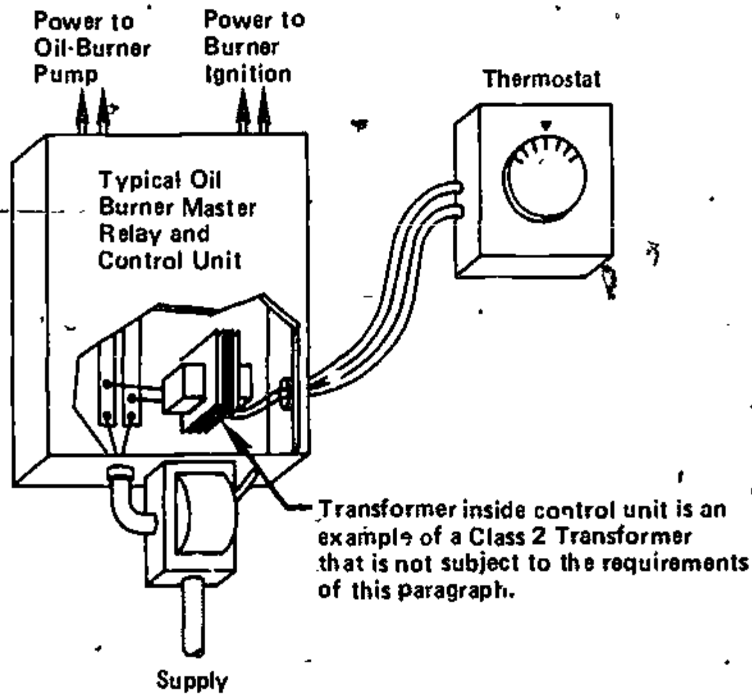


FIGURE 62. TYPICAL CLASS 2 CIRCUIT

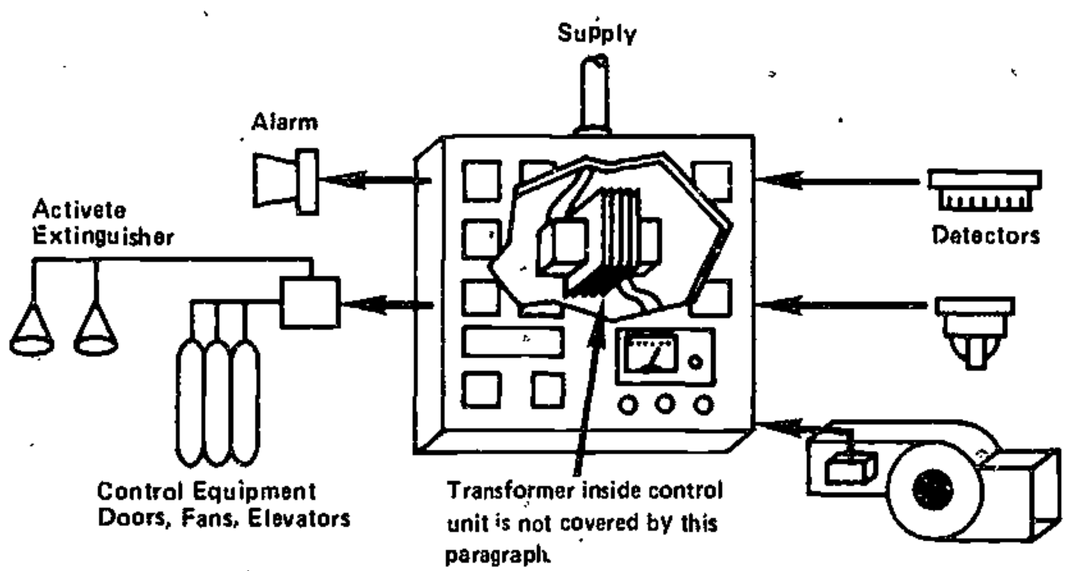


FIGURE 63. TYPICAL POWER-LIMITED, FIRE-PROTECTIVE SIGNALING CIRCUIT

(e) Liquid-filled or dry-type transformers used for research, development, or testing, where effective safeguard arrangements are provided.

(ii) The operating voltage of exposed live parts of transformer installations shall be indicated by warning signs or visible markings on the equipment or structure.

(iii) Dry-type, high fire point liquid-insulated, and askarel-insulated transformers installed indoors and rated over 35kV shall be in a vault.

(iv) If they present a fire hazard to employees, oil-insulated transformers installed indoors shall be in a vault.

(v) Combustible material, combustible buildings and parts of buildings, fire escapes, and door and window openings shall be safeguarded from fires which may originate in oil-insulated transformers attached to or adjacent to a building or combustible material.

- TRANSFORMERS

TRANSFORMERS THAT USE OIL AS AN INSULATOR ARE SUBJECT TO FIRES BECAUSE OF THE COMBUSTIBLE NATURE OF OIL AND THE HEAT-GENERATING NATURE OF ELECTRICAL EQUIPMENT. THEREFORE, IF AN OIL-INSULATED TRANSFORMER IS INSTALLED OUTDOORS NEXT TO OR ATTACHED TO A BUILDING OR SOME OTHER TYPE OF COMBUSTIBLE MATERIAL, THE TRANSFORMER MUST BE LOCATED OR OTHERWISE PROTECTED SO THAT THE FIRE HAZARD THAT ALREADY EXISTS IS NOT INCREASED. FIRE ESCAPES, WINDOWS, AND DOORS, AS WELL AS COMBUSTIBLE MATERIALS AND THE BUILDING (IF PART OR ALL OF IT IS CONSTRUCTED OF COMBUSTIBLE MATERIALS), MUST ALSO BE PROTECTED FROM THE POTENTIAL FIRE HAZARD. PROTECTION CAN BE ACHIEVED BY LOCATING THE TRANSFORMER AWAY FROM THE BUILDING (SPACE SEPARATION); CONSTRUCTING FIRE-RESISTANT BARRIERS SUCH AS CONCRETE BLOCK WALLS BETWEEN THE TRANSFORMER AND THE BUILDING; OR INSTALLING A SPECIALIZED AUTOMATIC SPRINKLER SYSTEM THAT WILL PROVIDE A WATER SPRAY TO CONTROL AN OIL FIRE. IN ADDITION TO ANY OF THESE METHODS, A DIKE OR CURB SHOULD BE INSTALLED AROUND THE TRANSFORMER SO THAT AN OIL FIRE WOULD BE CONTAINED IN ONE AREA AND COULD NOT SPREAD TO THE BUILDING. FIGURE 64 ILLUSTRATES TWO OF THESE SAFEGUARDING METHODS.

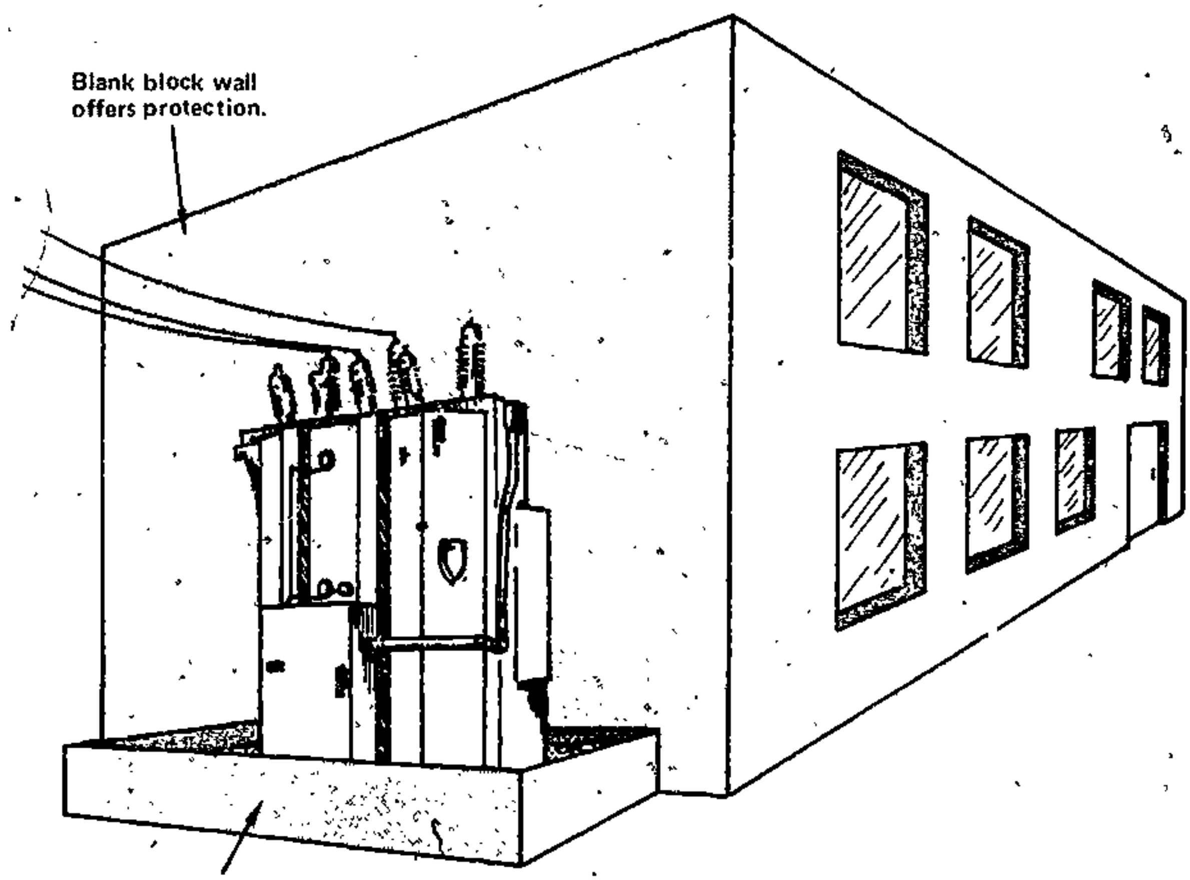


FIGURE 64. EXAMPLES OF SAFEGUARDING METHODS FOR TRANSFORMERS

(vi) Transformer vaults shall be constructed so as to contain fire and combustible liquids within the vault and to prevent unauthorized access. Locks and latches shall be so arranged that a vault door can be readily opened from the inside.

(vii) Any pipe or duct system foreign to the vault installation may not enter or pass through a transformer vault.

(viii) Materials may not be stored in transformer vaults.

(6) Capacitors.

(i) All capacitors, except surge capacitors or capacitors included as a component part of other apparatus, shall be provided with an automatic means of draining the stored charge after the capacitor is disconnected from its source of supply.

- CAPACITORS

CAPACITORS STORE ELECTRICAL CHARGE AND CAN BE A SOURCE OF SEVERE SHOCK UNLESS THAT CHARGE IS DRAINED WHEN THE CAPACITORS ARE DISCONNECTED FROM THE POWER SOURCE. UNLESS SOME TYPE OF AUTOMATIC DISCHARGE IS DESIGNED INTO A SYSTEM, DEVICES SUCH AS RESISTORS MUST BE PERMANENTLY ATTACHED ACROSS THE TERMINALS OF THE CAPACITORS TO DRAIN THE CHARGE WHEN THE CIRCUIT IS OPEN (DE-ENERGIZED). MOST CAPACITORS ARE MANUFACTURED WITH THIS TYPE OF DISCHARGE RESISTOR ALREADY BUILT IN. SURGE CAPACITORS, WHICH ACT LIKE LIGHTNING RODS, DO NOT REQUIRE AN AUTOMATIC MEANS FOR DRAINING THE CHARGE.

(ii) Capacitors rated over 600 volts, nominal, shall comply with the following additional requirements:

(a) Isolating or disconnecting switches (with no interrupting rating) shall be interlocked with the load interrupting device or shall be provided with prominently displayed caution signs to prevent switching load current.

(b) For series capacitors (see §1910.302(b)(3)), the proper switching shall be assured by use of at least one of the following:

(1) Mechanically sequenced isolating and bypass switches,

(2) Interlocks, or

(3) Switching procedure prominently displayed at the switching location.

(7) Storage batteries. Provisions shall be made for sufficient diffusion and ventilation of gases from storage batteries to prevent the accumulation of explosive mixtures.

- STORAGE BATTERIES

STORAGE BATTERIES, WHICH ARE USUALLY LEAD-ACID OR ALKALI, PRODUCE EXPLOSIVE GASES, INCLUDING HYDROGEN, IF THEY ARE OVERCHARGED. THESE EXPLOSIVE GASES MUST NOT ACCUMULATE IN QUANTITIES THAT MAY FORM AN EXPLOSIVE MIXTURE WITH AIR. A SPARK OR OPEN FLAME COULD IGNITE THE MIXTURE AND CAUSE AN EXPLOSION. GOOD VENTILATION MUST BE PROVIDED TO PREVENT THIS ACCUMULATION.

§1910.306 SPECIFIC PURPOSE EQUIPMENT AND INSTALLATIONS

§1910.306 Specific purpose equipment and installations.

(a) Electric signs and outline lighting.

(1) Disconnecting means. Signs operated by electronic or electromechanical controllers located outside the sign shall have a disconnecting means located inside the controller enclosure or within sight of the controller location, and it shall be capable of being locked in the open position. Such disconnecting means shall have no pole that can be operated independently, and it shall open all ungrounded conductors that supply the controller and sign. All other signs, except the portable type, and all outline lighting installations shall have an externally operable disconnecting means which can open all ungrounded conductors and is within the sight of the sign or outline lighting it controls.

(2) Doors or covers giving access to uninsulated parts of indoor signs or outline lighting exceeding 600 volts and accessible to other than qualified persons shall either be provided with interlock switches to disconnect the primary circuit or shall be so fastened that the use of other than ordinary tools will be necessary to open them.

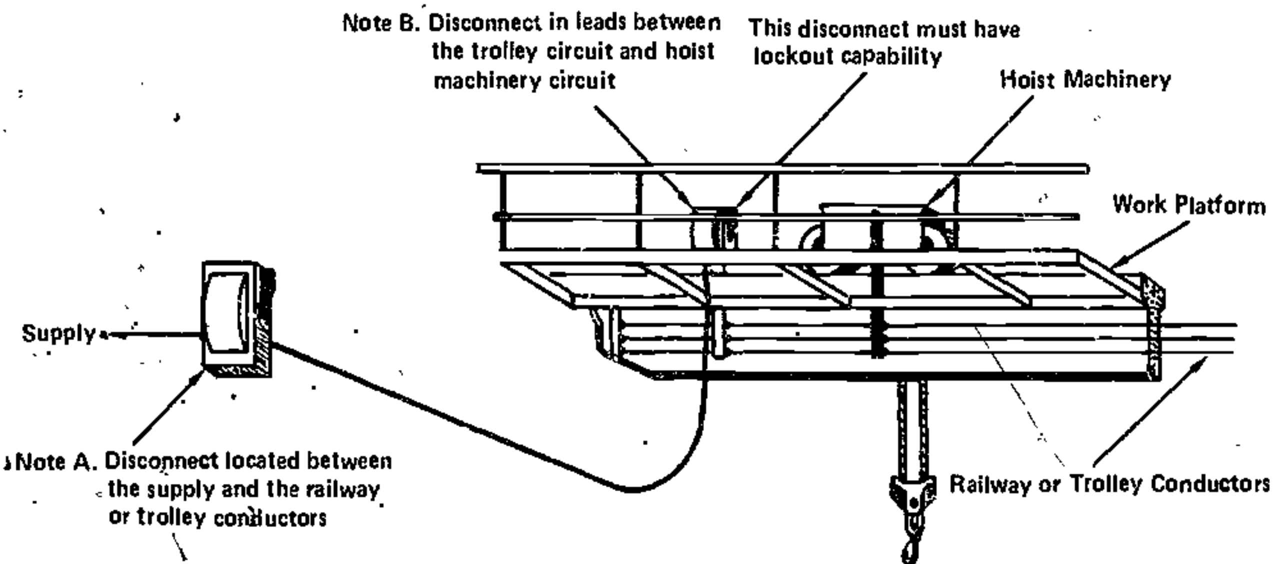
(b) Cranes and hoists. This paragraph applies to the installation of electric equipment and wiring used in connection with cranes, monorail hoists, hoists, and all runways.

(1) Disconnecting means.

(i) A readily accessible disconnecting means shall be provided between the runway contact conductors and the power supply.

(ii) Another disconnecting means, capable of being locked in the open position, shall be provided in the leads from the runway contact conductors or other power supply on any crane or monorail hoist.

• DISCONNECT SWITCHES ARE REQUIRED ON CRANES AND HOISTS TO ALLOW MAINTENANCE AND SERVICING OPERATIONS TO BE PERFORMED SAFELY. THERE ARE TWO KEY LOCATIONS IN A CRANE OR HOIST CIRCUIT WHERE A DISCONNECT IS REQUIRED. THE FIRST — SEE NOTE A, FIGURE 65 — IS LOCATED BETWEEN THE POWER SUPPLY AND THE RAILWAY OR TROLLEY CONTACT CONDUCTORS. THE SECOND — SEE NOTE B, FIGURE 65 — IS IN THE LEADS BETWEEN THE TROLLEY CONTACT CONDUCTORS AND THE HOIST MACHINERY. THIS SECOND DISCONNECT MUST BE CAPABLE OF BEING LOCKED OUT, THAT IS LOCKED IN THE OPEN OR OFF POSITION, TO AVOID A SAFETY HAZARD TO WORKERS WHO ARE SERVICING THE HOIST MACHINERY AND MAY NOT BE VISIBLE FROM THE POWER SUPPLY DISCONNECT.



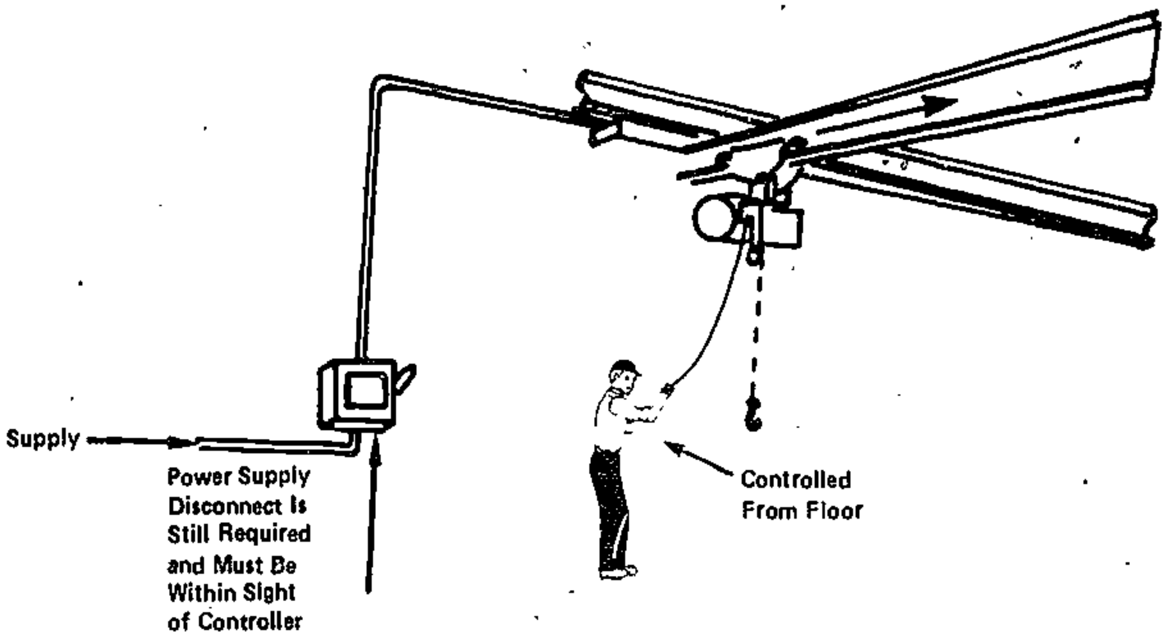
An additional control switch or a remote control switch is necessary if the second disconnecting means (B) is not accessible to the operator.

FIGURE 65. LOCATION OF DISCONNECT FOR GANTRY CRANE

(a) If this additional disconnecting means is not readily accessible from the crane or monorail hoist operating station, means shall be provided at the operating station to open the power circuit to all motors of the crane or monorail hoist.

(b) The additional disconnect may be omitted if a monorail hoist or hand-propelled crane bridge installation meets all of the following:
(1) The unit is floor controlled;
(2) The unit is within view of the power supply disconnecting means; and
(3) No fixed work platform has been provided for servicing the unit.

- THERE ARE THREE CONDITIONS THAT MUST BE MET BEFORE THE DISCONNECT SWITCH IN THE LEADS BETWEEN THE RAILWAY CONDUCTORS AND THE HOIST MACHINERY CAN BE OMITTED. THIS EXCEPTION ONLY APPLIES TO HAND-PROPELLED CRANE BRIDGE INSTALLATIONS AND MONORAIL HOISTS, AND ALL THREE OF THE FOLLOWING CONDITIONS MUST BE MET: (1) THE UNIT MUST BE FLOOR CONTROLLED, (2) THE HOISTING MACHINERY UNIT MUST BE WITHIN VIEW OF THE POWER SUPPLY DISCONNECTING MEANS, AND (3) NO FIXED WORK PLATFORM CAN BE INSTALLED ON THE MONORAIL HOIST OR HAND-PROPELLED BRIDGE CRANE. FIGURE 66 ILLUSTRATES A MONORAIL HOIST THAT MEETS THESE THREE CONDITIONS AND MAY OPERATE WITH ONLY ONE DISCONNECT SWITCH LOCATED IN THE POWER SUPPLY CONDUCTOR.



Second disconnect not required. A monorail hoist does not require a disconnecting means in the leads to the hoist machinery if it is controlled from the floor, if it is within view of the power supply disconnect, and if there is no work platform provided to service the hoist machinery.

FIGURE 66. SECOND DISCONNECT NOT REQUIRED

(2) Control. A limit switch or other device shall be provided to prevent the load block from passing the safe upper limit of travel of any hoisting mechanism.

(3) Clearance. The dimension of the working space in the direction of access to live parts which may require examination, adjustment, servicing, or maintenance while alive shall be a minimum of 2 feet 6 inches. Where controls are enclosed in cabinets, the door(s) shall either open at least 90 degrees or be removable.

(c) Elevators, dumbwaiters, escalators, and moving walks.

- (1) Disconnecting means. Elevators, dumbwaiters, escalators, and moving walks shall have a single means for disconnecting all ungrounded main power supply conductors for each unit.
- (2) Warning signs. If interconnections between control panels are necessary for operation of the system on a multicar installation that remains energized from a source other than the disconnecting means, a warning sign shall be mounted on or adjacent to the disconnecting means. The sign shall be clearly legible and shall read "Warning—Parts of the control panel are not de-energized by this switch." (See §1910.302(b)(3).)

- EACH ELEVATOR, DUMBWAITER. ESCALATOR, OR MOVING WALK IS REQUIRED TO HAVE A SINGLE DISCONNECTING SWITCH TO SHUT OFF POWER TO EACH UNIT. SOME INSTALLATIONS MAY HAVE INTERCONNECTED CONTROL PANELS WHICH WILL REMAIN ENERGIZED EVEN IF THE APPROPRIATE DISCONNECT SWITCH IS MOVED TO THE OPEN OR OFF POSITION. A COMMON EXAMPLE IS WHERE ELEVATOR CONTROL PANELS IN A HIGH RISE OFFICE BUILDING ARE INTERCONNECTED TO COORDINATE RESPONSES BETWEEN THE UPPER AND LOWER FLOORS. IF A DISCONNECT IS SHUT OFF FOR ONE UNIT, INTERCONNECTED CONTROL CIRCUITS MAY STILL BE ENERGIZED. WHEN THIS IS THE CASE FOR INSTALLATIONS MADE AFTER APRIL 16, 1981, A WARNING SIGN IS REQUIRED, STATING THAT A HAZARD STILL EXISTS. SEE FIGURE 67.

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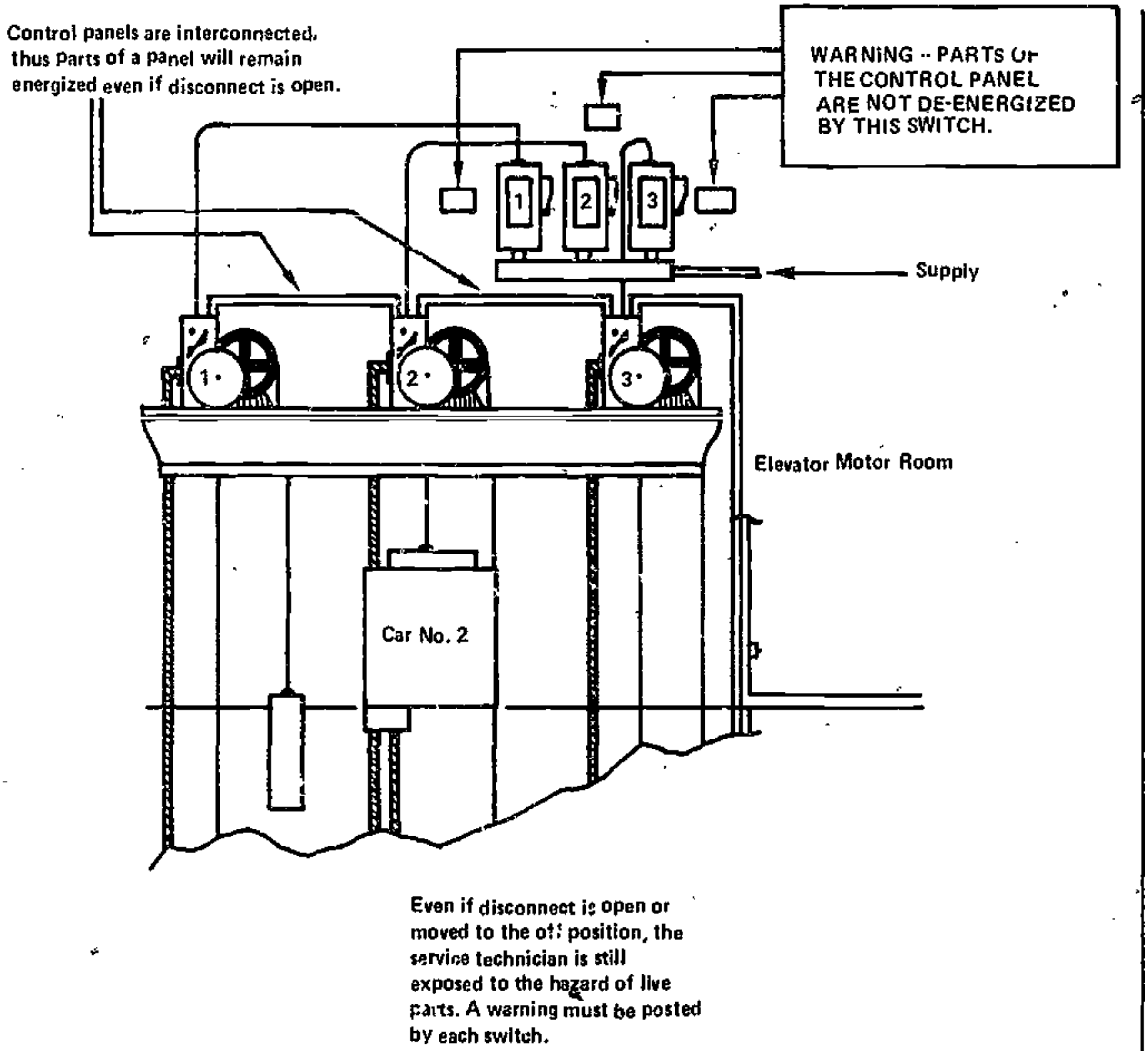


FIGURE 67. INTERCONNECTED CONTROL PANELS

(3) Control panels. If control panels are not located in the same space as the drive machine, they shall be located in cabinets with doors or panels capable of being locked closed.

(d) Electric welders--disconnecting means.

(1) A disconnecting means shall be provided in the supply circuit for each motor-generator arc welder, and for each AC transformer and DC rectifier arc welder which is not equipped with a disconnect mounted as an integral part of the welder.

(2) A switch or circuit breaker shall be provided by which each resistance welder and its control equipment can be isolated from the supply circuit. The ampere rating of this disconnecting means may not be less than the supply conductor ampacity.

- (e) Data processing systems—disconnecting means. A disconnecting means shall be provided to disconnect the power to all electronic equipment in data processing or computer rooms. This disconnecting means shall be controlled from locations readily accessible to the operator at the principal exit doors. There shall also be a similar disconnecting means to disconnect the air conditioning system serving this area.

- ELECTRICAL FIRES ARE COMMON TYPES OF FIRES THAT OCCUR IN COMPUTER ROOMS. THIS CREATES A NEED TO PROVIDE POSITIVE CONTROL OVER TWO KEY POWER SYSTEMS IN AN EMERGENCY. THESE ARE THE POWER SUPPLY SYSTEMS TO THE COMPUTER EQUIPMENT AND THE VENTILATION SYSTEM FOR THE COMPUTER ROOM. SHOULD AN EMERGENCY OCCUR, SHUTTING DOWN THE POWER SUPPLY TO THE COMPUTER, RELATED EQUIPMENT, AND ELECTRONIC SYSTEM WIRING UNDER THE RAISED FLOORS WILL ELIMINATE A SOURCE OF IGNITION THAT MAY PROPAGATE A FIRE. THE VENTILATION SYSTEM MAY CONTRIBUTE TO THE SPREAD OF THE FIRE BY FANNING IT OR BY RAPIDLY SPREADING SMOKE THROUGH THIS AREA. LOCATING DISCONNECT SWITCHES NEAR THE EXIT DOOR PERMITS THESE SYSTEMS TO BE SHUT DOWN EASILY WHILE THE FACILITY IS BEING EVACUATED. THESE SWITCHES MUST BE READILY ACCESSIBLE TO THE OPERATOR AND NOT BLOCKED BY EQUIPMENT OR A DOOR. LIGHTING SYSTEMS MUST REMAIN SEPARATE TO AID EVACUATION AND EMERGENCY OPERATIONS (SEE FIGURE 68). FIGURE 69 SHOWS THE OPERATION OF A DISCONNECT FOR ELECTRONIC EQUIPMENT IN A DATA PROCESSING ROOM.

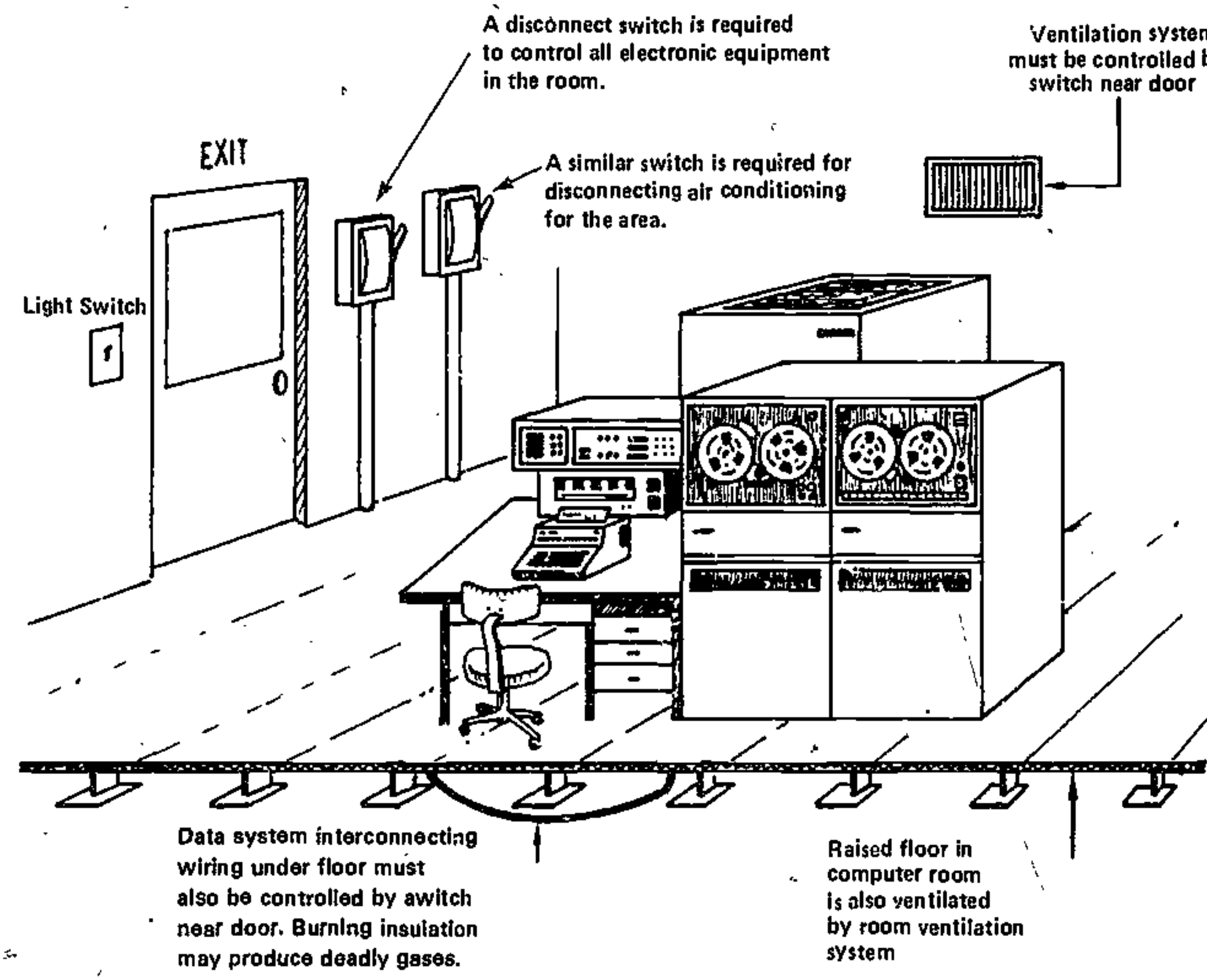
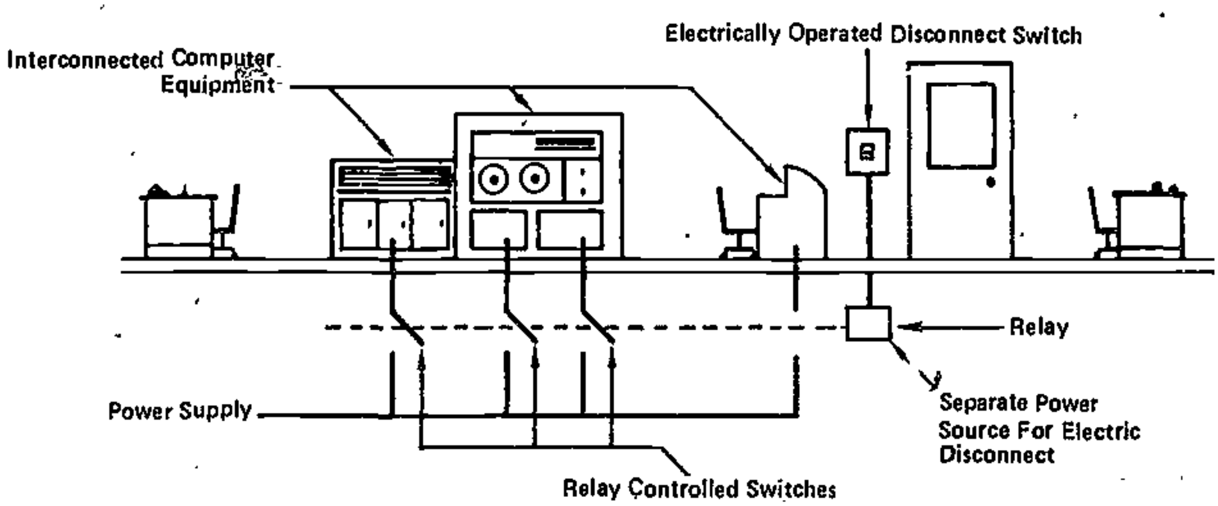


FIGURE 68. LOCATION OF DISCONNECT IN DATA PROCESSING CENTER



An electrically operated disconnect switch is commonly used in this application. This type of switch serves as a remote control switch that operates a relay to open the power supply conductors to the computer equipment.

FIGURE 69. TYPICAL OPERATION OF DISCONNECTING MEANS

(f) X-Ray equipment. This paragraph applies to X-ray equipment for other than medical or dental use.

(1) Disconnecting means.

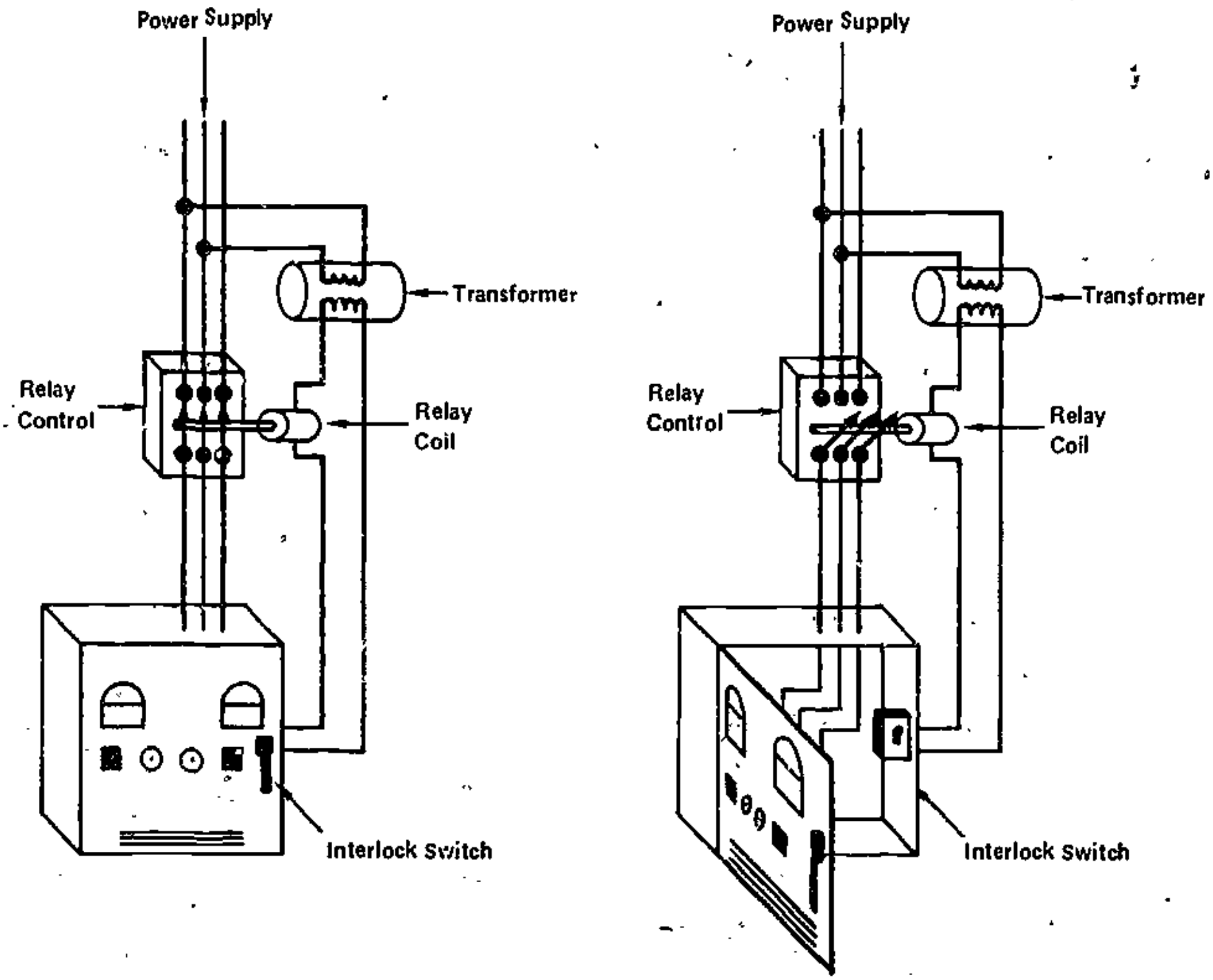
(i) A disconnecting means shall be provided in the supply circuit. The disconnecting means sh... be operable from a location readily accessible from the X-ray control. For equipment connected to a 120-volt branch circuit of 30 amperes or less, a grounding-type attachment plug cap and receptacle of proper rating may serve as a disconnecting means.

(ii) If more than one piece of equipment is operated from the same high-voltage circuit, each piece or each group of equipment as a unit shall be provided with a high-voltage switch or equivalent disconnecting means. This disconnecting means shall be constructed, enclosed, or located so as to avoid contact by employees with its live parts.

(2) Control.

- (i) Radiographic and fluoroscopic types. Radiographic and fluoroscopic-type equipment shall be effectively enclosed or shall have interlocks that de-energize the equipment automatically to prevent ready access to live current-carrying parts.

- RADIOGRAPHIC (X-RAY) AND FLUOROSCOPIC EQUIPMENT OPERATE AT HIGH ENERGY LEVELS AND HIGH VOLTAGES THAT PRESENT A SERIOUS HAZARD IF A SERVICE TECHNICIAN WERE TO OPEN ACCESS PANELS WHILE THE EQUIPMENT IS ENERGIZED. TO PREVENT EXPOSURE TO THIS HAZARD, RADIOGRAPHIC AND FLUOROSCOPIC-TYPE X-RAY EQUIPMENT MUST BE LOCATED IN METAL ENCLOSURES CONSTRUCTED TO PREVENT ACCESS BY UNQUALIFIED PERSONS. SHOULD ACCESS BE REQUIRED (E.G., TO MAKE AN ADJUSTMENT) THEN THE ACCESS PANEL OR DOOR MUST BE EQUIPPED WITH INTERLOCKS THAT WILL SHUT OFF POWER TO LIVE EQUIPMENT INSIDE WHEN THE DOOR IS OPEN (SEE FIGURE 70).



A. Power is supplied through a relay control that is connected to an interlock circuit.

B. When the panel door opens a spring-loaded switch operates a relay coil that opens the power supply conductors and de-energizes the equipment inside the enclosure.

FIGURE 70. INTERLOCKS

(ii) Diffraction and irradiation types. Diffraction- and irradiation-type equipment shall be provided with a means to indicate when it is energized unless the equipment or installation is effectively enclosed or is provided with interlocks to prevent access to live current-carrying parts during operation.

(g) Induction and dielectric heating equipment.

(1) Scope. Paragraphs (g)(2) and (g)(3) of this section cover induction and dielectric heating equipment and accessories for industrial and scientific applications, but not for medical or dental applications or for appliances.

(2) Guarding and grounding.

(i) Enclosures. The converting apparatus (including the DC line) and high-frequency electric circuits (excluding the output circuits and remote-control circuits) shall be completely contained within enclosures of noncombustible material.

(ii) Panel controls. All panel controls shall be of dead-front construction.

- INDUCTION HEATING EQUIPMENT USES HIGH FREQUENCY ALTERNATING CURRENTS. CONTROL PANELS FOR INDUCTION AND DIELECTRIC HEATING EQUIPMENT ARE REQUIRED TO BE OF DEAD-FRONT CONSTRUCTION; THAT IS, CONSTRUCTED SO THAT THERE ARE NO LIVE PARTS EXPOSED ON THE OPERATING SIDE OF THE EQUIPMENT. ALL CONNECTIONS AND TERMINATIONS MUST BE BEHIND THE FRONT PANEL.

(iii) Access to internal equipment. Where doors are used for access to voltages from 500 to 1000 volts AC or DC, either door locks or interlocks shall be provided. Where doors are used for access to voltages of over 1000 volts AC or DC, either mechanical lockouts with a disconnecting means to prevent access until voltage is removed from the cubicle, or both door interlocking and mechanical door locks, shall be provided.

(iv) Warning labels. "Danger" labels shall be attached on the equipment and shall be plainly visible even when doors are open or panels are removed from compartments containing voltages of over 250 volts AC or DC.

(v) Work applicator shielding. Protective cages or adequate shielding shall be used to guard work applicators other than induction heating coils. Induction heating coils shall be protected by insulation and/or refractory materials. Interlock switches shall be used on all hinged access doors, sliding panels, or other such means of access to the applicator. Interlock switches shall be connected in such a manner as to remove all power from the applicator when any one of the access doors or panels is open. Interlocks on access doors or panels are not required if the applicator is an induction heating coil at DC ground potential or operating at less than 150 volts AC.

(vi) Disconnecting means. A readily accessible disconnecting means shall be provided by which each unit of heating equipment can be isolated from its supply circuit.

(3) Remote control. If remote controls are used for applying power, a selector switch shall be provided and interlocked to provide power from only one control point at a time. Switches operated by foot pressure shall be provided with a shield over the contact button to avoid accidental closing of the switch.

- REMOTE CONTROLS MUST HAVE AN INTERLOCKED SELECTOR SWITCH SO ONLY ONE CONTROL POINT CAN OPERATE THE POWER TO A PARTICULAR HEATING PROCESS AT A TIME. FOR EXAMPLE, INDUCTION HEATING IS WELL SUITED FOR SURFACE HARDENING METAL PARTS TO PROTECT AGAINST WEAR. A COMMON PRODUCTION APPLICATION IS A SET-UP IN WHICH GEAR TEETH ARE SURFACE-HARDENED BY INDUCTION HEATING. THIS SET-UP MAY HAVE TWO OR MORE CONTROL POINTS TO

FACILITATE PRODUCTION AND ALLOW THE OPERATOR TO OBSERVE THE PROCESS FROM A REMOTE LOCATION. AN INTERLOCKED SELECTOR SWITCH MUST BE PROVIDED TO ALLOW CONTROL FROM ONLY ONE POINT AT A TIME, THUS PROTECTING AGAINST ACCIDENTAL OPERATION AT UNATTENDED CONTROL LOCATIONS (SEE FIGURE 71).

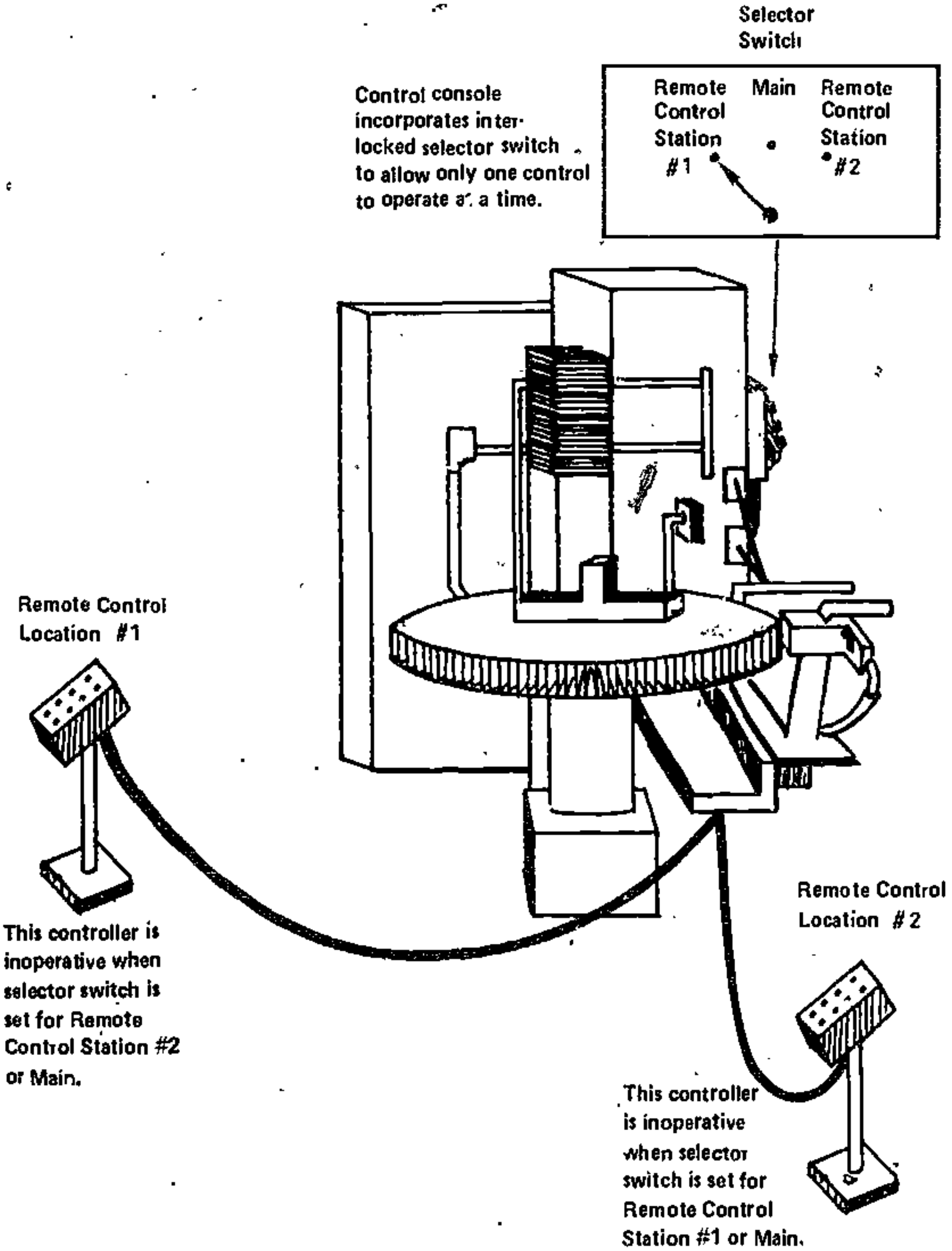


FIGURE 71. INDUCTION HEAT TREATING PROCESS

(h) Electrolytic cells.

(1) Scope. These provisions for electrolytic cells apply to the installation of the electrical components and accessory equipment or electrolytic cells, electrolytic cell lines, and process power supply for the production of aluminum, cadmium, chlorine, copper, fluorine, hydrogen peroxide, magnesium, sodium, sodium chlorate, and zinc. Cells used as a source of electric energy and for electroplating processes and cells used for the production of hydrogen are not covered by these provisions.

(2) Definitions applicable to this paragraph.

Cell line: An assembly of electrically interconnected electrolytic cells supplied by a source of direct-current power.

Cell line attachments and auxiliary equipment: Cell line attachments and auxiliary equipment include, but are not limited to: auxiliary tanks; process piping; duct work; structural supports; exposed cell line conductors; conduits and other raceways; pumps; positioning equipment and cell cutout or bypass electrical devices. Auxiliary equipment also includes tools, welding machines, crucibles, and other portable equipment used for operation and maintenance within the electrolytic cell line working zone. In the cell line working zone, auxiliary equipment includes the exposed conductive surfaces of ungrounded cranes and crane-mounted cell-servicing equipment.

Cell line working zone: The cell line working zone is the space envelope wherein operation or maintenance is normally performed on or in the vicinity of exposed energized surfaces of cell lines or their attachments.

- PARAGRAPH 1910.303(g)(2) REQUIRES LIVE PARTS OF EQUIPMENT OPERATING AT 50 VOLTS OR MORE TO BE GUARDED. RECOGNIZING A SPECIAL CASE, PARAGRAPH 1910.306(h) PERMITS ELECTROLYTIC CELLS TO OPERATE WITH LIVE PARTS EXPOSED, PROVIDED THAT SPECIFIC ALTERNATE SAFETY MEASURES ARE EMPLOYED.

ELECTROLYTIC CELLS DIFFER IN CERTAIN RESPECTS FROM STANDARD ELECTRICAL INSTALLATIONS. IN A STANDARD ELECTRICAL CIRCUIT, ALL LIVE PARTS ARE REQUIRED TO BE INSULATED OR GUARDED. ONE SIDE OF THE CIRCUIT IS CONNECTED TO GROUND TO PROVIDE A COMMON REFERENCE AND TO STABILIZE VOLTAGES, AND THUS A POTENTIAL EXISTS BETWEEN ANY LIVE CONDUCTOR AND ANY GROUNDED SURFACE. A PERSON COMING IN CONTACT WITH BOTH A LIVE CONDUCTOR AND A GROUNDED SURFACE WILL PROVIDE A PATH FOR ELECTRIC CURRENT TO FLOW AND WILL RECEIVE A SHOCK VARYING IN SEVERITY WITH THE AMOUNT OF CURRENT THAT FLOWS THROUGH THE BODY. THE PURPOSE OF THE GUARDING PROVISIONS OF THE NEC IS TO PREVENT CONTACT WITH LIVE PARTS SINCE CONTACT WITH GROUNDED SURFACES IS VERY COMMON.

IN AN ELECTROLYTIC CELL LINE, HOWEVER, THE ACTUAL WORKING PARTS AND SOME WORKING SURFACES ARE, BY NECESSITY, THE BARE LIVE PARTS OF AN ELECTRIC CIRCUIT. EMPLOYEE CONTACT WITH THESE LIVE PARTS IS NECESSARY IN NORMAL ELECTROLYTIC CELL WORKING PROCEDURES. THEREFORE, WHEREAS A

STANDARD CIRCUIT NECESSITATES GUARDING OF LIVE PARTS, EMPLOYEES WORKING ON ELECTROLYTIC CELLS MUST BE PROTECTED AGAINST CONTACT WITH GROUND. THE PROVISIONS OF PARAGRAPH 1910.306(h) RECOGNIZE THE DIFFERENT WORKING CONDITIONS OF ELECTROLYTIC CELL LINES AND OUTLINE THE PROCEDURES TO BE USED AS AN ALTERNATIVE TO GUARDING OF LIVE PARTS.

AN ELECTROLYTIC CELL LINE AND ITS DC POWER SUPPLY CIRCUITS, ALL WITHIN THE CELL LINE WORKING ZONE, ARE CONSIDERED A SINGLE UNIT JUST AS A MACHINE TOOL IS CONSIDERED A SINGLE UNIT SUPPLIED FROM A SINGLE POWER SOURCE. CELL LINE INSTALLATIONS MAY COVER SEVERAL ACRES OF FLOOR SPACE AND MAY HAVE LOADS IN EXCESS OF 400,000 AMPERES DC AT VOLTAGES IN EXCESS OF 1,000 VOLTS DC.

THE HEAVY BUS BARS AND CONNECTIONS CARRYING THIS CURRENT ARE USUALLY BARE; AND, THEREFORE, IT IS NECESSARY TO MINIMIZE THE POSSIBILITY OF WORKERS TOUCHING THE BARS WHILE ALSO TOUCHING OTHER CONDUCTIVE SURFACES AT A DIFFERENT POTENTIAL. TO DO THIS, THE NATIONAL ELECTRICAL CODE (NEC) DEFINES BOUNDARIES TO THE CELL LINE UNIT.

THE BOUNDARIES OF THE CELL LINE WORKING ZONE ARE SPECIFIED IN SECTION 668-10 OF THE NEC AND ARE KEYED TO VERTICAL AND HORIZONTAL MEASUREMENTS FROM ENERGIZED SURFACES OF THE CELL LINE OR THEIR ATTACHMENTS. THESE MEASUREMENTS INCLUDE: THE SPACE WITHIN 96 INCHES ABOVE ANY ENERGIZED PART, THE SPACE BELOW ENERGIZED SURFACES PROVIDED THE HEADROOM IS LESS THAN 96 INCHES, AND THE SPACE WITHIN 42 INCHES HORIZONTALLY FROM ENERGIZED SURFACES OR FROM THE 96-INCH VERTICAL ENVELOPE. THESE SPACE REQUIREMENTS DO NOT EXTEND BEYOND WALLS OR OTHER FIXED BARRIERS. FIGURE 72 ILLUSTRATES A TYPICAL ALUMINUM REDUCTION CELL LINE ARRANGEMENT SHOWING THE LOCATION OF THE CELL LINE WORKING ZONE BOUNDARIES.

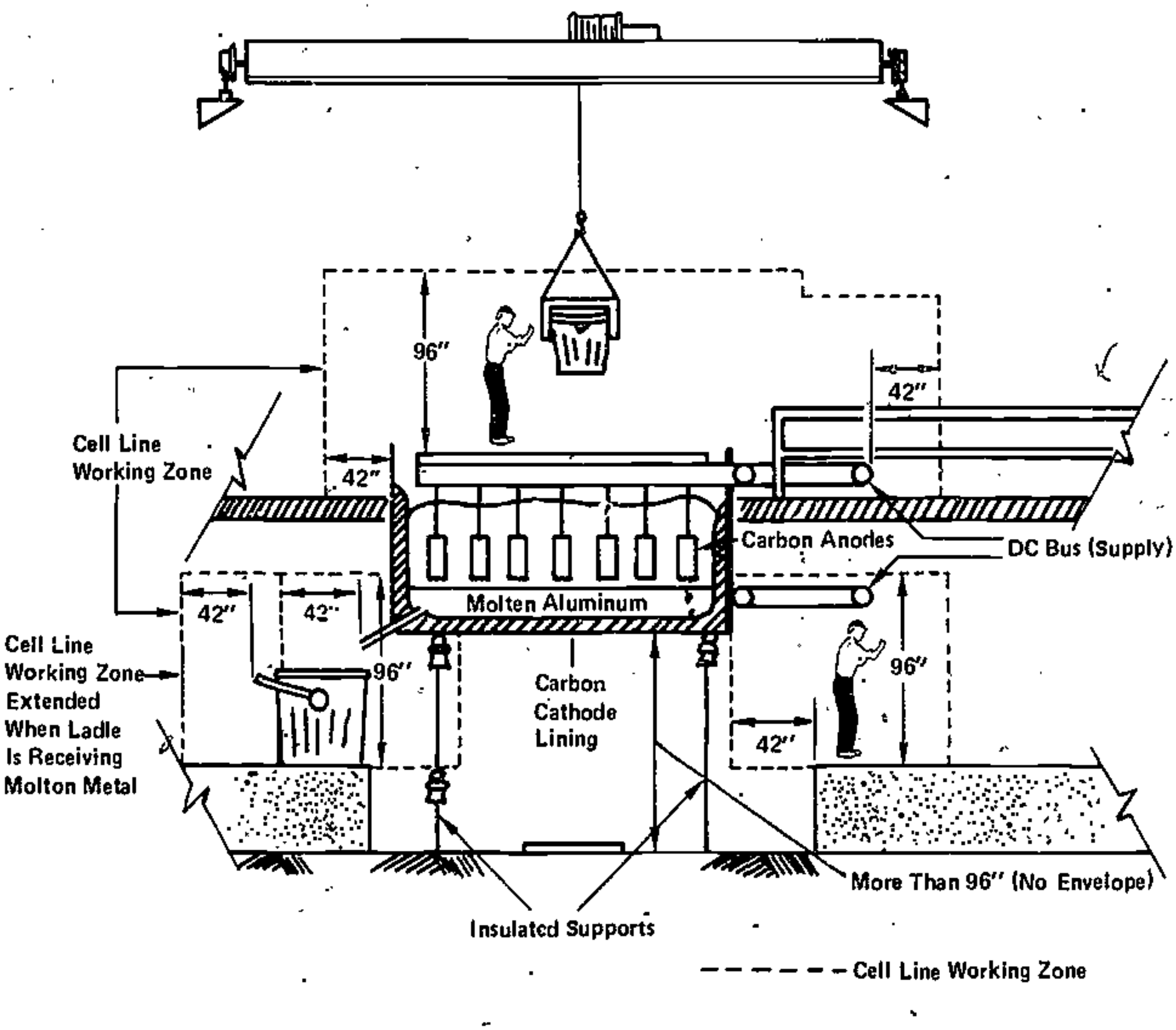


FIGURE 72. THE BOUNDARIES OF THE CELL LINE AS A SINGLE FUNCTIONAL UNIT

Electrolytic Cells: A receptacle or vessel in which electrochemical reactions are caused by applying energy for the purpose of refining or producing usable materials.

(3) Application. Installations covered by paragraph (h) of this section shall comply with all applicable provisions of this subpart, except as follows:

(i) Overcurrent protection of electrolytic cell DC process power circuits need not comply with the requirements of §1910.304(e).

(ii) Equipment located or used within the cell line working zone or associated with the cell line DC power circuits need not comply with the provisions of §1910.304(f).

(iii) Electrolytic cells, cell line conductors, cell line attachments, and the wiring of auxiliary equipment and devices within the cell line working zone need not comply with the provisions of §§1910.303, and 1910.304(b) and (c).

(4) Disconnecting means.

(i) If more than one DC cell line process power supply serves the same cell line, a disconnecting means shall be provided on the cell line circuit side of each power supply to disconnect it from the cell line circuit.

(ii) Removable links or removable conductors may be used as the disconnecting means.

(5) Portable electric equipment.

(i) The frames and enclosures of portable electric equipment used within the cell line working zone may not be grounded. However, these frames and enclosures may be grounded if the cell line circuit voltage does not exceed 200 volts DC or if the frames are guarded.

(ii) Ungrounded portable electric equipment shall be distinctively marked and may not be interchangeable with grounded portable electric equipment.

(6) Power supply circuits and receptacles for portable electric equipment.

(i) Circuits supplying power to ungrounded receptacles for hand-held, cord- and plug-connected equipment shall be electrically isolated from any distribution system supplying areas other than the cell line working zone and shall be ungrounded. Power for these circuits shall be supplied through isolating transformers.

(ii) Receptacles and their mating plugs for ungrounded equipment may not have provision for a grounding conductor and shall be of a configuration which prevents their use for equipment required to be grounded.

(iii) Receptacles on circuits supplied by an isolating transformer with an ungrounded secondary shall have a distinctive configuration, shall be distinctively marked, and may not be used in any other location in the plant.

- THE CELL LINE DC CIRCUITS OPERATE AT HIGH VOLTAGE AND POWER RATINGS. ALUMINUM REDUCTION, FOR INSTANCE, CAN BE RATED AT 600 VOLTS DC AND 155,000 AMPERES DC.

VOLTAGE TO GROUND FROM THESE CURRENT-CARRYING PARTS IS GENERALLY UNKNOWN. THEREFORE, IT IS NECESSARY TO MINIMIZE THE POSSIBILITY OF WORKERS ACCIDENTALLY PROVIDING A PATH TO GROUND AT ANY POINT. TO PREVENT THE INTRODUCTION OF INADVERTENT GROUNDS, TOOL FRAMES MUST BE INSULATED FROM GROUND RATHER THAN GROUNDED, AND EVEN THE CIRCUITS SUPPLYING SUCH TOOLS CANNOT HAVE A GROUNDED CONDUCTOR. GROUNDING IS PERMITTED, HOWEVER, IF THE CELL LINE VOLTAGE IS 200 VOLTS OR LESS.

ISOLATING TRANSFORMERS ARE USED TO SUPPLY POWER TO HAND-HELD CORD-CONNECTED EQUIPMENT USED IN THE CELL LINE WORKING ZONE. THE SECONDARY WINDINGS OF ISOLATING TRANSFORMERS HAVE NO ELECTRICAL CONNECTION TO THE PRIMARY WINDINGS. THEREFORE, THE LOAD SIDE OF THE CIRCUIT IS NOT INFLUENCED BY THE GROUNDING OF THE DISTRIBUTION SYSTEM SUPPLYING THE PRIMARY WINDINGS. THESE ISOLATED CIRCUITS MUST NOT BE GROUNDED. FIGURE 73 ILLUSTRATES A SCHEMATIC DRAWING OF AN ISOLATED CIRCUIT USED TO SUPPLY HAND-HELD POWER TOOLS.

PLUGS AND RECEPTACLES USED FOR EQUIPMENT CONNECTED TO A CIRCUIT SUPPLIED BY AN ISOLATING TRANSFORMER MUST HAVE A CONFIGURATION DIFFERENT FROM ANY OTHERS USED IN THE PLANT.

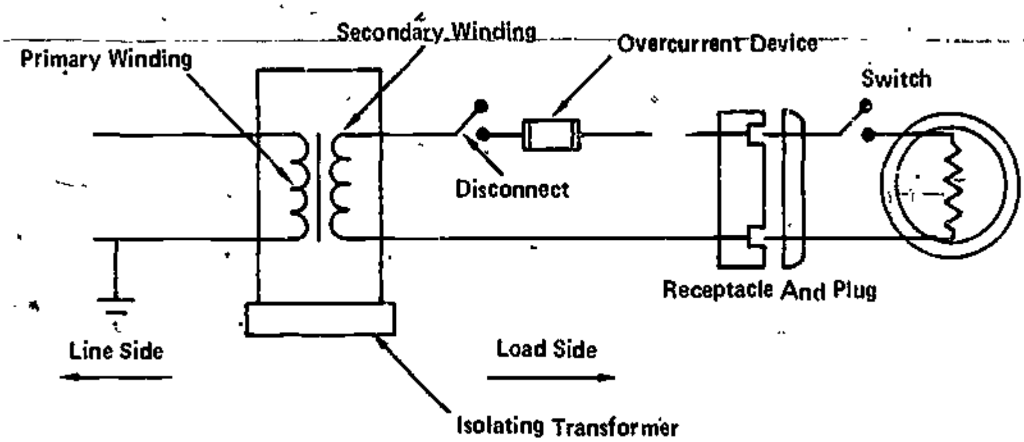


FIGURE 73. ISOLATING TRANSFORMER SUPPLYING HAND-HELD DOUBLE INSULATED TOOL FOR USE IN CELL LINE WORKING ZONE

(7) Fixed and portable electric equipment.

(i) AC systems supplying fixed and portable electric equipment within the cell line working zone need not be grounded.

(ii) Exposed conductive surfaces, such as electric equipment housings, cabinets, boxes, motors, raceways and the like that are within the cell line working zone need not be grounded.

(iii) Auxiliary electrical devices, such as motors, transducers, sensors, control devices, and alarms, mounted on an electrolytic cell or other energized surface, shall be connected by any of the following means:

(a) Multiconductor hard usage or extra hard usage flexible cord;

(b) Wire or cable in suitable raceways; or

(c) Exposed metal conduit, cable tray, armored cable, or similar metallic systems installed with insulating breaks such that they will not cause a potentially hazardous electrical condition.

(iv) Fixed electric equipment may be bonded to the energized conductive surfaces of the cell line, its attachments, or auxiliaries. If fixed electric equipment is mounted on an energized conductive surface, it shall be bonded to that surface.

(8) Auxiliary nonelectric connections. Auxiliary nonelectric connections, such as air hoses, water hoses, and the like, to an electrolytic cell, its attachments, or auxiliary equipment may not have continuous conductive reinforcing wire, armor, braids, and the like. Hoses shall be of a nonconductive material.

(9) Cranes and hoists.

(i) The conductive surfaces of cranes and hoists that enter the cell line working zone need not be grounded. The portion of an overhead crane or hoist which contacts an energized electrolytic cell or energized attachments shall be insulated from ground.

(ii) Remote crane or hoist controls which may introduce hazardous electrical conditions into the cell line working zone shall employ one or more of the following systems:

(a) Insulated and ungrounded control circuit;
(b) Nonconductive rope operator;
(c) Pendant pushbutton with nonconductive supporting means and having nonconductive surfaces or ungrounded exposed conductive surfaces; or
(d) Radio.

(i) Electrically driven or controlled irrigation machines. (See §1910.302(b)(3).)

(1) Lightning protection. If an electrically driven or controlled irrigation machine has a stationary point, a driven ground rod shall be connected to the machine at the stationary point for lightning protection.

(2) Disconnecting means. The main disconnecting means for a center pivot irrigation machine shall be located at the point of connection of electrical power to the machine and shall be readily accessible and capable of being locked in the open position. A disconnecting means shall be provided for each motor and controller.

(j) Swimming pools, fountains, and similar installations.

(1) Scope. Paragraphs (j)(2) through (j)(5) of this section apply to electric wiring for and equipment in or adjacent to all swimming, wading, therapeutic, and decorative pools and fountains, whether permanently installed or storable, and to metallic auxiliary equipment, such as pumps, filters, and similar equipment. Therapeutic pools in health care facilities are exempt from these provisions.

(2) Lighting and receptacles.

• (i) Receptacles. A single receptacle of the locking and grounding type that provides power for a permanently installed swimming pool recirculating pump motor may be located not less than 5 feet from the inside walls of a pool. All other receptacles on the property shall be located at least 10 feet from the inside walls of a pool. Receptacles which are located within 15 feet of the inside walls of the pool shall be protected by ground-fault circuit interrupters.

NOTE: In determining these dimensions, the distance to be measured is the shortest path the supply cord of an appliance connected to the receptacle would follow without piercing a floor, wall, or ceiling of a building or other effective permanent barrier.

• A SINGLE RECEPTACLE FOR THE POOL RECIRCULATING PUMP MAY BE LOCATED AS CLOSE AS 5 FEET FROM THE INSIDE WALL OF THE POOL. THIS ALLOWS FOR THE USE OF A CORD-CONNECTED PUMP MOTOR AND PROVIDES A MEANS TO EASILY REMOVE THE MOTOR DURING THE WINTER TO PREVENT FREEZING. THE RECEPTACLE AND PLUG MUST BE THE LOCKING AND GROUNDING TYPE. FIGURE 74 ILLUSTRATES THE NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA) CONFIGURATION FOR LOCKING PLUGS AND RECEPTACLES.

ALL OTHER RECEPTACLES MUST BE AT LEAST 10 FEET FROM THE INSIDE WALL OF THE POOL. ANY RECEPTACLE WITHIN 15 FEET OF THE POOL WALL MUST BE EQUIPPED WITH A GROUND-FAULT CIRCUIT INTERRUPTER (GFCI). FIGURE 75 ILLUSTRATES THESE KEY DISTANCES WHERE RECEPTACLES ARE PERMITTED.

THIS REQUIREMENT FOR A GFCI IS DIRECTED TOWARD THE HAZARD OF SHOCK WHERE ELECTRICITY IS USED IN AND AROUND SWIMMING POOLS. A PERSON IN CONTACT WITH THE WATER OR WET SURFACES MAY PROVIDE A PATH FROM AN ENERGIZED CIRCUIT, POSSIBLY THROUGH A FAULTY APPLIANCE, TO GROUND.

THE GROUND-FAULT CIRCUIT INTERRUPTER IS A FAST-ACTING DEVICE WHICH SENSES SMALL CURRENT LEAKAGE TO GROUND AND, IN A FRACTION OF A SECOND, SHUTS OFF THE ELECTRICITY AND "INTERRUPTS" ITS FAULTY FLOW TO GROUND. PLACED BETWEEN THE ELECTRICAL SERVICE AND THE TOOL OR APPLIANCE IT SERVES, THE GFCI CONTINUALLY MATCHES THE AMOUNT OF CURRENT GOING TO AND FROM THE TOOL ALONG THE NORMAL PATH OF THE CIRCUIT CONDUCTORS. WHENEVER THE AMOUNT "GOING" DIFFERS FROM THE AMOUNT "RETURNING" BY A SET TRIP LEVEL (5mA ± 1mA ON CURRENTLY APPROVED GFCI'S), THE GFCI INTERRUPTS THE ELECTRIC POWER IN AS LITTLE AS 1/40 OF A SECOND. THIS DIFFERENCE IN CURRENT IS CALLED LEAKAGE CURRENT TO GROUND AND THE PATH IT TAKES TO GROUND COULD BE THROUGH A PERSON — IN WHICH CASE, THE RAPID RESPONSE OF THE GFCI IS FAST ENOUGH TO PREVENT ELECTROCUTION. THIS PROTECTION PROVIDED BY THE GFCI IS INDEPENDENT OF THE CONDITION OF THE EQUIPMENT GROUNDING CONDUCTOR. THUS, THE GFCI CAN PROVIDE PROTECTION EVEN IF THE EQUIPMENT GROUNDING CONDUCTOR BECOMES INOPERATIVE.

IT SHOULD BE NOTED THAT A FUSE OR CIRCUIT BREAKER CANNOT POSSIBLY PROVIDE THIS KIND OF PERSONNEL PROTECTION, BECAUSE IT MONITORS ONLY THE AMOUNT OF CURRENT FLOWING, NOT THE PATH OF CURRENT AND CANNOT DETECT LEAKAGE CURRENT THROUGH A FAULT. FOR EXAMPLE, A 20-AMPERE CIRCUIT BREAKER WILL NOT TRIP OUT EVEN IF ALL THE 20 AMPERES ARE FLOWING THROUGH A GROUND FAULT, BUT THE GFCI WILL TRIP OUT IF .005 AMPERES OR MORE START TO FLOW THROUGH A GROUND FAULT. THIS SMALL AMOUNT OF CURRENT FLOWING FOR THE EXTREMELY SHORT TIME REQUIRED TO TRIP THE GFCI WOULD NOT ELECTROCUTE A PERSON. FIGURE 76A ILLUSTRATES A SCHEMATIC OF A GFCI. FIGURE 76B SHOWS A GFCI INCORPORATED INTO A RECEPTACLE.

Voltage Rating	NEMA Line Number	15 AMPERE Receptacle	15 AMPERE Plug	20 AMPERE Receptacle	20 AMPERE Plug
125V.	5	L5-15R 	L5-15P 	L5-20R 	L5-20P 
250V.	6	L6-15R 	L6-15P 	L6-20R 	L6-20P 

FIGURE 74. NEMA CONFIGURATIONS FOR 3-WIRE 2-POLE GROUNDING PLUGS AND RECEPTACLES

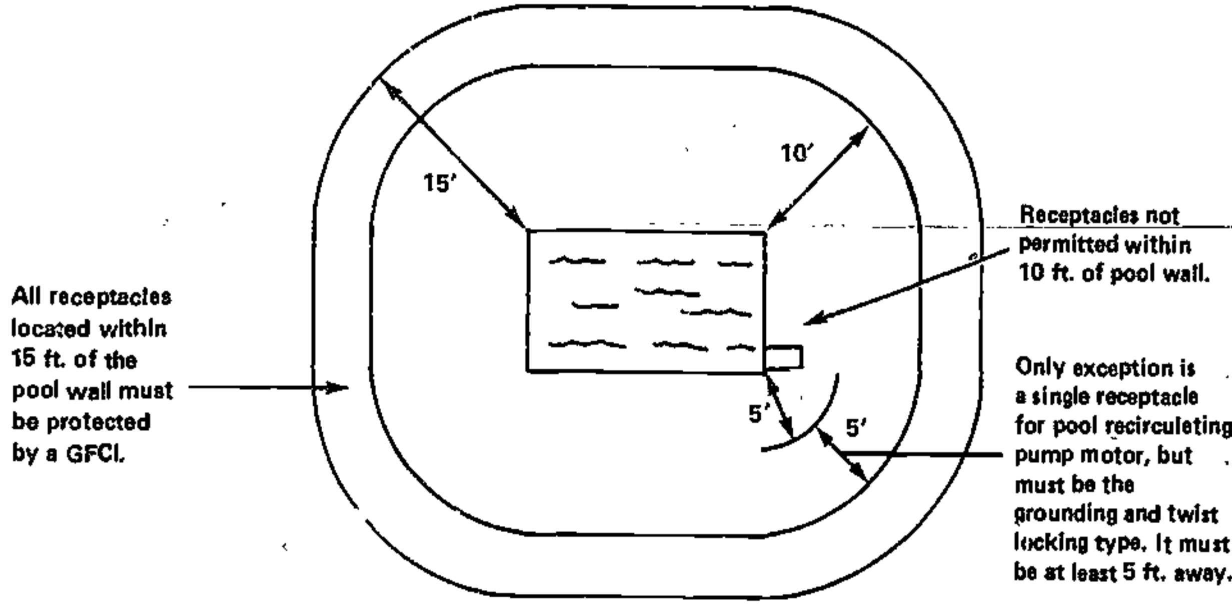


FIGURE 75. PERMANENTLY INSTALLED SWIMMING POOL

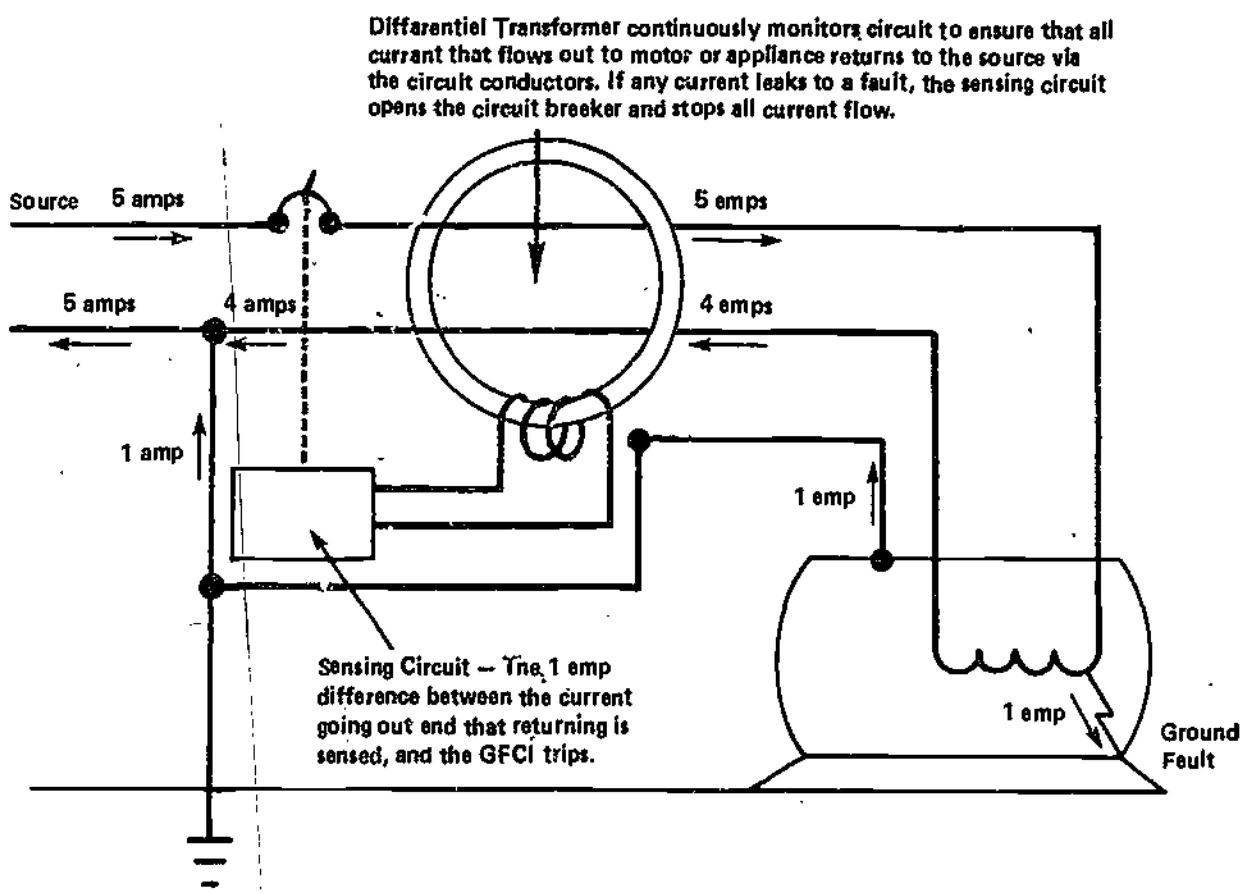


FIGURE 76A. GROUND-FAULT CIRCUIT INTERRUPTER

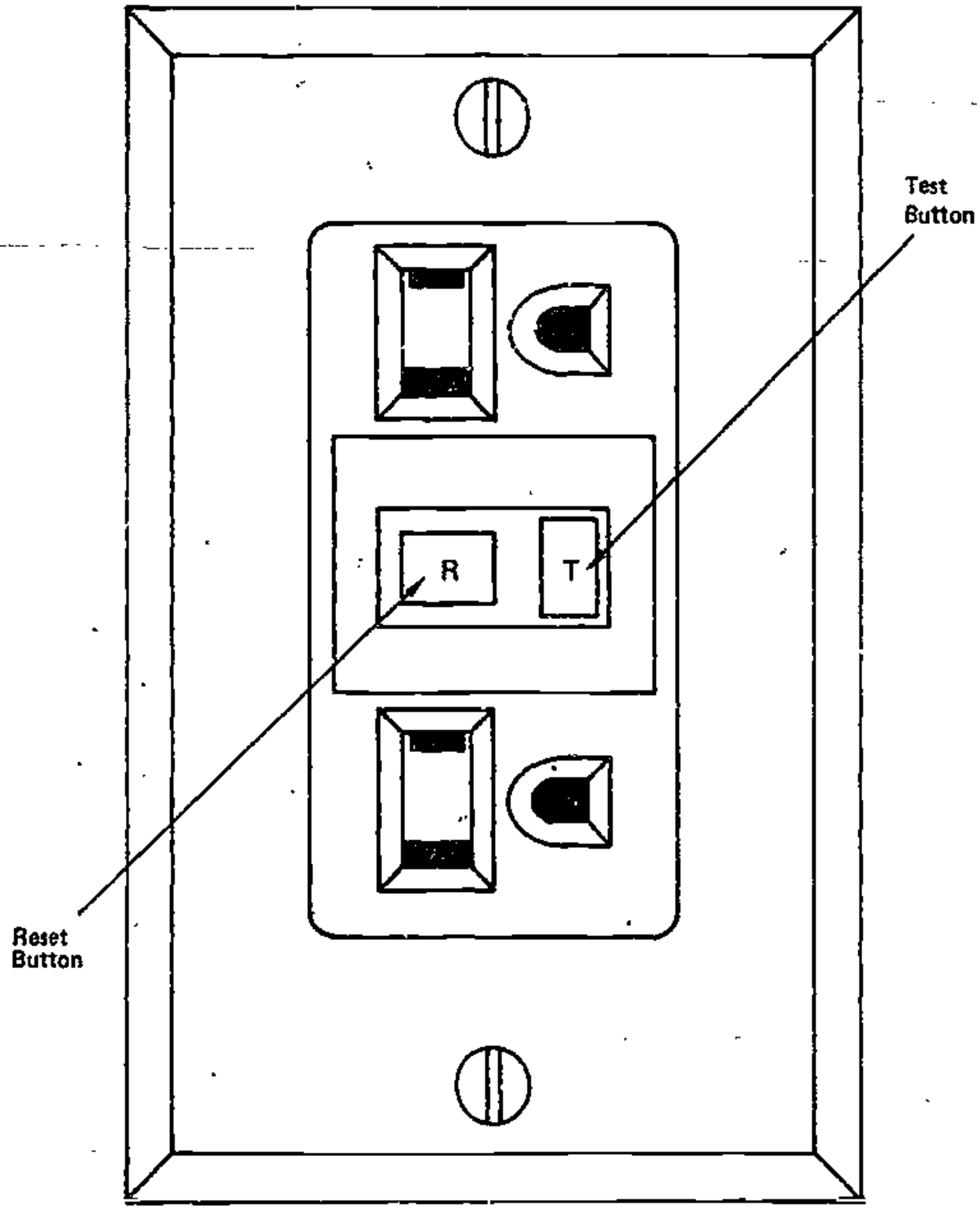


FIGURE 76B. RECEPTACLE-TYPE GROUND-FAULT CIRCUIT INTERRUPTER (GFCI)

(ii) Lighting fixtures and lighting outlets.

(a) Unless they are 12 feet above the maximum water level, lighting fixtures and lighting outlets may not be installed over a pool or over the area extending 5 feet horizontally from the inside walls of a pool. However, a lighting fixture or lighting outlet which has been installed before April 16, 1981, may be located less than 5 feet measured horizontally from the inside walls of a pool if it is at least 5 feet above the surface of the maximum water level and shall be rigidly attached to the existing structure. It shall also be protected by a ground-fault circuit interrupter installed in the branch circuit supplying the fixture.

(b) Unless installed 5 feet above the maximum water level and rigidly attached to the structure adjacent to or enclosing the pool, lighting fixtures and lighting outlets installed in the area extending between 5 feet and 10 feet horizontally from the inside walls of a pool shall be protected by a ground-fault circuit interrupter.

(3) Cord- and plug-connected equipment. Flexible cords used with the following equipment may not exceed 3 feet in length and shall have a copper equipment grounding conductor with a grounding-type attachment plug.

(i) Cord- and plug-connected lighting fixtures installed within 16 feet of the water surface of permanently installed pools.

(ii) Other cord- and plug-connected, fixed or stationary equipment used with permanently installed pools.

(4) Underwater equipment.

(i) A ground-fault circuit interrupter shall be installed in the branch circuit supplying underwater fixtures operating at more than 15 volts. Equipment installed underwater shall be approved for the purpose.

(ii) No underwater lighting fixtures may be installed for operation at over 150 volts between conductors.

(5) Fountains. All electric equipment operating at more than 15 volts, including power supply cords, used with fountains shall be protected by ground-fault circuit interrupters. (See §1910.302(b)(3).)

§1910.307 HAZARDOUS (CLASSIFIED) LOCATIONS

§1910.307 Hazardous (classified) locations.

(a) Scope. This section covers the requirements for electric equipment and wiring in locations which are classified depending on the properties of the flammable vapors, liquids or gases, or combustible dusts or fibers which may be present therein and the likelihood that a flammable or combustible concentration or quantity is present. Hazardous (classified) locations may be found in occupancies such as, but not limited to, the following: aircraft hangers, gasoline dispensing and service stations, bulk storage plants for gasoline or other volatile flammable liquids, paint-finishing process plants, health care facilities, agricultural or other facilities where excessive combustible dusts may be present, marinas, boat yards, and petroleum and chemical processing plants. Each room, section or area shall be considered individually in determining its classification. These hazardous (classified) locations are assigned six designations as follows:

Class I, Division 1
Class I, Division 2
Class II, Division 1
Class II, Division 2
Class III, Division 1
Class III, Division 2

For definitions of these locations see §1910.399(a). All applicable requirements in this subpart shall apply to hazardous (classified) locations, unless modified by provisions of this section.

- THE FOLLOWING DISCUSSION PROVIDES A GENERAL OVERVIEW OF THE GUIDELINES CONTAINED IN THE NATIONAL ELECTRICAL CODE, CHAPTER 5. ALSO, HIGHLIGHTS AND SUMMARY INFORMATION ARE PRESENTED TO AID IN UNDERSTANDING DESIGN CONCEPTS AND EQUIPMENT SELECTION. SEVERAL REFERENCES ARE MADE TO NEC ARTICLES 500, 501, 502, AND 503. CAREFUL STUDY OF THESE AND THEIR ASSOCIATED ARTICLES SHOULD PRECEDE ANY DESIGN DEVELOPMENT ACTIVITIES.

HAZARDOUS LOCATIONS

HAZARDOUS LOCATIONS ARE AREAS WHERE FLAMMABLE LIQUIDS, GASES, OR VAPORS, OR COMBUSTIBLE DUSTS EXIST IN SUFFICIENT QUANTITIES TO PRODUCE AN EXPLOSION OR FIRE. IN HAZARDOUS LOCATIONS, SPECIALLY DESIGNED EQUIPMENT AND SPECIAL INSTALLATION TECHNIQUES MUST BE USED TO PROTECT AGAINST THE EXPLOSIVE AND FLAMMABLE POTENTIAL OF THESE SUBSTANCES.

HAZARDOUS LOCATIONS ARE CLASSIFIED AS CLASS I, CLASS II, OR CLASS III, DEPENDING ON WHAT TYPE OF HAZARDOUS SUBSTANCE IS OR MAY BE PRESENT. IN GENERAL, CLASS I LOCATIONS ARE THOSE IN WHICH FLAMMABLE VAPORS AND GASES MAY BE PRESENT. CLASS II LOCATIONS ARE THOSE IN WHICH COMBUSTIBLE DUSTS MAY BE FOUND. CLASS III LOCATIONS ARE THOSE IN WHICH THERE ARE IGNITIBLE FIBERS AND FLYINGS.

EACH OF THESE CLASSES IS DIVIDED INTO TWO HAZARD CATEGORIES, DIVISION 1 AND DIVISION 2, DEPENDING ON THE LIKELIHOOD OF THE PRESENCE OF A FLAMMABLE OR IGNITIBLE CONCENTRATION OF A SUBSTANCE. DIVISION 1 LOCATIONS ARE DESIGNATED AS SUCH BECAUSE A FLAMMABLE GAS, VAPOR, OR DUST IS NORMALLY PRESENT IN HAZARDOUS QUANTITIES. IN DIVISION 2 LOCATIONS, THE EXISTENCE OF HAZARDOUS QUANTITIES OF THESE MATERIALS IS NOT NORMAL, BUT THEY MAY OCCASIONALLY EXIST EITHER ACCIDENTALLY OR WHEN MATERIAL IN STORAGE IS HANDLED. IN GENERAL, THE INSTALLATION REQUIREMENTS FOR DIVISION 1 LOCATIONS ARE MORE STRINGENT THAN FOR DIVISION 2 LOCATIONS.

ADDITIONALLY, CLASS I AND CLASS II LOCATIONS ARE ALSO SUBDIVIDED INTO GROUPS OF GASES, VAPORS, AND DUSTS HAVING SIMILAR PROPERTIES.

TABLE 3 SUMMARIZES THE VARIOUS HAZARDOUS (CLASSIFIED) LOCATIONS. THE DEFINITIONS OF THE LOCATIONS ARE GIVEN IN PARAGRAPH 1910.399(a) OF THE STANDARD.

TABLE 3. SUMMARY OF CLASS I, II, III HAZARDOUS LOCATIONS

CLASSES	GROUPS	DIVISIONS 1	DIVISIONS 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 IS OR MAY BE IN SUSPENSION, OR CONDUCTIVE DUST MAY BE PRESENT	DUST NOT NORMALLY SUSPENDED IN AN IGNITIBLE 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.

(b) Electrical installations. Equipment, wiring methods, and installations of equipment in hazardous (classified) locations shall be intrinsically safe, or approved for the hazardous (classified) location, or safe for the hazardous (classified) location. Requirements for each of these options are as follows:

(1) Intrinsically safe. Equipment and associated wiring approved as intrinsically safe shall be permitted in any hazardous (classified) location for which it is approved.

(2) Approved for the hazardous (classified) location.

(i) Equipment shall be approved not only for the class of location but also for the ignitible or combustible properties of the specific gas, vapor, dust, or fiber that will be present.

NOTE: NFPA 70, the National Electrical Code, lists or defines hazardous gases, vapors, and dusts by "Groups" characterized by their ignitible or combustible properties.

(ii) Equipment shall be marked to show the class, group, and operating temperature or temperature range, based on operation in a 40 degrees C ambient, for which it is approved. The temperature marking may not exceed the ignition temperature of the specific gas or vapor to be encountered. However, the following provisions modify this marking requirement for specific equipment:

(a) Equipment of the non-heat-producing type, such as junction boxes, conduit, and fittings, and equipment of the heat-producing type having a maximum temperature not more than 100 degrees C (212 degrees F) need not have a marked operating temperature or temperature range.

(b) Fixed lighting fixtures marked for use in Class I, Division 2 locations only, need not be marked to indicate the group.

(c) Fixed general-purpose equipment in Class I locations, other than lighting fixtures, which is acceptable for use in Class I, Division 2 locations need not be marked with the class, group, division, or operating temperature.

(d) Fixed dust-tight equipment, other than lighting fixtures, which is acceptable for use in Class II, Division 2 and Class III locations need not be marked with the class, group, division, or operating temperature.

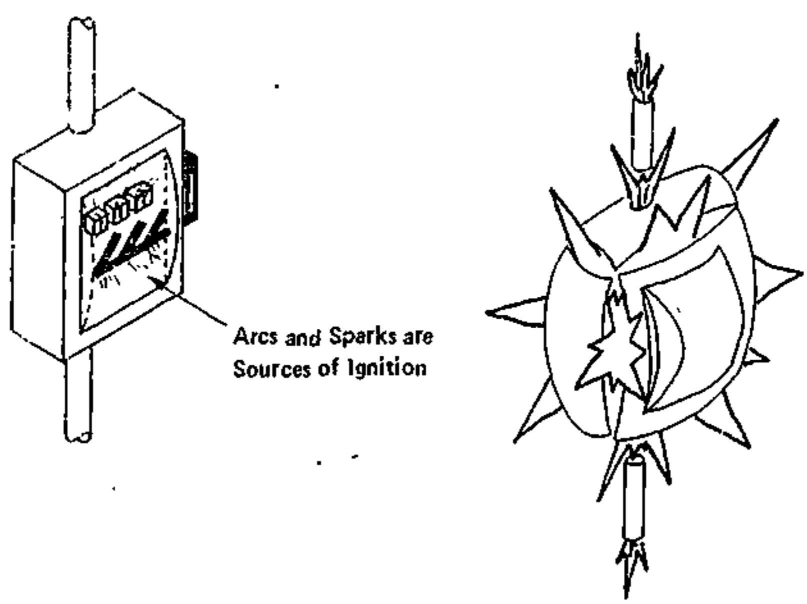
(3) Safe for the hazardous (classified) location. Equipment which is safe for the location shall be of a type and design which the employer demonstrates will provide protection from the hazards arising from the combustibility and flammability of vapors, liquids, gases, dusts, or fibers.

NOTE: The National Electrical Code, NFPA 70, contains guidelines for determining the type and design of equipment and installations which will meet this requirement. The guidelines of this document address electric wiring, equipment, and systems installed in hazardous (classified) locations and contain specific provisions for the following: wiring methods, wiring connections; conductor insulation, flexible cords, sealing and drainage, transformers, capacitors, switches, circuit breakers, fuses, motor controllers, receptacles, attachment plugs, meters, relays, instruments, resistors, generators, motors, lighting fixtures, storage battery charging equipment, electric cranes, electric hoists and similar equipment, utilization equipment, signaling systems, alarm systems, remote control systems, local loud speaker and communication systems, ventilation piping, live parts, lightning surge protection, and grounding. Compliance with these guidelines will constitute one means, but not the only means, of compliance with this paragraph.

- EQUIPMENT DESIGN

GENERAL-PURPOSE ELECTRICAL EQUIPMENT CAN CAUSE EXPLOSIONS AND FIRES IN AREAS WHERE FLAMMABLE VAPORS, LIQUIDS, AND GASES, AND COMBUSTIBLE DUSTS OR FIBERS ARE PRESENT. THESE AREAS REQUIPE SPECIAL ELECTRICAL EQUIPMENT WHICH IS DESIGNED FOR THE SPECIFIC HAZARD INVOLVED. THIS INCLUDES EXPLOSION-PROOF EQUIPMENT FOR FLAMMABLE VAPOR, LIQUID AND GAS HAZARDS AND DUST-IGNITION-PROOF EQUIPMENT FOR COMBUSTIBLE DUST. OTHER EQUIPMENT USED INCLUDE: NONSPARKING EQUIPMENT, INTRINSICALLY SAFE EQUIPMENT AND PURGED AND PRESSURIZED EQUIPMENT. IN SOME CASES, GENERAL PURPOSE OR DUST-TIGHT EQUIPMENT IS PERMITTED IN DIVISION 2 AREAS.

MANY PIECES OF ELECTRICAL EQUIPMENT INCLUDE CERTAIN PARTS THAT ARC, SPARK, OR PRODUCE HEAT UNDER NORMAL OPERATING CONDITIONS. FOR EXAMPLE, CIRCUIT CONTROLS, SWITCHES, AND CONTACTS MAY ARC OR SPARK WHEN OPERATED. MOTORS AND LIGHTING FIXTURES ARE EXAMPLES OF EQUIPMENT THAT MAY HEAT UP. THESE ENERGY SOURCES CAN PRODUCE TEMPERATURES HIGH ENOUGH TO CAUSE IGNITION. SEE FIGURE 77. ELECTRICAL EQUIPMENT SHOULD NOT BE INSTALLED IN KNOWN OR POTENTIALLY HAZARDOUS LOCATIONS UNLESS ABSOLUTELY NECESSARY. HOWEVER, WHEN ELECTRICAL EQUIPMENT MUST BE INSTALLED IN THESE AREAS, THE SPARKING, ARCING, AND HEATING NATURE OF THE EQUIPMENT MUST BE CONTROLLED.



IF GENERAL-PURPOSE EQUIPMENT IS USED IN HAZARDOUS LOCATIONS, A SERIOUS FIRE AND EXPLOSION HAZARD EXISTS.

FIGURE 77. EXPLOSION OCCURRING IN GENERAL PURPOSE EQUIPMENT

INSTALLATIONS IN HAZARDOUS LOCATIONS MUST BE: (1) INTRINSICALLY SAFE, (2) APPROVED FOR THE HAZARDOUS LOCATION, OR (3) OF A TYPE AND DESIGN WHICH PROVIDES PROTECTION FROM THE HAZARDS ARISING FROM THE COMBUSTIBILITY AND FLAMMABILITY OF THE VAPORS, LIQUIDS, GASES, DUSTS, OR FIBERS THAT WILL BE PRESENT. INSTALLATIONS CAN BE ONE OR ANY COMBINATION OF THESE OPTIONS. EACH OPTION IS DESCRIBED IN THE FOLLOWING DISCUSSION.

*INTRINSICALLY SAFE

EQUIPMENT AND WIRING APPROVED AS INTRINSICALLY SAFE IS ACCEPTABLE IN ANY HAZARDOUS (CLASSIFIED) LOCATION FOR WHICH IT IS DESIGNED. INTRINSICALLY SAFE EQUIPMENT IS NOT CAPABLE OF RELEASING SUFFICIENT ELECTRICAL OR THERMAL ENERGY UNDER NORMAL OR ABNORMAL CONDITIONS TO CAUSE IGNITION OF A SPECIFIC FLAMMABLE OR COMBUSTIBLE ATMOSPHERIC MIXTURE IN ITS MOST EASILY IGNITIBLE CONCENTRATION.

TO AVOID CONTAMINATING NONHAZARDOUS LOCATIONS, THE PASSAGE OF FLAMMABLE GASES AND VAPORS THROUGH THE EQUIPMENT MUST BE PREVENTED. ADDITIONALLY, ALL INTERCONNECTIONS BETWEEN CIRCUITS MUST BE EVALUATED TO BE SURE THAT AN UNEXPECTED SOURCE OF IGNITION IS NOT INTRODUCED THROUGH OTHER NONINTRINSICALLY SAFE EQUIPMENT. SEPARATION OF INTRINSICALLY SAFE AND NONINTRINSICALLY SAFE WIRING MAY BE NECESSARY TO ENSURE THAT THE CIRCUITS IN HAZARDOUS (CLASSIFIED) LOCATIONS REMAIN SAFE.

*APPROVED FOR THE HAZARDOUS (CLASSIFIED) LOCATION

UNDER THIS OPTION, EQUIPMENT MUST BE APPROVED FOR THE CLASS, DIVISION, AND GROUP OF LOCATION. THERE ARE TWO TYPES OF EQUIPMENT SPECIFICALLY DESIGNED FOR HAZARDOUS (CLASSIFIED) LOCATIONS – EXPLOSION PROOF AND DUST-IGNITION PROOF. EXPLOSION-PROOF APPARATUS IS INTENDED FOR CLASS I LOCATIONS, WHILE DUST-IGNITION-PROOF EQUIPMENT IS PRIMARILY INTENDED FOR CLASS II AND III LOCATIONS. EQUIPMENT APPROVED SPECIFICALLY FOR HAZARDOUS LOCATIONS CARRIES AN UNDERWRITERS' LABORATORIES, INC. (UL), LABEL AND INDICATES IN WHAT CLASS, DIVISION, AND GROUP OF LOCATION IT MAY BE INSTALLED. SEE FIGURE 78. EQUIPMENT APPROVED FOR USE IN A DIVISION 1 LOCATION MAY BE INSTALLED IN A DIVISION 2 LOCATION OF THE SAME CLASS AND GROUP.

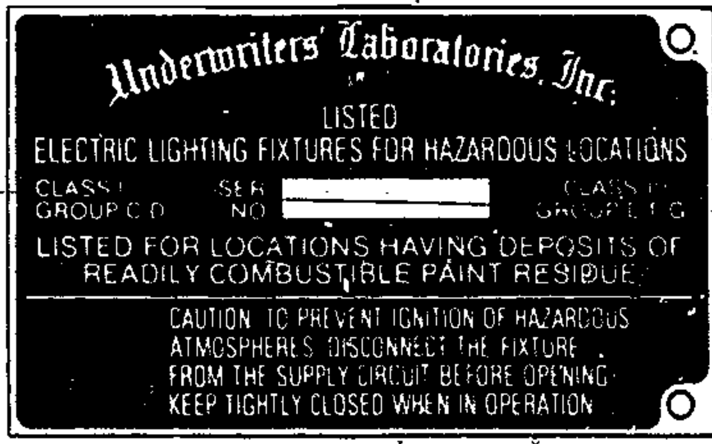
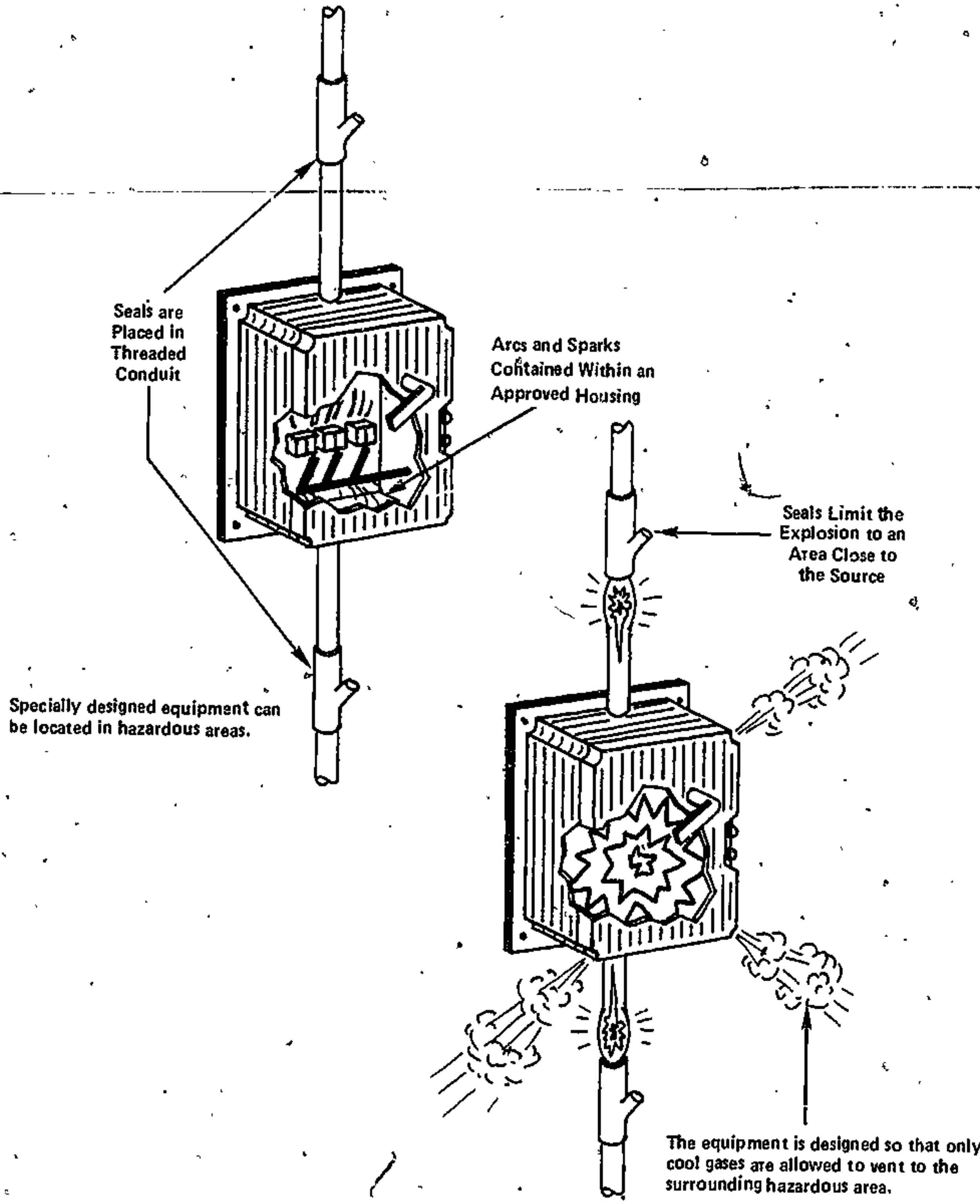


FIGURE 78. LABEL SHOWING APPROVAL FOR USE IN HAZARDOUS (CLASSIFIED) LOCATIONS

EXPLOSION-PROOF EQUIPMENT

GENERALLY, EQUIPMENT INSTALLED IN CLASS I LOCATIONS MUST BE APPROVED AS EXPLOSION-PROOF. SINCE IT IS IMPRACTICAL TO KEEP FLAMMABLE GASES OUTSIDE OF ENCLOSURES, ARCING EQUIPMENT MUST BE INSTALLED IN ENCLOSURES THAT ARE DESIGNED TO WITHSTAND AN EXPLOSION. THIS MINIMIZES THE RISK OF HAVING AN EXTERNAL EXPLOSION OCCUR WHEN A FLAMMABLE GAS ENTERS THE ENCLOSURE AND IS IGNITED BY THE ARCS. SEE FIGURE 79. NOT ONLY MUST THE EQUIPMENT BE STRONG ENOUGH TO WITHSTAND AN INTERNAL EXPLOSION, BUT THE ENCLOSURES MUST BE DESIGNED TO VENT THE RESULTING EXPLOSIVE GASES. THIS VENTING MUST ENSURE THAT THE GASES ARE COOLED TO A TEMPERATURE BELOW THAT OF IGNITION TEMPERATURE OF THE HAZARDOUS SUBSTANCE INVOLVED BEFORE BEING RELEASED INTO THE HAZARDOUS ATMOSPHERE.



WHEN ARCS AND SPARKS CAUSE IGNITION OF FLAMMABLE GASES, VAPORS AND LIQUIDS, THE EQUIPMENT CONTAINS THE EXPLOSION AND VENTS ONLY COOL GASES INTO THE SURROUNDING HAZARDOUS AREA.

FIGURE 79. EXPLOSION OCCURRING IN APPROVED EQUIPMENT

WHEN AN INTERNAL EXPLOSION OCCURS, IT TENDS TO DISTORT THE SHAPE OF THE ENCLOSURE FROM RECTANGULAR TO ELLIPTICAL AS EXAGGERATED IN FIGURE 80. ADEQUATE STRENGTH IS ONE REQUIREMENT FOR THE DESIGN OF AN EXPLOSION-PROOF ENCLOSURE: A SAFETY FACTOR OF 4 IS GENERALLY USED. TO PREVENT FAILURE OF THE ENCLOSURE, OPENINGS ARE DESIGNED TO RELIEVE THE PRESSURE OF THE EXPANDING GASES. ALL JOINTS AND FLANGES ARE HELD TO NARROW TOLERANCES — THE ACCURATELY MACHINED JOINTS ACT TO COOL THE HOT GASES RESULTING FROM AN INTERNAL EXPLOSION SO THAT BY THE TIME THEY REACH THE OUTSIDE HAZARDOUS ATMOSPHERE THEY ARE TOO COOL TO CAUSE IGNITION.

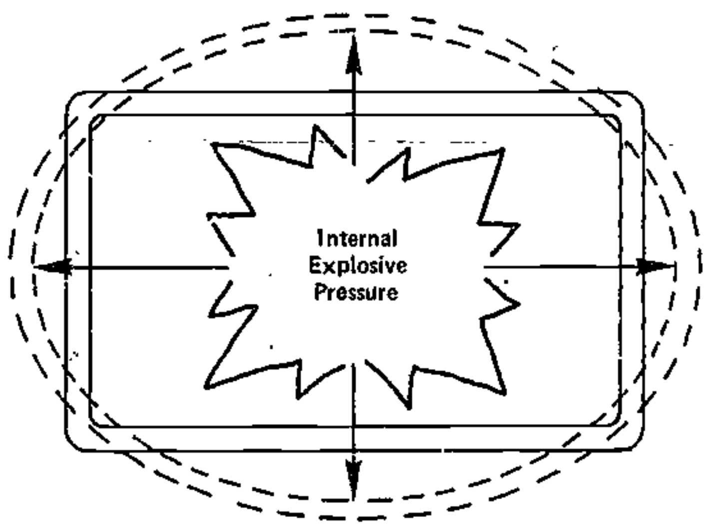
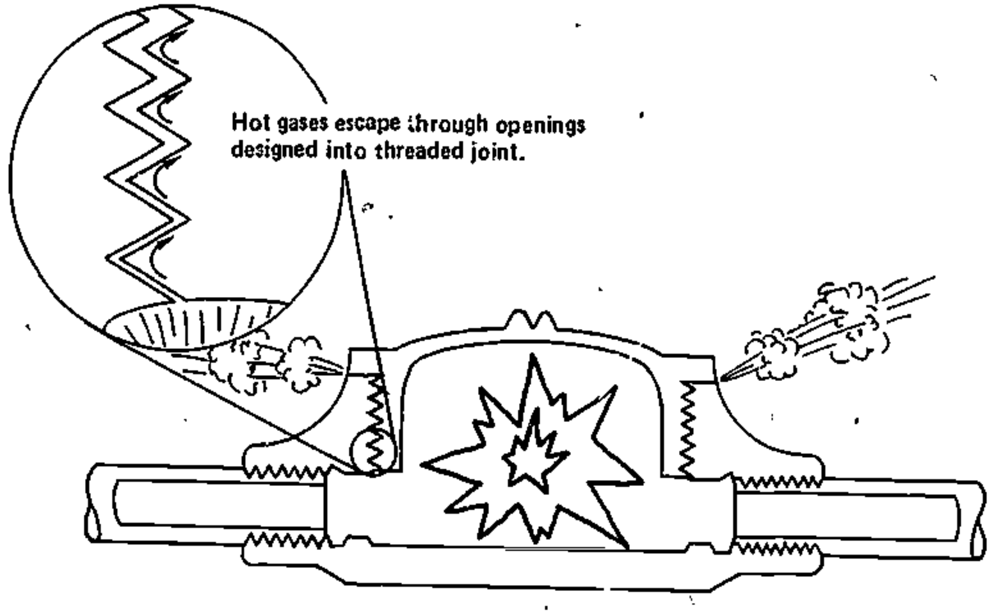


FIGURE 80. INTERNAL EXPLOSIVE PRESSURE

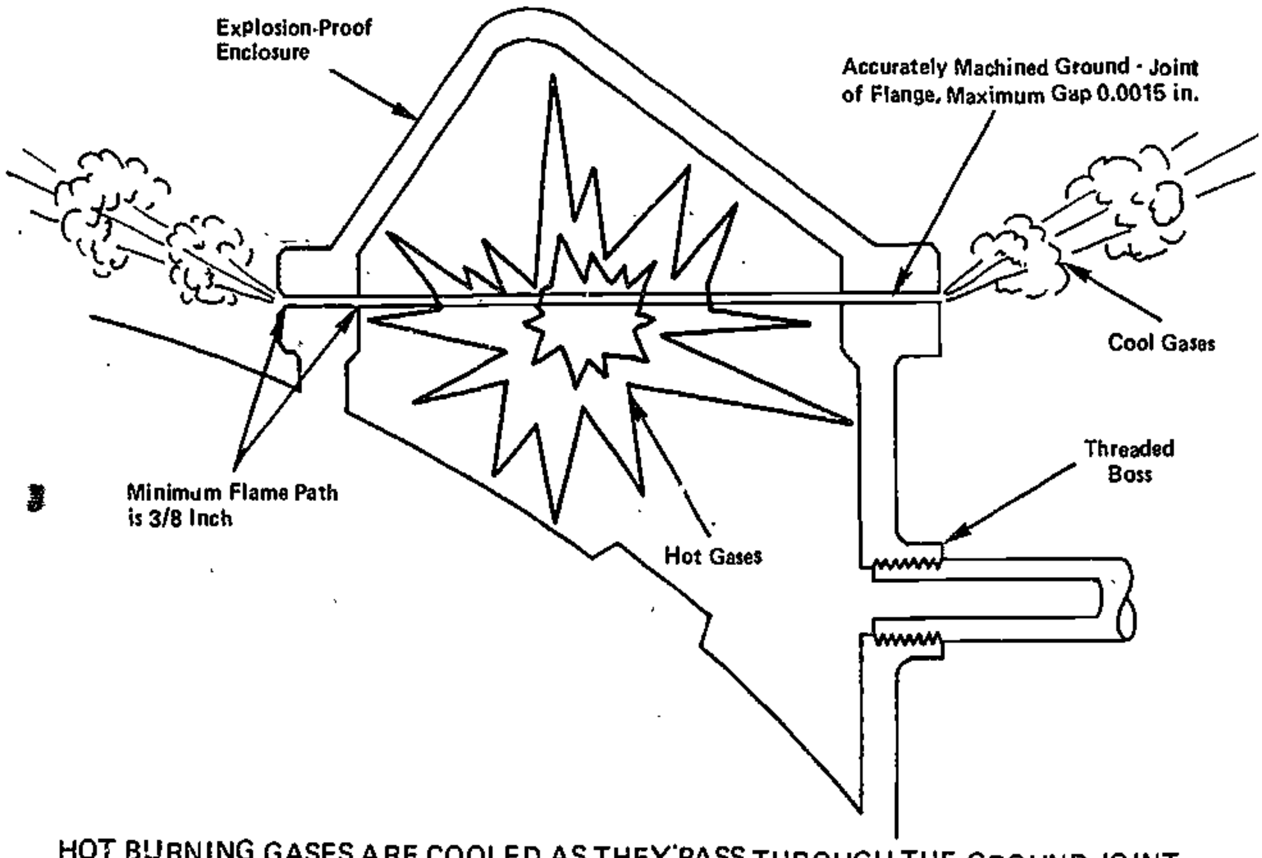
THERE ARE TWO COMMON ENCLOSURE DESIGNS: THREADED-JOINT ENCLOSURES (SEE FIGURE 81) AND GROUND-JOINT ENCLOSURES (SEE FIGURE 82). WHEN HOT GASES TRAVEL THROUGH THE VERY SMALL OPENINGS IN EITHER OF THESE JOINTS, THEY ARE COOLED BEFORE REACHING THE SURROUNDING HAZARDOUS ATMOSPHERE.

OTHER DESIGN REQUIREMENTS, SUCH AS SEALING, PREVENT THE PASSAGE OF GASES, VAPORS OR FUMES FROM ONE PORTION OF AN ELECTRICAL SYSTEM TO ANOTHER. MOTORS, WHICH TYPICALLY CONTAIN SPARKING BRUSHES OR COMMUTATORS AND TEND TO HEAT UP, MUST ALSO BE DESIGNED TO PROVIDE FOR THE CONTROL OF INTERNAL EXPLOSIONS.



THE CASE OF THE ENCLOSURE IS MADE OF CAST METAL, STRONG ENOUGH TO WITHSTAND THE MAXIMUM EXPLOSION PRESSURE OF A SPECIFIC GROUP OF HAZARDOUS GASES OR VAPORS.

FIGURE 81. OPENINGS DESIGNED INTO THREADED JOINT



HOT BURNING GASES ARE COOLED AS THEY PASS THROUGH THE GROUND-JOINT OF FLANGES, DESIGNED WITHIN NARROW STANDARD TOLERANCES.

FIGURE 82. OPENINGS DESIGNED INTO GROUND JOINT

BECAUSE THE EXPLOSION CHARACTERISTICS OF HAZARDOUS SUBSTANCES VARY WITH THE SPECIFIC MATERIAL INVOLVED, EACH GROUP REQUIRES SPECIAL DESIGN CONSIDERATIONS. FOR CLASS I HAZARDOUS LOCATIONS, THERE ARE FOUR GROUPS – A, B, C, AND D. SEE TABLE 4A. DESIGN CHARACTERISTICS FOR THESE FOUR GROUPS REQUIRE THE CONTAINMENT OF MAXIMUM EXPLOSION PRESSURE, MAXIMUM SAFE CLEARANCE BETWEEN PARTS OF ENCLOSURES – INCLUDING THREADED JOINTS OR JOINTS THAT ARE GROUND TO NARROW TOLERANCES – AND OPERATION AT A TEMPERATURE BELOW THE IGNITION TEMPERATURE OF THE ATMOSPHERIC MIXTURE INVOLVED.

TABLE 4A. CHEMICALS BY GROUPS – CLASS I

GROUP A ATMOSPHERES:	ACETYLENE
GROUP B ATMOSPHERES:	ACROLEIN (INHIBITED), ARSINE, BUTADIENE, ETHYLENE OXIDE, HYDROGEN, MANUFACTURED GASES CONTAINING MORE THAN 30% HYDROGEN (BY VOLUME), PROPYLENE OXIDE, PROPYLNITRATE
GROUP C ATMOSPHERES:	ACETALDEHYDE, ALLYL ALCOHOL, N-BUTYRALDEHYDE, CARBON MONOXIDE, CROTONALDEHYDE, CYCLOPROPANE, DIETHYL ETHER, DIETHYLAMINE, EPICHLOROHYDRINE, ETHYLENE, ETHYLENIMINE, ETHYL MERCAPTAN, ETHYL SULFIDE, HYDROGEN CYANIDE, HYDROGEN SULFIDE, MORPHOLINE, 2-NITROPROPANE, TETRAHYDROFURAN, UNSYMMETRICAL DIMETHYL HYDRAZINE (UDMH 1, 1-DIMETHYL HYDRAZINE)
GROUP D ATMOSPHERES:	ACETIC ACID (GLACIAL), ACETONE, ACRYLONITRILE, AMMONIA, BENZENE, BUTANE, 1-BUTANOL (BUTYL ALCOHOL), 2-BUTANOL (SECONDARY BUTYL ALCOHOL), N-BUTYL ACETATE, ISOBUTYL ACETATE, DI-ISOBUTYLENE, ETHANE, ETHANOL (ETHYL ALCOHOL), ETHYL ACETATE, ETHYL ACRYLATE (INHIBITED), ETHYLENE DIAMINE (ANHYDROUS), ETHYLENE DICHLORIDE, ETHYLENE GLYCOL MONOMETHYL ETHER, GASOLINE, HEPTANES, HEXANES, ISOPRENE, ISOPROPYL ETHER, MESITYL OXIDE, METHANE (NATURAL GAS), METHANOL (METHYL ALCOHOL), 3-METHYL-1-BUTANOL (ISOAMYL ALCOHOL), METHYL ETHYL KETONE, METHYL ISOBUTYL KETONE, 2-METHYL-1-PROPANOL (ISOBUTYL ALCOHOL), 2-METHYL-2-PROPANOL (TERTIARY BUTYL ALCOHOL), PETROLEUM NAPHTHA, PYRIDINE, OCTANES, PENTANES, 1-PENTANOL (AMYL ALCOHOL), PROPANE, 1-PROPANOL (PROPYL ALCOHOL), 2-PROPANOL (ISOPROPYL ALCOHOL), PROPYLENE, STYRENE, TOLUENE, VINYL ACETATE, VINYL CHLORIDE, XYLENES

SOURCE: TABLE 500-2, ARTICLE 500 – HAZARDOUS (CLASSIFIED) LOCATIONS, 1981 NATIONAL ELECTRICAL CODE, NATIONAL FIRE PROTECTION ASSOCIATION, BOSTON, MASS.

DUST-IGNITION-PROOF EQUIPMENT

IN CLASS II, DIVISION 1 LOCATIONS, EQUIPMENT MUST GENERALLY BE DUST-IGNITION-PROOF. SECTION 502-1 OF THE NEC DEFINES DUST-IGNITION-PROOF AS EQUIPMENT "ENCLOSED IN A MANNER THAT WILL EXCLUDE IGNITIBLE AMOUNTS OF DUST OR AMOUNTS THAT MIGHT AFFECT PERFORMANCE OR RATING AND THAT, WHERE INSTALLED AND PROTECTED IN ACCORDANCE WITH THIS CODE, WILL NOT PERMIT ARCS, SPARKS, OR HEAT OTHERWISE GENERATED OR LIBERATED INSIDE THE ENCLOSURE TO CAUSE IGNITION OF EXTERIOR ACCUMULATIONS OR ATMOSPHERIC SUSPENSIONS OF A SPECIFIED DUST ON OR IN THE VICINITY OF THE ENCLOSURE."

DUST-IGNITION-PROOF EQUIPMENT IS DESIGNED TO KEEP IGNITIBLE AMOUNTS OF DUST FROM ENTERING THE ENCLOSURE. IN ADDITION, DUST MAY ACCUMULATE ON ELECTRICAL EQUIPMENT, CAUSING OVERHEATING OF THE EQUIPMENT, AS WELL AS THE DEHYDRATION OR GRADUAL CARBONIZATION OF ORGANIC DUST DEPOSITS. OVERHEATED EQUIPMENT MAY MALFUNCTION AND CAUSE A FIRE. DUST THAT HAS CARBONIZED IS SUSCEPTABLE TO SPONTANEOUS IGNITION OR SMOLDERING. THEREFORE, EQUIPMENT MUST ALSO BE DESIGNED TO OPERATE BELOW THE IGNITION TEMPERATURE OF THE SPECIFIC DUST INVOLVED EVEN WHEN BLANKETED. THE SHAPE OF THE ENCLOSURE MUST BE DESIGNED TO MINIMIZE DUST ACCUMULATION WHEN FIXTURES ARE OUT OF REACH OF NORMAL HOUSEKEEPING ACTIVITIES, E.G., LIGHTING FIXTURE CANOPYS.

IN CLASS II HAZARDOUS LOCATIONS THERE ARE THREE GROUPS – E, F, AND G. (SEE TABLE 4B.) SPECIAL DESIGNS ARE REQUIRED TO PREVENT DUST FROM ENTERING INTO THE ELECTRICAL EQUIPMENT ENCLOSURE. ASSEMBLY JOINTS AND MOTOR SHAFT OPENINGS MUST BE TIGHT ENOUGH TO PREVENT DUST FROM ENTERING THE ENCLOSURE. IN ADDITION THE DESIGN MUST TAKE INTO ACCOUNT THE INSULATING EFFECTS OF DUST LAYERS ON EQUIPMENT AND MUST ENSURE THAT THE EQUIPMENT WILL OPERATE BELOW THE IGNITION TEMPERATURE OF THE DUST INVOLVED. IF CONDUCTIVE COMBUSTIBLE DUSTS ARE PRESENT, THE DESIGN OF EQUIPMENT MUST TAKE THE SPECIAL NATURE OF THESE DUSTS INTO ACCOUNT.

IN GENERAL, EQUIPMENT WHICH IS APPROVED EXPLOSION-PROOF IS NOT DESIGNED FOR, AND IS NOT ACCEPTABLE FOR USE IN, CLASS II LOCATIONS, UNLESS SPECIFICALLY APPROVED FOR USE IN SUCH LOCATIONS. FOR EXAMPLE, SINCE GRAIN DUST HAS A LOWER IGNITION TEMPERATURE THAN THAT OF MANY FLAMMABLE VAPORS, EQUIPMENT APPROVED FOR CLASS I LOCATIONS MAY OPERATE AT A TEMPERATURE THAT IS TOO HIGH FOR CLASS II LOCATIONS. ON THE OTHER HAND, EQUIPMENT THAT IS DUST-IGNITION-PROOF IS GENERALLY ACCEPTABLE FOR USE IN CLASS III LOCATIONS, SINCE THE SAME DESIGN CONSIDERATIONS ARE INVOLVED.

TABLE 4B. CHEMICALS BY GROUPS – CLASS II

GROUP E ATMOSPHERES:	METAL DUST, INCLUDING ALUMINUM, MAGNESIUM, AND THEIR COMMERCIAL ALLOYS, AND OTHER METALS OF SIMILARLY HAZARDOUS CHARACTERISTICS HAVING RESISTIVITY OF 10^2 OHM-CENTIMETER OR LESS.
GROUP F ATMOSPHERES:	CARBON BLACK, CHARCOAL, COAL, OR COKE DUSTS
GROUP G ATMOSPHERES.	FLOUR, STARCH, GRAIN DUST, OR COMBUSTIBLE PLASTIC OR CHEMICAL DUSTS HAVING RESISTIVITY GREATER THAN 10^8 OHM-CENTIMETER.

MARKING

APPROVED EQUIPMENT MUST BE MARKED TO INDICATE THE CLASS, GROUP, AND OPERATING TEMPERATURE RANGE (BASED ON A 40° C AMBIENT TEMPERATURE) IN WHICH IT IS DESIGNED TO BE USED. FURTHERMORE, THE TEMPERATURE MARKED ON THE EQUIPMENT MUST NOT BE GREATER THAN THE IGNITION TEMPERATURE OF THE SPECIFIC GASES OR VAPORS IN THE AREA.

THERE ARE, HOWEVER, FOUR EXCEPTIONS TO THIS MARKING REQUIREMENT. FIRST, EQUIPMENT THAT DOES NOT PRODUCE HEAT (FOR EXAMPLE, JUNCTION BOXES OR CONDUITS) AND EQUIPMENT THAT DOES PRODUCE HEAT BUT THAT HAS A MAXIMUM SURFACE TEMPERATURE OF LESS THAN 100°C (OR 212°F) ARE NOT REQUIRED TO BE MARKED WITH THE OPERATING TEMPERATURE RANGE. THE HEAT NORMALLY RELEASED FROM THIS EQUIPMENT CANNOT IGNITE GASES, LIQUIDS, VAPORS, OR DUSTS.

SECOND, ANY PERMANENT LIGHTING FIXTURES THAT ARE APPROVED AND MARKED FOR USE IN CLASS I, DIVISION 2 LOCATIONS DO NOT NEED TO BE MARKED TO SHOW A SPECIFIC GROUP. THIS IS BECAUSE THESE FIXTURES ARE ACCEPTABLE FOR USE WITH ALL OF THE CHEMICAL GROUPS FOR CLASS I (THAT IS, GROUPS A, B, C, AND D).

THIRD, FIXED GENERAL-PURPOSE EQUIPMENT IN CLASS I LOCATIONS, OTHER THAN LIGHTING FIXTURES, THAT IS ACCEPTABLE FOR USE IN DIVISION 2 LOCATIONS DOES NOT HAVE TO BE LABELED ACCORDING TO CLASS, GROUP, DIVISION, OR OPERATING TEMPERATURE. THIS TYPE OF EQUIPMENT DOES NOT CONTAIN ANY DEVICES THAT MIGHT PRODUCE ARCS OR SPARKS AND, THEREFORE, IS NOT A POTENTIAL IGNITION SOURCE. FOR EXAMPLE, SQUIRREL-CAGE INDUCTION MOTORS WITHOUT BRUSHES, SWITCHING MECHANISMS OR SIMILAR ARC-PRODUCING DEVICES ARE PERMITTED IN CLASS I, DIVISION 2 LOCATIONS (SEE NEC SECTION 501-8(b)); THEREFORE, THEY NEED NO MARKING.

FOURTH, FOR CLASS II, DIVISION 2 AND CLASS III LOCATIONS, FIXED DUST-TIGHT EQUIPMENT (OTHER THAN LIGHTING FIXTURES) IS NOT REQUIRED TO BE MARKED. IN THESE LOCATIONS, DUST-TIGHT EQUIPMENT DOES NOT PRESENT A HAZARD SO IT NEED NOT BE IDENTIFIED.

* SAFE FOR THE HAZAROOUS (CLASSIFIED) LOCATION

UNOER THIS OPTION, EQUIPMENT INSTALLEO IN HAZAROOUS (CLASSIFIEO) LOCATIONS MUST BE OF A TYPE ANO DESIGN WHICH PROVIOES PROTECTION FROM THE HAZARDS ARISING FROM THE COMBUSTIBILITY AND FLAMMABILITY OF VAPORS, LIQUIOS, GASES, OUSTS, OR FIBERS. THE EMPLOYER HAS THE RESPONSIBILITY OF OEMONSTRATING THAT THE INSTALLATION MEETS THIS REQUIREMENT. GUIOELINES FOR INSTALLING EQUIPMENT UNDER THIS OPTION ARE CONTAINEO IN THE NATIONAL ELECTRICAL COOE IN EFFECT AT THE TIME OF INSTALLATION OF THAT EQUIPMENT. COMPLIANCE WITH THESE GUIOELINES ARE NOT THE ONLY MEANS OF COMPLYING WITH THIS OPTION; HOWEVER, THE EMPLOYER MUST OEMONSTRATE THAT HIS INSTALLATION IS SAFE FOR THE HAZAROOUS (CLASSIFIEO) LOCATION.

THE FOLLOWING PARAGRAPHS SUMMARIZE INSTALLATION PRACTICES GIVEN IN THE 1981 NEC. THESE PRACTICES WOULO BE AN ACCEPTABLE MEANS OF COMPLYING WITH THIS THIRD OPTION GIVEN FOR EQUIPMENT IN HAZAROOUS LOCATIONS.

- CLASS I, DIVISION 1

ARTICLE 501 OF THE NATIONAL ELECTRICAL CODE (NEC) CONTAINS INSTALLATION REQUIREMENTS FOR ELECTRICAL WIRING ANO EQUIPMENT USED IN CLASS I HAZARDOUS AREAS. THE REQUIREMENTS AS THEY PERTAIN TO CLASS I OIVISION 1 HAZARDOUS LOCATIONS ARE SUMMARIZED IN FIGURE 83 ANO TABLE 5. THE REQUIREMENTS FOR CLASS I DIVISION 2 LOCATIONS ARE SUMMARIZED IN FIGURE 83 ANO TABLE 6.

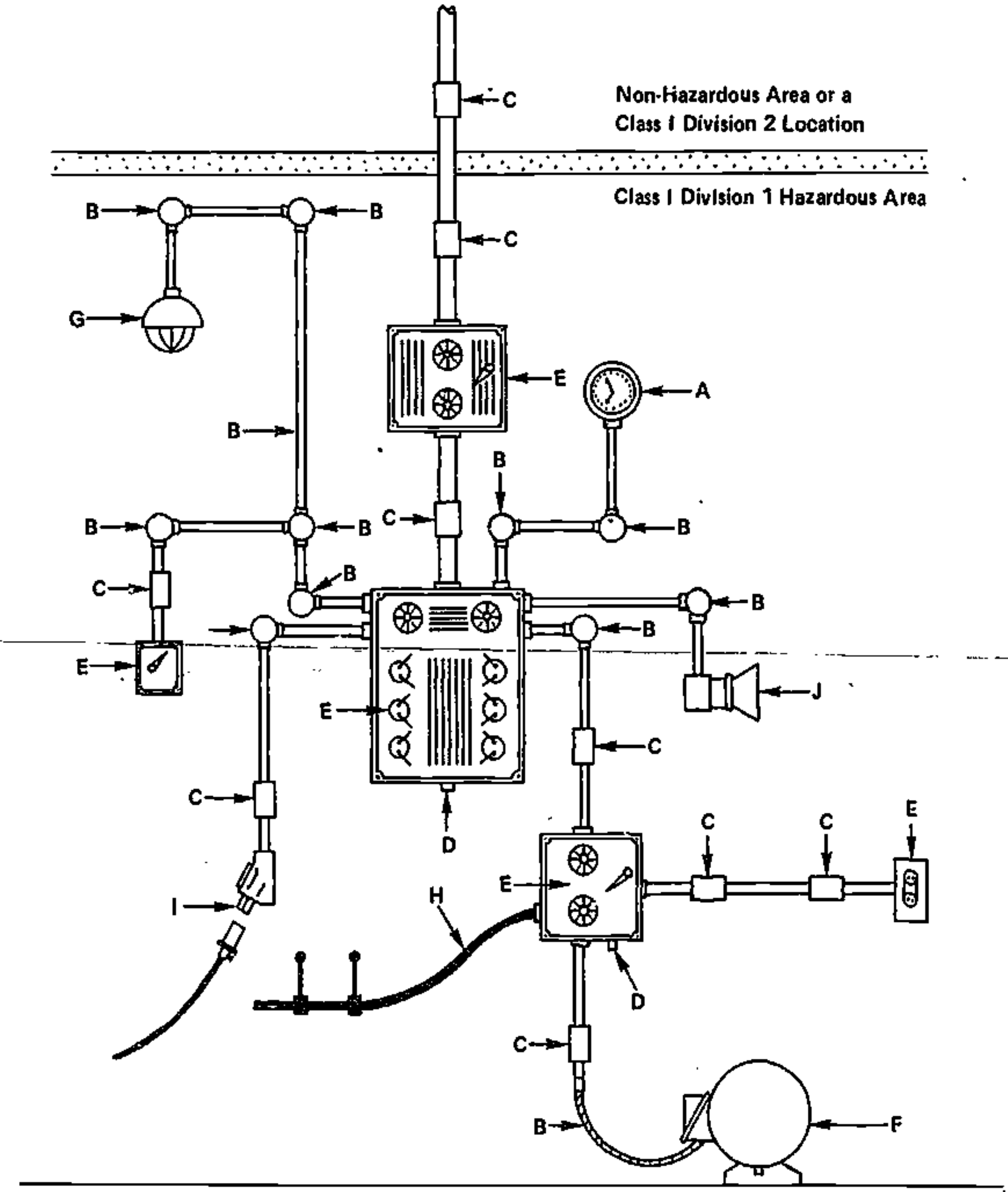


FIGURE 83. CLASS I DIVISION 1 HAZARDOUS LOCATION
(SEE TABLE 5)

TABLE 5. SUMMARY OF EQUIPMENT REQUIREMENTS FOR CLASS I DIVISION 1 HAZARDOUS LOCATIONS

(SEE FIGURE 83)

A. METERS, RELAYS, AND INSTRUMENTS, SUCH AS VOLTAGE OR CURRENT METERS AND PRESSURE OR TEMPERATURE SENSORS, MUST BE IN ENCLOSURES APPROVED FOR CLASS I, DIVISION 1 LOCATIONS. SUCH ENCLOSURES INCLUDE EXPLOSION-PROOF AND PURGED AND PRESSURIZED ENCLOSURES. SEE NEC SECTION 501-3(a).

B. WIRING METHODS ACCEPTABLE FOR USE IN CLASS I DIVISION 1 LOCATION INCLUDE: THREADED RIGID METAL OR STEEL INTERMEDIATE METAL CONDUIT AND TYPE MI CABLE. FLEXIBLE FITTINGS, SUCH AS MOTOR TERMINATIONS, MUST BE APPROVED FOR CLASS I LOCATIONS. ALL BOXES AND ENCLOSURES MUST BE EXPLOSION-PROOF AND THREADED FOR CONDUIT OR CABLE TERMINATIONS. ALL JOINTS MUST BE WRENCH TIGHT WITH A MINIMUM OF FIVE THREADS ENGAGED. SEE NEC 501-4(a).

C. SEALING IS REQUIRED FOR CONDUIT AND CABLE SYSTEMS TO PREVENT THE PASSAGE OF GASES, VAPORS, AND FLAME FROM ONE PART OF THE ELECTRICAL INSTALLATION TO ANOTHER THROUGH THE CONDUIT. TYPE MI CABLE INHERENTLY PREVENTS THIS FROM HAPPENING BY ITS CONSTRUCTION; HOWEVER, IT MUST BE SEALED TO KEEP MOISTURE AND OTHER FLUIDS FROM ENTERING THE CABLE AT TERMINATIONS. SEE FIGURE 84. SEE ALSO NEC SECTION 501-5.

(1) SEALS ARE REQUIRED WHERE CONDUIT PASSES FROM DIVISION 1 TO DIVISION 2 OR NON-HAZARDOUS LOCATIONS.
(2) SEALS ARE REQUIRED WITHIN 18 INCHES FROM ENCLOSURES CONTAINING ARCING DEVICES.
(3) SEALS ARE REQUIRED IF CONDUIT IS 2 INCHES IN DIAMETER OR LARGER ENTERING AN ENCLOSURE CONTAINING TERMINATIONS, SPLICES, OR TAPS. SEE FIGURE 85 FOR A DESCRIPTION OF SEALS.

D. DRAINAGE IS REQUIRED WHERE LIQUID OR CONDENSED VAPOR MAY BE TRAPPED WITHIN AN ENCLOSURE OR RACEWAY. AN APPROVED SYSTEM OF PREVENTING ACCUMULATIONS OR TO PERMIT PERIODIC DRAINAGE ARE TWO METHODS TO CONTROL CONDENSATION OF VAPORS AND LIQUID ACCUMULATION. SEE NEC SECTION 501-5(f).

E. ARCING DEVICES, SUCH AS SWITCHES, CIRCUIT BREAKERS, MOTOR CONTROLLERS, AND FUSES, MUST BE APPROVED FOR CLASS I LOCATIONS. SEE NEC SECTION 501-6(A).

F. MOTORS SHALL BE

(1) APPROVED FOR USE IN CLASS I, DIVISION 1 LOCATIONS;
(2) TOTALLY ENCLOSED WITH POSITIVE PRESSURE VENTILATION;
(3) TOTALLY ENCLOSED INERT-GAS-FILLED WITH A POSITIVE PRESSURE WITHIN THE ENCLOSURE; OR
(4) SUBMERGED IN A FLAMMABLE LIQUID OR GAS.

THE LAST KIND OF INSTALLATION IS PERMISSIBLE, HOWEVER, ONLY WHEN THERE IS PRESSURE ON THE ENCLOSURE THAT IS GREATER THAN ATMOSPHERIC PRESSURE AND THE LIQUID OR GAS IS ONLY FLAMMABLE IN AIR. THIS TYPE OF MOTOR IS NOT PERMITTED TO BE ENERGIZED UNTIL IT HAS BEEN PURGED OF ALL AIR. THE LATTER THREE TYPES OF MOTORS MUST BE ARRANGED TO BE DE-ENERGIZED SHOULD THE PRESSURE FAIL OR THE SUPPLY OF LIQUID OR GAS FAIL – AS WITH THE SUBMERGED TYPE. TYPES (2) AND (3) MAY NOT OPERATE AT A SURFACE TEMPERATURE ABOVE 80 PERCENT OF THE IGNITION TEMPERATURE OF THE GAS OR VAPOR INVOLVED. SEE NEC SECTION 501-8(a)

G LIGHTING FIXTURES, BOTH FIXED AND PORTABLE, MUST BE EXPLOSION-PROOF AND GUARDED AGAINST PHYSICAL DAMAGE. SEE NEC SECTION 501-9(a).

H. FLEXIBLE CORDS MUST BE DESIGNED FOR EXTRA HARD USAGE, CONTAIN AN EQUIPMENT GROUNDING CONDUCTOR (SEE FIGURE 83), BE SUPPORTED SO THAT THERE WILL BE NO TENSION ON THE TERMINAL CONNECTIONS, AND BE PROVIDED WITH SEALS WHERE THEY ENTER EXPLOSION-PROOF ENCLOSURES. SEE NEC SECTION 501-11.

NOTE: NEC-NATIONAL ELECTRICAL CODE, NFPA 70.

TABLE 5 (CONTINUED)

I. RECEPTACLES AND ATTACHMENT PLUGS FOR USE WITH PORTABLE EQUIPMENT MUST BE APPROVED EXPLOSION-PROOF AND PROVIDED WITH AN EQUIPMENT GROUNDING CONNECTION. SEE NEC SECTION 501-12.

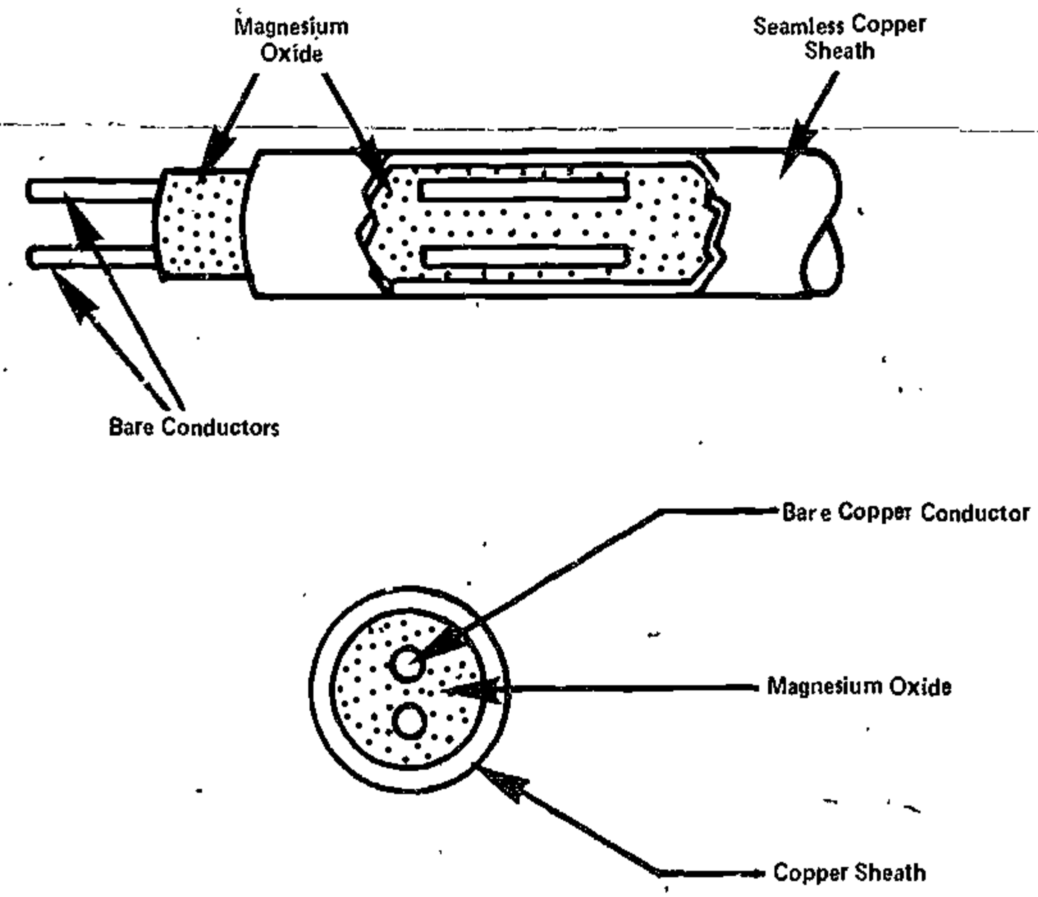
J. SIGNALING, ALARM, REMOTE CONTROL AND COMMUNICATIONS SYSTEMS ARE REQUIRED TO BE APPROVED FOR CLASS I, DIVISION 1 LOCATIONS REGARDLESS OF VOLTAGE. SEE NEC SECTION 501-14(A).

K. EQUIPMENT GROUNDING IS REQUIRED OF ALL NON-CURRENT-CARRYING METAL PARTS OF THE ELECTRICAL SYSTEM. IN ADDITION, LOCK NUTS AND BRUSHINGS MUST NOT BE RELIED UPON FOR ELECTRICAL CONNECTION BETWEEN RACEWAYS AND EQUIPMENT. IF LOCKNUTS AND BUSHINGS ARE USED, BONDING JUMPERS ARE REQUIRED. SEE NEC SECTION 501-16.

NOTE: NEC-NATIONAL ELECTRICAL CODE, NFPA 70.

THE FOLLOWING SECTIONS FURTHER EXPLAIN REQUIREMENTS FOR TYPE MI CABLE, SEALING, MOTORS, GROUNDING, AND BONDING.

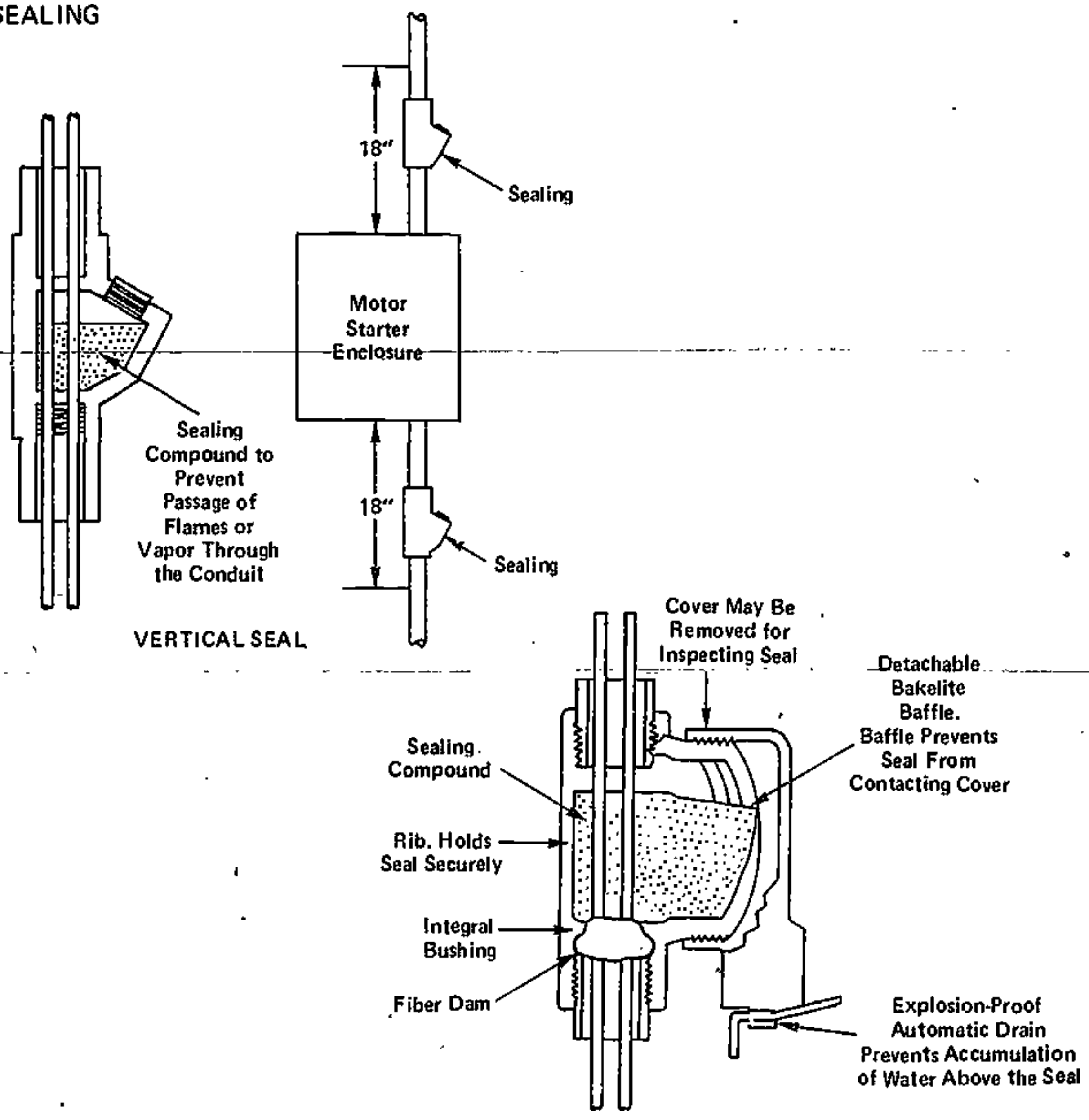
TYPE MI (MINERAL INSULATED) CABLE



TYPE MI CABLE IS A MINERAL-INSULATED CABLE OF COPPER CONDUCTORS IN TIGHTLY COMPRESSED MAGNESIUM OXIDE THAT IS ENCLOSED IN A LIQUIDTIGHT AND GASTIGHT COPPER COVERING. SINCE TYPE MI CABLE FITTINGS SUITABLE FOR NONHAZARDOUS LOCATIONS MAY NOT BE EXPLOSION PROOF, FITTINGS USED WITH THE CABLE MUST BE SPECIALLY DESIGNED FOR CLASS I LOCATIONS. BOXES, FITTINGS, AND JOINTS USED WITH THE CABLE MUST ALSO BE EXPLOSION-PROOF.

FIGURE 84. CONSTRUCTION OF TYPE MI (MINERAL INSULATED) CABLE

SEALING



A FIBER DAM IS PLACED IN THE CONDUIT WHERE IT ENTERS THE SEAL FITTING. THIS SERVES TO CONTAIN THE SEALING COMPOUND WHILE IT HARDENS. THE SEALING COMPOUND FORMS A TIGHT SEAL TO PREVENT THE PASSAGE OF VAPORS OR FLAMES THROUGH THE CONDUIT SYSTEM. SEE NEC SECTION 501-5.

FIGURE 85. SEALING

MOTORS

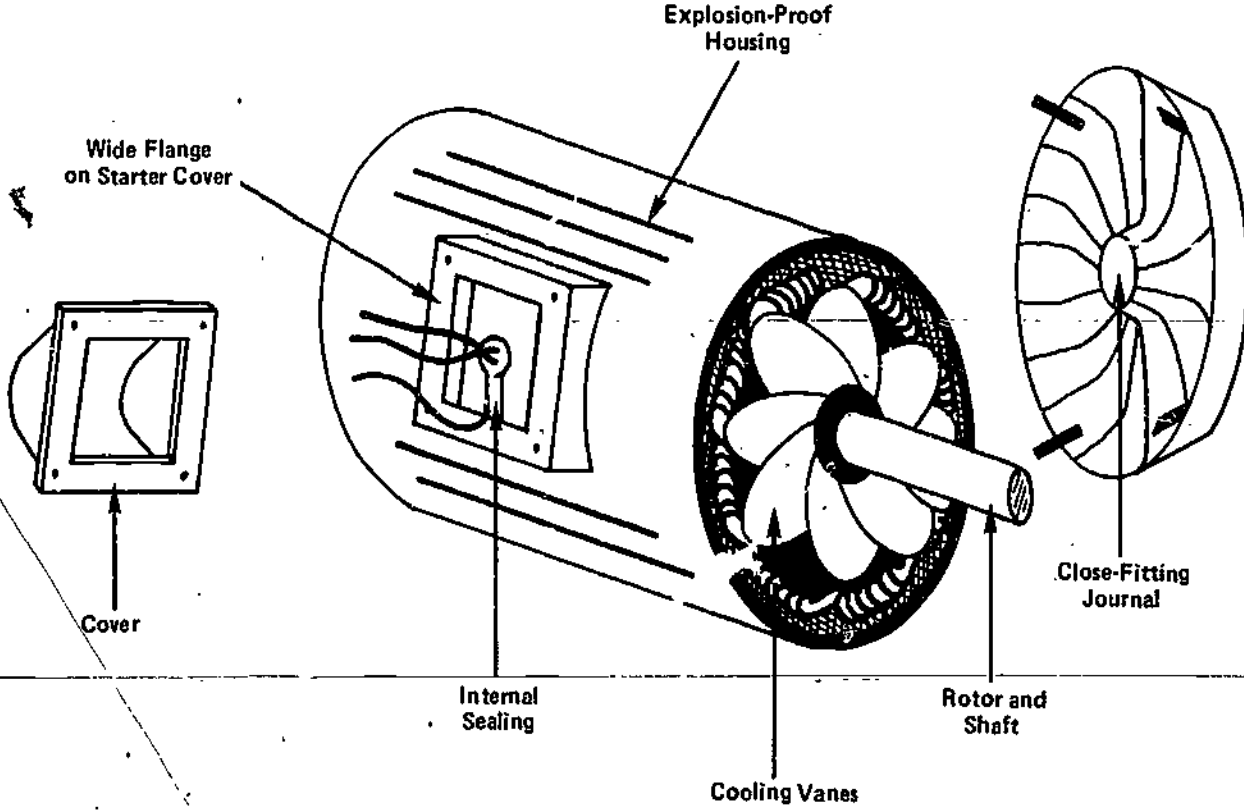
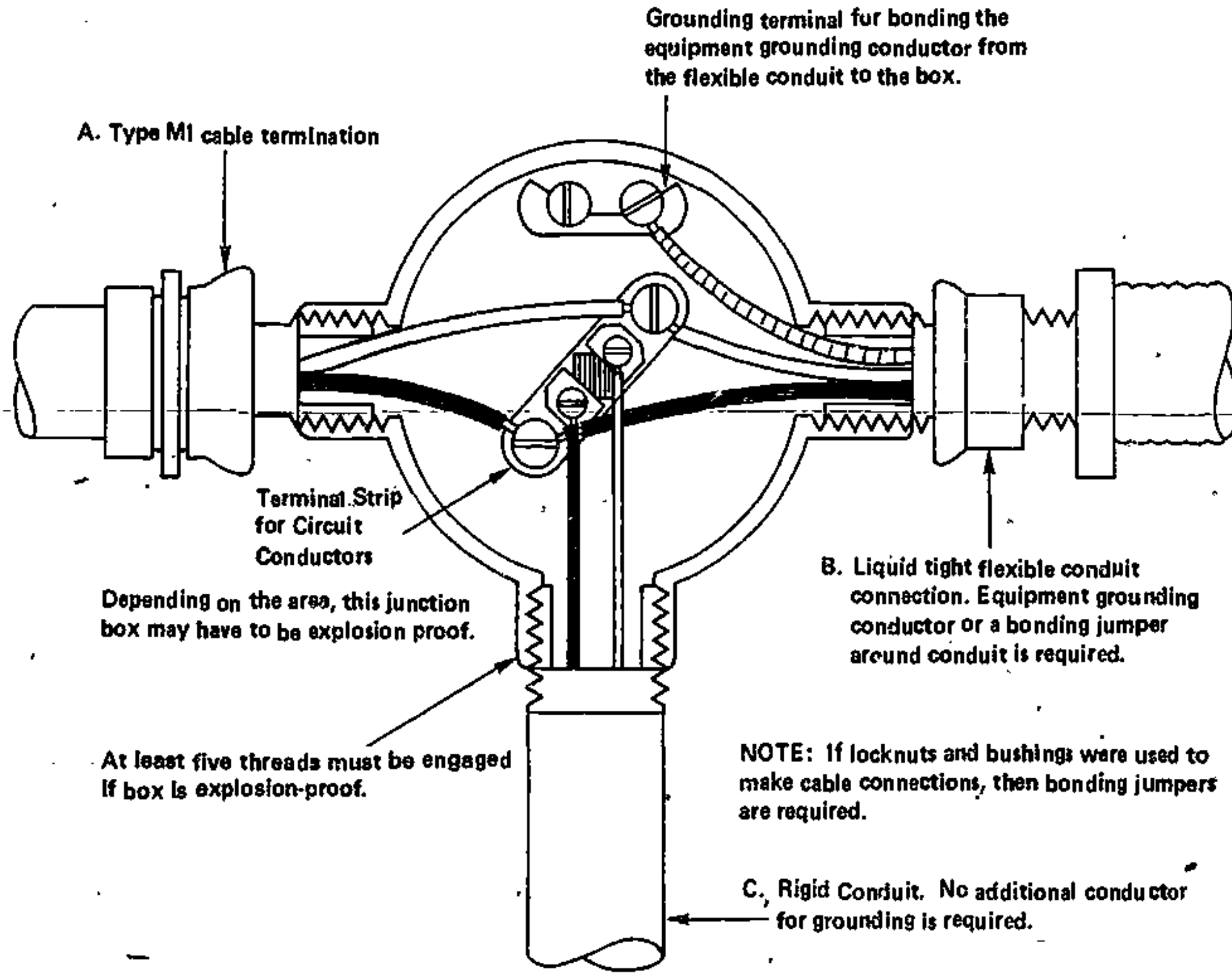


FIGURE 86 SHOWS AN INTERNAL VIEW OF A TOTALLY ENCLOSED FAN-COOLED EXPLOSION-PROOF MOTOR. THE ROTOR AND ITS WINDINGS AND FAN ARE COMPLETELY ENCLOSED. AN INTERNAL SEAL, A WIDE FLANGE ON THE STARTER COVER, AND A CLOSE-FITTING JOURNAL PREVEN. THE ESCAPE OF HOT GASES OR FLAMES FROM THE ENCLOSURE. AN INTERNAL FAN CIRCULATES AIR INSIDE THE ENCLOSURE, TRANSFERRING THE HEAT FROM THE WINDINGS TO THE ENCLOSURE. THE FRAME OR ENCLOSURE IS EXPLOSION-PROOF AND MAY HAVE AN EXTERNAL FAN THAT FORCES AIR OVER ITS OUTSIDE SURFACES. THIS FORCED EXTERNAL CIRCULATION WILL PROVIDE MORE EFFECTIVE MOTOR COOLING THAN WOULD NATURAL AIR CIRCULATION. HOWEVER, NONE OF THIS EXTERNAL AIR COMES IN CONTACT WITH THE WINDINGS.

FIGURE 86. DESIGN FEATURES OF A TOTALLY ENCLOSED, FAN-COOLED, EXPLOSION-PROOF MOTOR



IN CLASS I DIVISION 1 AND DIVISION 2 HAZARDOUS LOCATIONS, EXPOSED NON-CURRENT-CARRYING METAL PARTS OF EQUIPMENT, SUCH AS FRAMES AND CABINETS, MUST BE GROUNDED. THE GROUND MUST PROVIDE A PATH BACK TO THE SOURCE IF AN ACCIDENTAL FAULT OCCURS.

BONDING IS ALSO REQUIRED TO PROVIDE A PERMANENT GROUND FOR EXPOSED METAL PARTS. TO BE CONSIDERED EFFECTIVE, BONDING MUST PREVENT THE OCCURRENCE OF ARCS OR SPARKS CAUSED BY POOR CONNECTIONS. FIGURE 87 SHOWS A TYPICAL GROUNDING AND BONDING TECHNIQUE. SEE NEC ARTICLE 250 AND SECTION 501-16.

SPECIAL CARE MUST BE TAKEN TO MAKE PROPEF BONDING CONNECTIONS NOT ONLY TO ASSURE THAT THERE IS A CONTINUOUS EQUIPMENT GROUNDING PATH BUT TO BE POSITIVE THAT NO ARCING OR SPARKING WILL TAKE PLACE BETWEEN CONNECTIONS. LOCK NUT-BUSHINGS AND DOUBLE-LOCK NUT CONNECTORS CANNOT BE RELIED UPON FOR BONDING PURPOSES. FIGURE 87 ILLUSTRATES THREE TYPICAL ARRANGEMENTS OF CONDUIT AND CABLE CONNECTIONS TO AN EXPLOSION-PROOF ENCLOSURE, AND BONDING METHODS. THESE ARE: A) TYPE MI CABLE TERMINATION, B) FLEXIBLE CONDUIT CONNECTION, AND C) RIGID CONDUIT CONNECTION.

FIGURE 87. BONDING IN CLASS I HAZARDOUS (CLASSIFIED) LOCATIONS

CLASS 1 DIVISION 2

THE REQUIREMENTS FOR CLASS I DIVISION 2 HAZARDOUS LOCATIONS ARE SUMMARIZED IN FIGURE 88 AND TABLE 6 AS FOLLOWS:

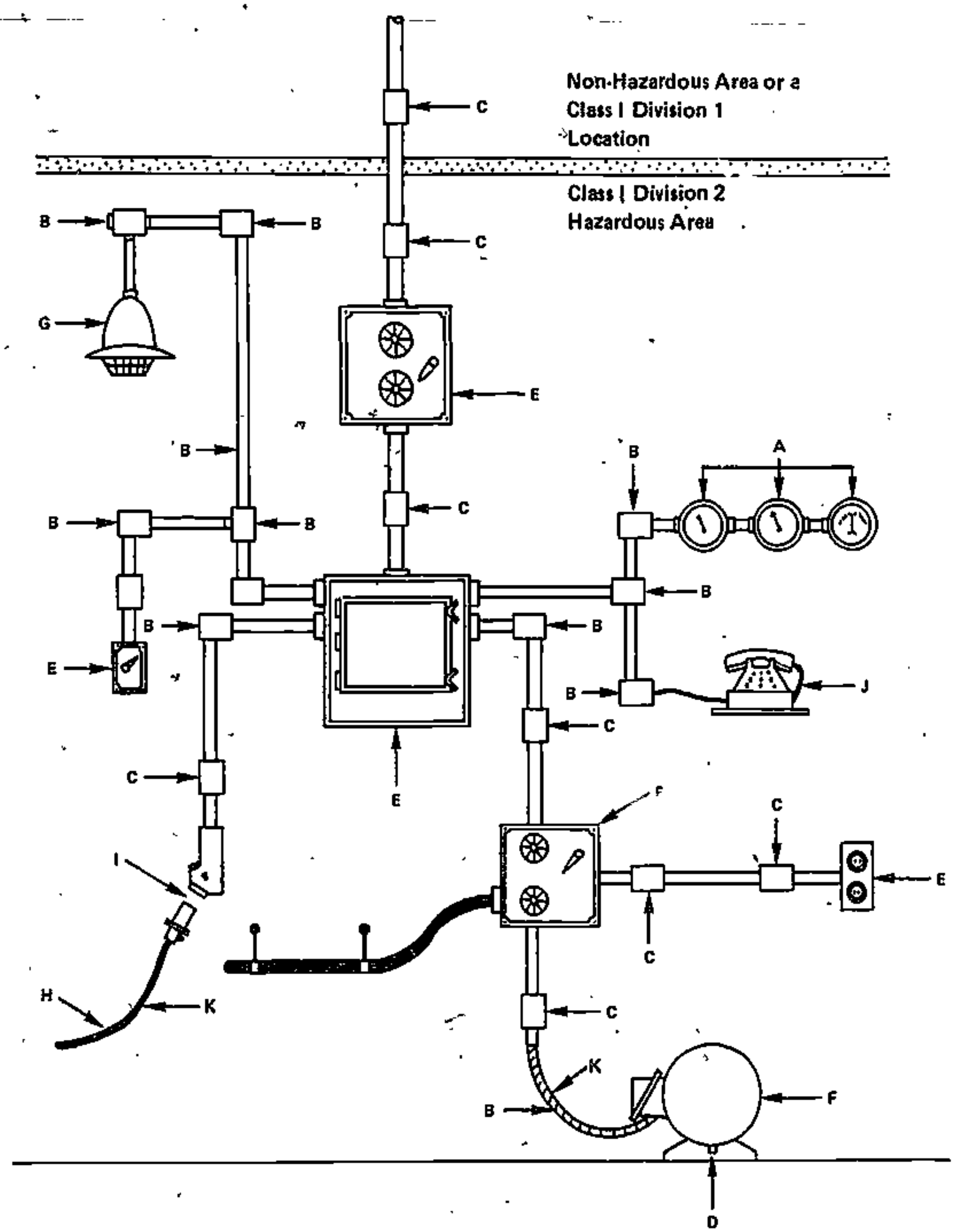


FIGURE 88. CLASS I DIVISION 2 HAZARDOUS LOCATIONS
(SEE TABLE 6)

TABLE 6. SUMMARY OF CLASS 1, DIVISION 2 HAZARDOUS LOCATIONS

(SEE FIGURE 88)

A. METERS, INSTRUMENTS AND RELAYS IN CLASS 1, DIVISION 2 LOCATIONS MUST BE IN APPROVED EXPLOSION-PROOF ENCLOSURES. HOWEVER, GENERAL-PURPOSE EQUIPMENT MAY BE USED, IF CIRCUIT INTERRUPTING CONTACTS ARE IMMERSED IN OIL OR ENCLOSED IN A HERMETICALLY SEALED CHAMBER OR IN CIRCUITS THAT DO NOT RELEASE ENOUGH ENERGY TO IGNITE THE HAZARDOUS ATMOSPHERE. SEE NEC SECTION 501-3(b).

B. WIRING METHODS. GENERALLY, THREADED RIGID OR INTERMEDIATE CONDUIT OR TYPES PLTC, MI, MC, MV, TC, OR SNM CABLE SYSTEMS MUST BE USED. BOXES AND FITTINGS ARE NOT REQUIRED TO BE EXPLOSION PROOF UNLESS THEY ENCLOSE ARCING OR SPARKING DEVICES. SEE NEC SECTION 501-4(b).

C. SEALS ARE REQUIRED FOR ALL CONDUIT SYSTEMS CONNECTED TO EXPLOSION-PROOF ENCLOSURES. SEALS ARE ALSO REQUIRED WHERE CONDUIT PASSES FROM HAZARDOUS TO NON-HAZARDOUS AREAS OR FROM DIVISION 1 TO DIVISON 2 AREAS. (SEE NEC SECTION 501-5(b).

D. DRAINAGE IS REQUIRED WHERE LIQUID OR CONDENSED VAPOR MAY BE TRAPPED WITHIN AN ENCLOSURE OR ALONG A RACEWAY. SEE NEC SECTION 501-5(f).

E. MOST ARCING DEVICES ARE REQUIRED TO BE IN EXPLOSION-PROOF ENCLOSURES. THESE INCLUDE ITEMS SUCH AS SWITCHES, CIRCUIT BREAKERS, MOTOR CONTROLLERS AND FUSES. HOWEVER, GENERAL PURPOSE ENCLOSURES MAY BE USED FOR CLASS 1, DIVISION 2 LOCATIONS. IF THE ARCING AND SPARKING PARTS ARE CONTAINED IN A HERMETICALLY SEALED CHAMBER OR ARE OIL IMMERSED. SEE NEC SECTION 501-6(b).

F. MOTORS, GENERATORS AND OTHER ROTATING ELECTRICAL MACHINERY SUITABLE FOR USE IN CLASS 1, DIVISION 1 LOCATIONS ARE ALSO ACCEPTABLE IN CLASS I, DIVISION 2 LOCATIONS. OTHER MOTORS MUST HAVE THEIR CONTACTS, SWITCHING DEVICES, AND RESISTANCE DEVICES IN ENCLOSURES SUITABLE FOR CLASS I, DIVISION 2 LOCATIONS (SEE NOTE E, ABOVE). MOTORS WITHOUT BRUSHES, SWITCHING MECHANISMS, OR SIMILAR ARC-PRODUCING DEVICES ARE ALSO ACCEPTABLE. SEE NEC SECTION 501-8(b).

G. LIGHTING FIXTURES IN CLASS 1 DIVISION 2 LOCATIONS MUST BE TOTALLY ENCLOSED AND PROTECTED FROM PHYSICAL DAMAGE. IF NORMAL OPERATING SURFACE TEMPERATURES EXCEED 80 PERCENT OF THE IGNITION TEMPERATURE OF THE GAS, LIQUID OR VAPOR INVOLVED, THEN EXPLOSION-PROOF FIXTURES MUST BE INSTALLED. SEE NEC SECTION 501-9(b).

H. FLEXIBLE CORDS IN DIVISIONS 1 AND 2 ARE REQUIRED TO: 1) BE SUITABLE FOR EXTRA HARD USAGE, 2) CONTAIN AN EQUIPMENT GROUNDING CONDUCTOR, 3) BE CONNECTED TO TERMINALS IN AN APPROVED MANNER, 4) BE PROPERLY SUPPORTED, AND 5) BE PROVIDED WITH SUITABLE SEALS WHERE NECESSARY. SEE NEC SECTION 501-11.

I. IN GENERAL, RECEPTACLES AND ATTACHMENT PLUGS MUST BE APPROVED FOR CLASS 1 LOCATIONS. SEE NEC SECTION 501-12.

J. SIGNALING SYSTEMS AND OTHER SIMILAR SYSTEMS: SEE NEC SECTION 501-14.

K. EQUIPMENT GROUNDING IS REQUIRED OF ALL NON-CURRENT-CARRYING METAL PARTS OF THE ELECTRICAL SYSTEM. IN ADDITION, LOCK NUTS AND BUSHINGS MUST NOT BE RELIED UPON FOR ELECTRICAL CONNECTION BETWEEN RACEWAYS AND EQUIPMENT. IF LOCKNUTS AND BUSHINGS ARE USED, BONDING JUMPERS ARE REQUIRED. SEE NEC SECTION 501-16.

NOTE: NEC-NATIONAL ELECTRICAL CODE, NFPA 70.

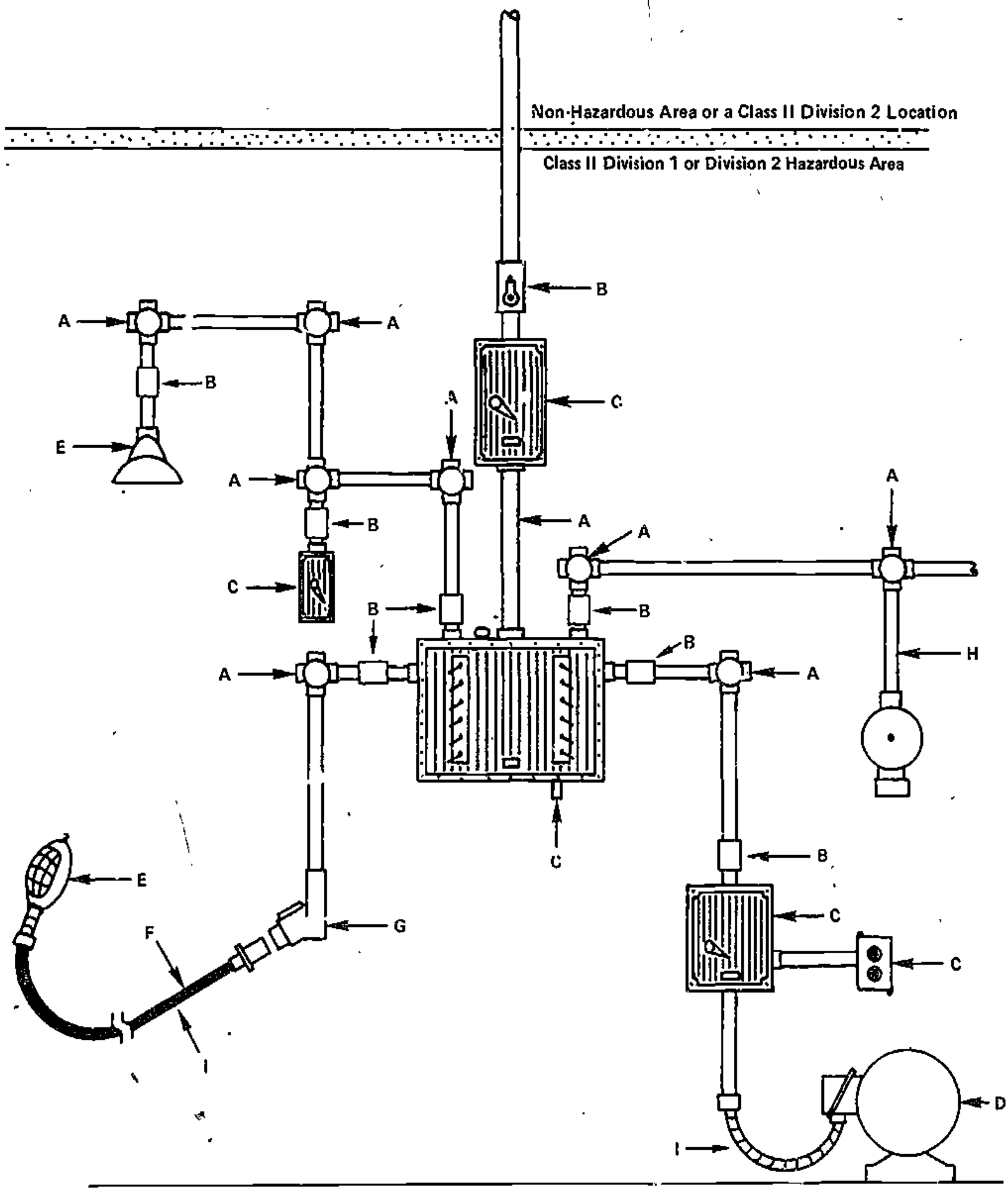


FIGURE 89. CLASS II HAZARDOUS LOCATIONS

(SEE TABLE 7)

CLASS II HAZARDOUS LOCATIONS

ARTICLE 502 OF THE NATIONAL ELECTRICAL CODE (NEC) IS CONCERNED WITH THE INSTALLATION REQUIREMENTS FOR ELECTRICAL WIRING AND EQUIPMENT USED IN CLASS II HAZARDOUS AREAS. THE REQUIREMENTS AS THEY PERTAIN TO CLASS II DIVISION 1 AND DIVISION 2 LOCATIONS ARE SUMMARIZED IN FIGURE B9 AND TABLE 7.

CLASS II LOCATIONS ARE HAZARDOUS BECAUSE OF THE PRESENCE OF COMBUSTIBLE DUST. AS DISCUSSED PREVIOUSLY, THESE DUSTS ARE BROKEN DOWN INTO THREE GROUPS – E, F, AND G. THE DUSTS ARE ALSO DIVIDED INTO TWO CATEGORIES: CONDUCTIVE (HAVING RESISTIVITY LESS THAN 10^5 OHM-CENTIMETER) AND NON-CONDUCTIVE. WHERE CONDUCTIVE DUSTS ARE PRESENT, THERE ARE ONLY CLASS II, DIVISION 1 LOCATIONS. GROUP E DUSTS ARE CONDUCTIVE, SOME GROUP F DUSTS ARE CONDUCTIVE, AND GROUP G DUSTS ARE NONCONDUCTIVE.

TABLE 7. SUMMARY OF CLASS II HAZARDOUS LOCATIONS

(SEE FIGURE 89)

A. WIRING METHODS FOR CLASS II, DIVISION I LOCATIONS: BOXES AND FITTINGS CONTAINING ARCING AND SPARKING PARTS ARE REQUIRED TO BE IN DUST-IGNITION-PROOF ENCLOSURES. FOR OTHER THAN FLEXIBLE CONNECTIONS THREADED METAL CONDUIT OR TYPE MI CABLE WITH APPROVED TERMINATIONS IS REQUIRED FOR CLASS II, DIVISION 1 LOCATIONS. SEE NEC SECTION 502-4(a)

IN CLASS II DIVISION 2 LOCATIONS, BOXES ANO FITTINGS ARE NOT REQUIRED TO BE DUST-IGNITION PROOF BUT MUST BE DESIGNED TO MINIMIZE THE ENTRANCE OF DUST AND PREVENT THE ESCAPE OF SPARKS OR BURNING MATERIAL. IN ADOITION TO THE WIRING SYSTEMS SUITABLE FOR DIVISION 1 LOCATIONS, THE FOLLOWING SYSTEMS ARE SUITABLE FOR OIVISION 2 LOCATIONS: ELECTRICAL METALLIC TUBING, DUST-TIGHT WIREWAYS, ANO TYPES MC AND SNM CABLES. SEE NEC SECTION 502-4(b).

B. SUITABLE MEANS OF PREVENTING THE ENTRANCE OF DUST INTO A DUST-IGNITION-PROOF ENCLOSURE MUST BE PROVIOED WHERE A RACEWAY PROVIDES A PATH TO THE DUST-IGNITION-PROOF ENCLOSURE FROM ANOTHER ENCLOSURE THAT COULD ALLOW THE ENTRANCE OF OUST. SEE FIGURES 90-92. ALSO SEE NEC SECTION 502-5.

C. SWITCHES, CIRCUIT BREAKERS, MOTOR CONTROLLERS, ANO FUSES INSTALLED IN CLASS II, OIVISION 1 LOCATIONS MUST BE OUST-IGNITION PROOF.

IN CLASS II, OIVISION 2 AREAS, ENCLOSURES FOR FUSES, SWITCHES, CURCUIT BREAKERS, AND MOTOR CONTROLLERS MUST BE DUST-TIGHT. SEE NEC SECTION 502-6.

D. IN CLASS II, DIVISION 1 LOCATIONS, MOTORS, GENERATORS, AND OTHER ROTATING ELECTRICAL MACHINERY MUST BE DUST-IGNITION PROOF OR TOTALLY ENCLOSED PIPE VENTILATED.

IN CLASS II, OIVISION 2 AREAS, ROTATING EQUIPMENT MUST BE ONE OF THE FOLLOWING TYPES:
1) DUST-IGNITION-PROOF,
2) TOTALLY ENCLOSED PIPE VENTILATED,
3) TOTALLY ENCLOSEO NONVENTILATED, OR
4) TOTALLY ENCLOSEO FAN COOLEO.
UNDER CERTAIN CONDITIONS, STANDARD OPEN-TYPE MACHINES ANO SELF-CLEANING SQUIRREL-CAGE MOTORS MAY BE USED. SEE NEC SECTION 502-8.

E. IN CLASS II, OIVISION 1 LOCATIONS, LIGHTING FIXTURES MUST BE OUST-IGNITION PROOF.

LIGHTING FIXTURES IN CLASS II OIVISION 2 LOCATIONS MUST BE DESIGNEO TO MINIMIZE ACCUMULATION OF DUST AND MUST BE ENCLOSED TO PREVENT THE RELEASE OF SPARKS OR HOT METAL.

IN BOTH DIVISIONS, EACH FIXTURE MUST BE CLEARLY MARKED FOR THE MAXIMUM WATTAGE OF THE LAMP, SO THAT THE MAXIMUM PERMISSIBLE SURFACE TEMPERATURE FOR THE FIXTURE IS NOT EXCEEDED. AODITIONALLY, FIXTURES MUST BE PROTECTEO FROM DAMAGE. SEE NEC SECTION 502-11.

F. FLEXIBLE CORDS IN DIVISIONS 1 ANO 2 ARE REQUIREO TO: 1) BE SUITABLE FOR EXTRA HARD USAGE, 2) CONTAIN AN EQUIPMENT GROUNDING CONDUCTOR, 3) BE CONNECTED TO TERMINALS IN AN APPROVEO MANNER, 4) BE PROPERLY SUPPORTED, AND 5) BE PROVIDED WITH SUITABLE SEALS WHERE NECESSARY. SEE NEC SECTION 502-12.

G. RECEPTACLES AND ATTACHMENT PLUGS USEO IN CLASS II, DIVISION 1 AREAS ARE REQUIREO TO BE APPROVEO FOR CLASS II LOCATIONS AND PROVIDEO WITH A CONNECTION FOR AN EQUIPMENT GROUNDING CONOUCTOR.

IN DIVISION 2 AREAS, THE RECEPTACLE MUST BE DESIGNED SO THE CONNECTION TO THE SUPPLY CIRCUIT CANNOT BE MADE OR BROKEN WHILE THE PARTS ARE EXPOSED. THIS IS COMMONLY DONE WITH AN INTERLOCKING ARRANGEMENT BETWEEN A CIRCUIT BREAKER AND THE RECEPTACLE. THE PLUG CANNOT BE REMOVED UNTIL THE CIRCUIT BREAKER IS IN THE OFF POSITION, AND THE BREAKER CANNOT BE SWITCHEO TO THE ON POSITION UNLESS THE PLUG IS INSERTED IN THE RECEPTACLE. SEE NEC SECTION 502-13.

NOTE: NEC-NATIONAL ELECTRICAL CODE, NFPA 70.

TABLE 7 (CONTINUED)

H. SIGNALING SYSTEMS AND OTHER SIMILAR SYSTEMS: SEE NEC SECTION 502-14.

I. EQUIPMENT GROUNDING IS REQUIRED OF ALL NON-CURRENT-CARRYING METAL PARTS OF THE ELECTRICAL SYSTEM. LOCK NUTS AND BUSHINGS MUST NOT BE RELIED UPON FOR ELECTRICAL CONNECTION BETWEEN RACEWAYS AND EQUIPMENT ENCLOSURES. IF LOCKNUTS OR BUSHINGS ARE USED, BONDING JUMPERS ARE REQUIRED. SEE NEC SECTION 502-16.

NOTE: NEC-NATIONAL ELECTRICAL CODE, NFPA 70.

IN GENERAL, EQUIPMENT IN CLASS II, DIVISION 1 LOCATIONS SHOULD BE DUST-IGNITION PROOF, WHILE EQUIPMENT IN DIVISION 2 LOCATIONS NEED ONLY BE DUST TIGHT. ADDITIONALLY, EQUIPMENT SHOULD BE ABLE TO FUNCTION AT FULL RATING WITHOUT CAUSING EXCESSIVE DEHYDRATION OR CARBONIZATION OF ORGANIC DUST DEPOSITS. MAXIMUM OPERATING SURFACE TEMPERATURES ARE GIVEN IN TABLE 8. SINCE SOME GROUP G CHEMICAL AND PLASTIC DUSTS HAVE IGNITION TEMPERATURES APPROACHING OR BELOW THOSE GIVEN IN THE TABLE, EQUIPMENT USED WITH SUCH DUSTS SHOULD HAVE EVEN LOWER OPERATING SURFACE TEMPERATURES.

TABLE 8. MAXIMUM SURFACE TEMPERATURES

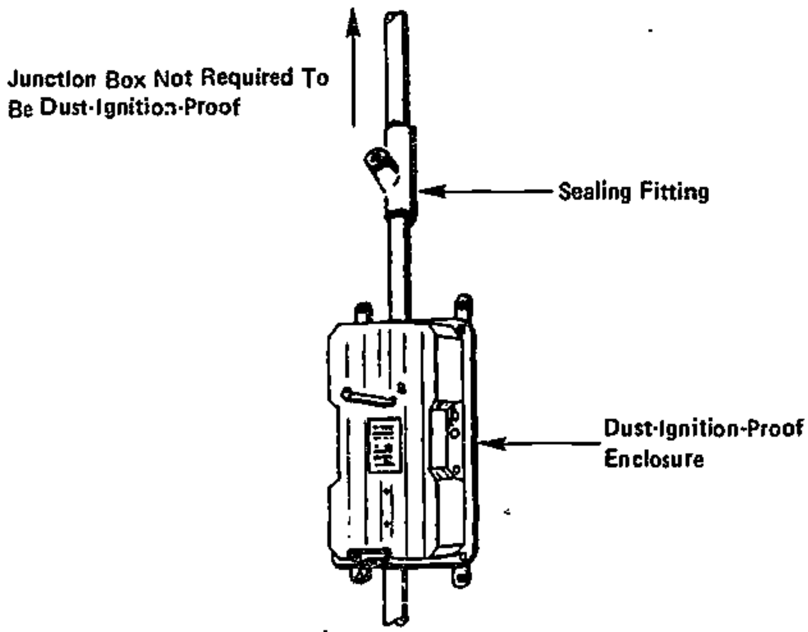
	EQUIPMENT THAT IS NOT SUBJECT TO OVERLOADING		EQUIPMENT (SUCH AS MOTORS OR POWER TRANSFORMERS) THAT MAY BE OVERLOADED			
			NORMAL OPERATION		ABNORMAL OPERATION	
CLASS II GROUP	DEGREES °C	DEGREES °F	DEGREES °C	DEGREES °F	DEGREES °C	DEGREES °F
E	200	392	200	392	200	392
F	200	392	150	302	200	392
G	165	329	120	248	165	329

SOURCE: TABLE 502-1 OF THE NATIONAL ELECTRICAL CODE, NFPA 80-1981.

THE FOLLOWING SECTIONS FURTHER EXPLAIN THE REQUIREMENTS FOR TRANSFORMERS AND CAPACITORS, SEALING, PIPE VENTILATION, AND GROUNDING AND BONDING IN CLASS II HAZARDOUS LOCATIONS.

TRANSFORMERS AND CAPACITORS

IN CLASS II, DIVISION 1 LOCATIONS, ALL TRANSFORMERS AND CAPACITORS MUST BE INSTALLED IN VAULTS OR MUST BE APPROVED AS A COMPLETE ASSEMBLY FOR CLASS II LOCATIONS. IN DIVISION 2 AREAS, TRANSFORMERS AND CAPACITORS CONTAINING LIQUIDS THAT WILL BURN MUST BE INSTALLED IN A VAULT. HOWEVER, NO TRANSFORMER OR CAPACITOR MAY BE INSTALLED WHERE ALUMINUM, MAGNESIUM, OR OTHER METALS OF SIMILARLY HAZARDOUS CHARACTERISTICS MAY BE PRESENT.



WHEN DUST-IGNITION-PROOF ENCLOSURES ARE IN A DUST-HAZARD AREA (CLASS II DIVISION 1 AND DIVISION 2) AND ARE CONNECTED BY A RACEWAY TO A NON-DUST-IGNITION-PROOF ENCLOSURE WHICH IS STILL IN A CLASS II LOCATION, DUST MUST NOT GET INTO THE APPROVED ENCLOSURE THROUGH THE RACEWAY. (NEC SECTION 502-5)

FIGURE 90. PREVENTING DUST FROM ENTERING THE DUST-IGNITION-PROOF ENCLOSURE BY SEALING BETWEEN ENCLOSURES

THIS CAN BE ACCOMPLISHED IN ONE OF THE FOLLOWING WAYS:

(1) BY INSTALLING PERMANENT, EFFECTIVE SEALS WITH FITTINGS THAT ARE EASY TO REACH FOR REPAIRS. SEE FIGURE 90.
(2) BY ARRANGING 10-FOOT OR LONGER RACEWAYS HORIZONTALLY BETWEEN ENCLOSURES. SEE FIGURE 91.

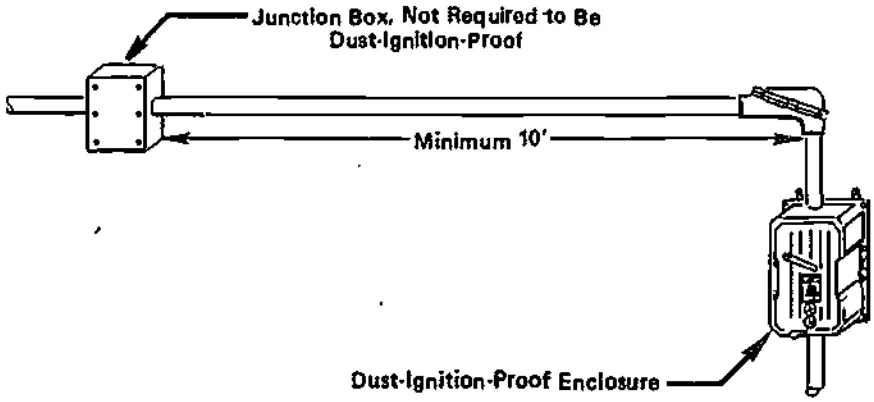


FIGURE 91. PREVENTING DUST FROM ENTERING THE DUST-IGNITION-PROOF ENCLOSURES BY HORIZONTAL DISTANCE (NO SEAL)

(3) ARRANGING 5-FOOT OR LONGER VERTICAL RACEWAYS THAT EXTEND DOWNWARD FROM THE DUST-IGNITION-PROOF ENCLOSURE TO A GENERAL PURPOSE ENCLOSURE. SEE FIGURE 92.

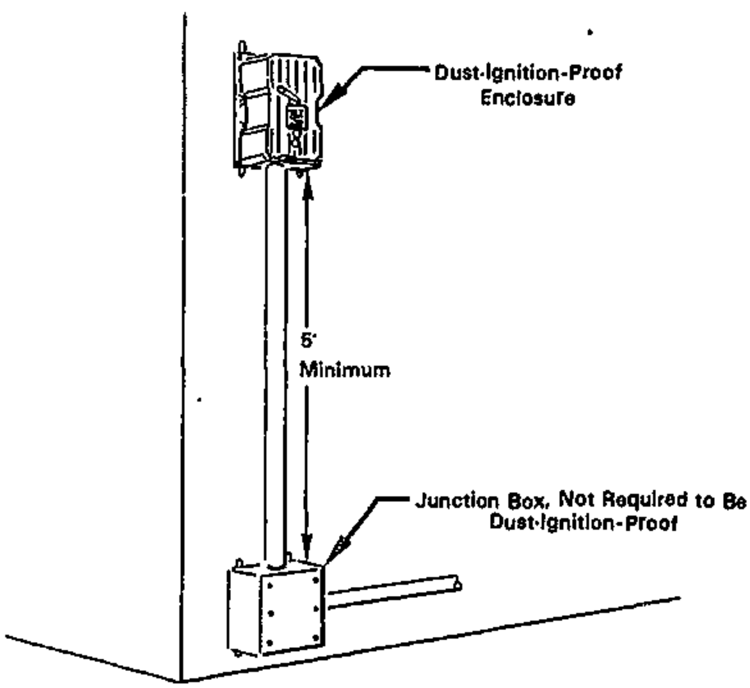
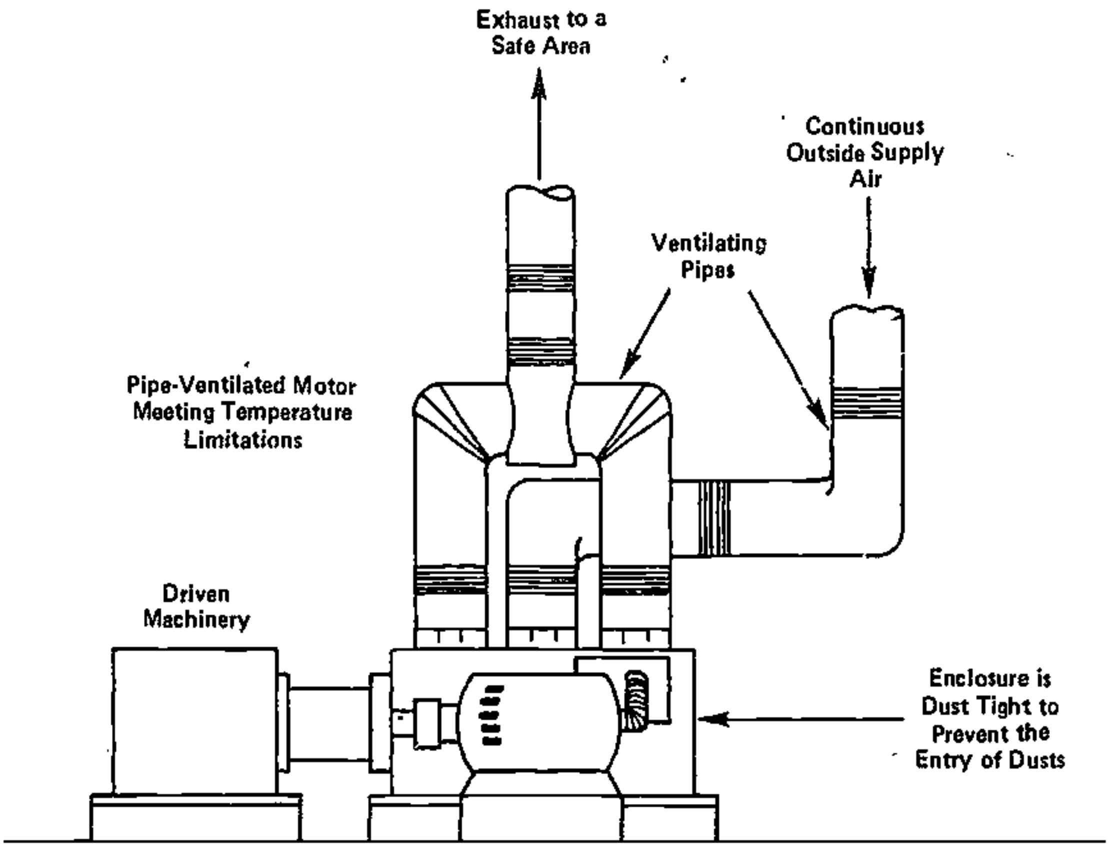


FIGURE 92. PREVENTING DUST FROM ENTERING THE DUST-IGNITION-PROOF ENCLOSURE BY VERTICAL DISTANCE (NO SEAL)

PIPE VENTILATION



PIPE-VENTILATED MOTORS, GENERATORS OR OTHER ROTATING ELECTRICAL MACHINERY MUST BE ENCLOSED IN A DUST-TIGHT ENCLOSURE THAT IS CONNECTED TO OUTSIDE CLEAN AIR.

IN CLASS II DIVISION 1 LOCATIONS, VENTILATING PIPE MUST BE DUST-TIGHT – THAT IS, CONSTRUCTED TO MINIMIZE THE ENTRANCE OF DUST. SEE NEC SECTION 502-9(a).

IN CLASS II DIVISION 2 LOCATIONS, VENTILATING PIPE MUST BE TIGHT ENOUGH TO PREVENT THE ENTRANCE OF APPRECIABLE QUANTITIES OF OUST AND TO PREVENT SPARKS AND BURNING MATERIAL FROM ESCAPING. SEE NEC SECTION 502-9(b).

FIGURE 93 ILLUSTRATES A PIPE-VENTILATED MOTOR FOR CLASS II DIVISION 1 AND 2 AREAS.

FIGURE 93. TOTALLY ENCLOSED PIPE-VENTILATED MOTOR

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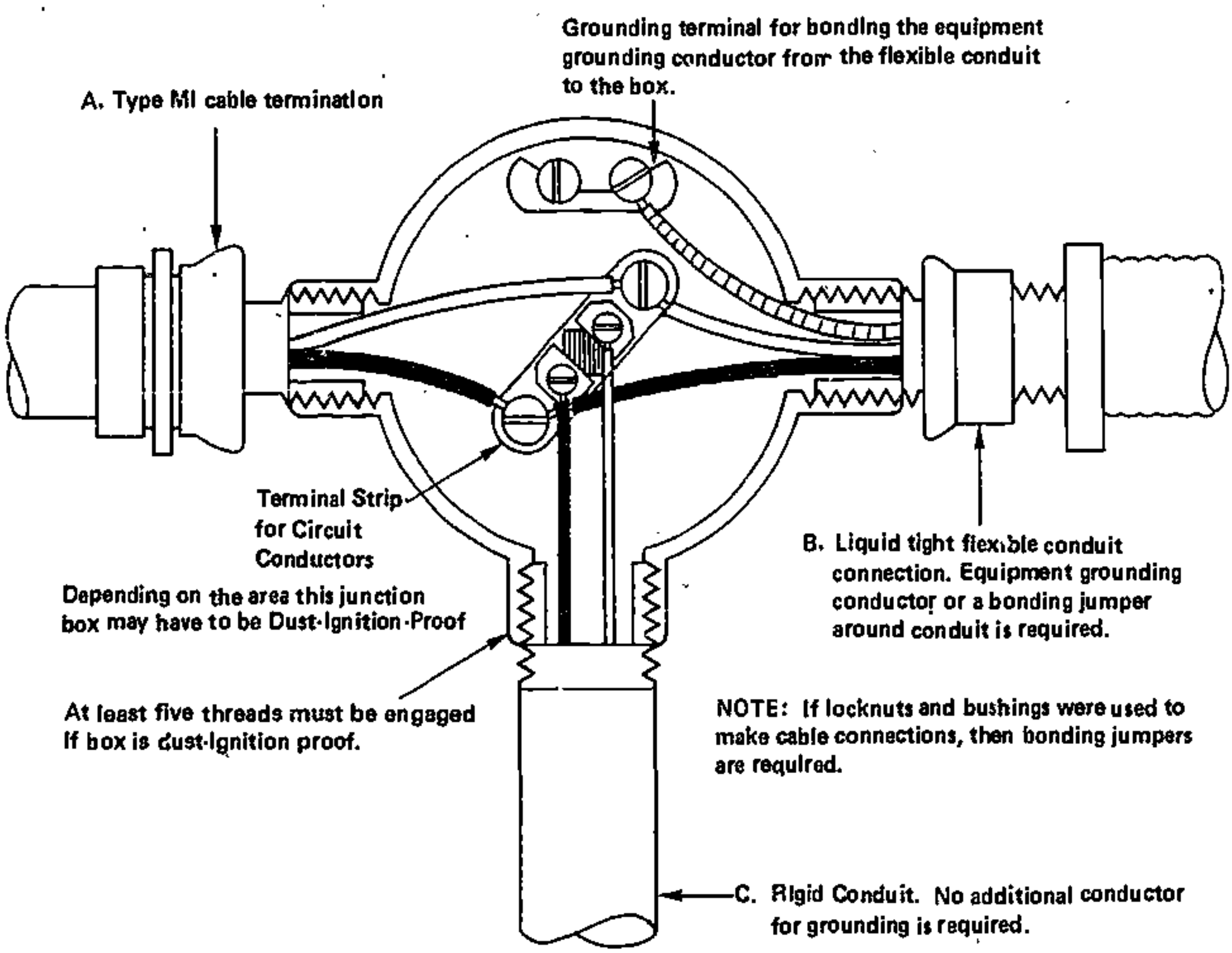
GROUNDING AND BONDING



IN CLASS II LOCATIONS ALL EXPOSED NON-CURRENT-CARRYING METAL PARTS OF THE ELECTRICAL SYSTEM MUST BE GROUNDED. BONDING JUMPERS ARE USED TO PREVENT ARCS ACROSS JOINTS AND ASSURE GROUNDING AROUND FLEXIBLE CONNECTIONS.

FIGURE 94. BONDING IN CLASS II HAZARDOUS (CLASSIFIED) LOCATIONS

CLASS III HAZARDOUS LOCATIONS

CLASS III HAZARDOUS LOCATIONS ARE AREAS WHERE IGNITABLE FIBERS AND FLYINGS ARE PRESENT. IN GENERAL, EQUIPMENT ACCEPTABLE FOR USE IN CLASS II, DIVISION 2 LOCATIONS IS ALSO ACCEPTABLE FOR INSTALLATION IN CLASS III LOCATIONS. EQUIPMENT IN CLASS III LOCATIONS SHOULD BE ABLE TO OPERATE AT FULL RATING WITHOUT CAUSING EXCESSIVE DEHYDRATION OR CARBONIZATION OF ACCUMULATED FIBERS OR FLYINGS. THE MAXIMUM OPERATING SURFACE TEMPERATURE IS 165° C (329° F) FOR EQUIPMENT THAT IS NOT SUBJECT TO OVERLOADING, AND 120° C (248° F) FOR EQUIPMENT THAT MAY BE OVERLOADED.

FIGURE 95 AND TABLE 9 SUMMARIZE SOME OF THE REQUIREMENTS FOR INSTALLATIONS IN CLASS III LOCATIONS.

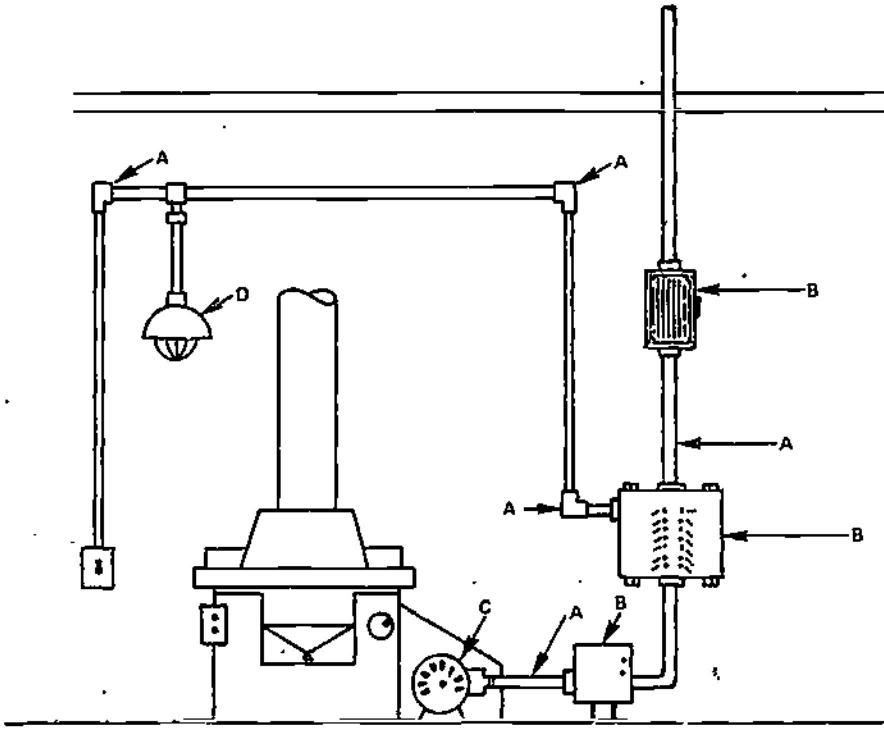


FIGURE 95. CLASS III HAZARDOUS LOCATIONS

(SEE TABLE 9)

TABLE 9. SUMMARY OF CLASS III HAZARDOUS LOCATIONS

(SEE FIGURE 95)

A. IN CLASS III HAZARDOUS LOCATIONS, WIRING MUST BE WITHIN A THREADED METAL CONDUIT OR BE OF TYPE MI OR MC CABLE UNLESS FLEXIBILITY IS REQUIRED. FITTINGS AND BOXES ARE REQUIRED TO PROVIDE AN ENCLOSURE WHICH WILL PREVENT THE ESCAPE OF SPARKS OR BURNING MATERIAL. SEE NEC SECTION 503.3

B. SWITCHES, CIRCUIT BREAKERS, MOTOR CONTROLLERS, AND SIMILAR DEVICES USED IN CLASS III HAZARDOUS LOCATIONS MUST BE WITHIN TIGHT METAL ENCLOSURES THAT ARE DESIGNED TO MINIMIZE THE ENTRY OF FIBERS AND FLYINGS AND MUST NOT HAVE ANY OPENINGS THROUGH WHICH SPARKS OR BURNING MATERIALS MIGHT ESCAPE. SEE NEC SECTION 503-4

C. MOTORS, GENERATORS, AND OTHER ROTATING ELECTRIC MACHINERY MUST BE TOTALLY ENCLOSED NONVENTILATED, TOTALLY ENCLOSED PIPE-VENTILATED, OR TOTALLY ENCLOSED FANCOOLED. THE WINDINGS OF TOTALLY ENCLOSED NONVENTILATED MOTORS ARE COMPLETELY ENCLOSED IN A TIGHT CASING AND ARE COOLED BY RADIATION AND CONDUCTION THROUGH THE FRAME. ENCLOSED PIPE-VENTILATED MOTORS HAVE OPENINGS FOR A VENTILATING PIPE, WHICH CONVEYS AIR TO THE MOTOR AND THEN DISCHARGES THE AIR TO A SAFE AREA. SEE FIGURE 93. IN TOTALLY ENCLOSED FAN-COOLED MOTORS, THE WINDINGS ARE COOLED BY AN INTERNAL FAN THAT CIRCULATES AIR INSIDE THE ENCLOSURE. UNDER CERTAIN CONDITIONS, SELF-CLEANING TEXTILE MOTORS AND STANDARD OPEN-TYPE MACHINES MAY BE USED. (SEE NEC SECTION 503-6.)

D. LIGHTING FIXTURES MUST HAVE ENCLOSURES DESIGNED TO MINIMIZE THE ENTRY OF FIBERS, TO PREVENT THE ESCAPE OF SPARKS OR HOT METAL, AND TO HAVE A MAXIMUM EXPOSED SURFACE TEMPERATURE OF LESS THAN 165° C. (NEC SECTION 503-9)

NOTE: NEC-NATIONAL ELECTRICAL CODE, NFPA 70.

IN ADDITION, REQUIREMENTS PERTAINING TO CRANES AND HOISTS, EXPOSED LIVE PARTS, AND GROUNDING ARE SUMMARIZED AS FOLLOWS:

CRANES AND HOISTS

ELECTRIC CRANES, HOISTS, AND SIMILAR EQUIPMENT INSTALLED OR LOCATED TO OPERATE OVER AREAS WHERE COMBUSTIBLE FIBERS ARE PRESENT MUST HAVE AN UNGROUNDED POWER SUPPLY THAT IS ISOLATED FROM ANY OTHER SYSTEM. ALSO, SUCH EQUIPMENT MUST HAVE A MEANS OF ALARMING AND AUTOMATICALLY DE-ENERGIZING THE CONTACT CONDUCTORS WHEN A GROUND FAULT OCCURS. A GROUND FAULT INDICATOR WHICH GIVES VISUAL AND AUDIBLE ALARM IS ALSO ACCEPTABLE IF THE ALARM IS MAINTAINED UNTIL THE CIRCUIT IS OPENED. THE CONTACT CONDUCTORS SHOULD BE LOCATED SO THAT THEY ARE GUARDED AGAINST TAMPERING AND CONTACT BY FOREIGN OBJECTS. THE CURRENT COLLECTORS MUST HAVE PROTECTION TO PREVENT THE ESCAPE OF SPARKS OR HOT PARTICLES, AND THEY MUST BE KEPT FREE OF LINT ACCUMULATIONS (SEE NEC SECTION 503-13.)

LIVE PARTS

LIVE PARTS OTHER THAN CONTACTS AND COLLECTORS FOR CRANES AND HOISTS MAY NOT BE EXPOSED IN CLASS III LOCATIONS.

GROUNDING

GROUNDING REQUIREMENTS FOR CLASS III LOCATIONS ARE THE SAME AS THOSE FOR CLASS II LOCATIONS (SEE NEC SECTIONS 503-16 AND 502-16).

(c) Conduits. All conduits shall be threaded and shall be made wrenchtight. Where it is impractical to make a threaded joint tight, a bonding jumper shall be utilized.

(d) Equipment in Division 2 locations. Equipment that has been approved for a Division 1 location may be installed in a Division 2 location of the same class and group. General-purpose equipment or equipment in general-purpose enclosures may be installed in Division 2 locations if the equipment does not constitute a source of ignition under normal operating conditions.

§1910.308 SPECIAL SYSTEMS

§1910.308 Special systems.

(a) Systems over 600 volts, nominal. Paragraphs (a)(1) through (a)(4) of this section cover the general requirements for all circuits and equipment operated at over 600 volts.

(1) Wiring methods for fixed installations.

(i) Above-ground conductors shall be installed in rigid metal conduit, in intermediate metal conduit, in cable trays, in cablebus, in other suitable raceways, or as open runs of metal-clad cable suitable for the use and purpose. However, open runs of non-metallic-sheathed cable or of bare conductors or busbars may be installed in locations accessible only to qualified persons. Metallic shielding components, such as tapes, wires, or braids for conductors, shall be grounded. Open runs of insulated wires and cables having a bare lead sheath or a braided outer covering shall be supported in a manner designed to prevent physical damage to the braid or sheath.

- FOR INSTALLATIONS OVER 600 VOLTS, INSULATED CONDUCTORS AND CABLES WHICH HAVE A LEAD SHEATH OR METAL-BRAIDED OUTER COVERING MUST BE SUPPORTED SO THAT THE SHEATH OR COVERING IS NOT DAMAGED. THE METALLIC SHEATH OR BRAID FOR OPEN CONDUCTORS IS GROUNDED TO PROVIDE A PATH FOR FAULT CURRENT TO OPERATE CIRCUIT BREAKERS IN THE EVENT OF A FAULT. ANY DAMAGE TO THE SHIELDING MAY CAUSE THE CONTINUITY OF THIS GROUND PATH TO BE BROKEN.

IN ADDITION, METAL BRAIDS AND LEAD SHEATHS PROVIDE PROTECTION FOR CONDUCTOR INSULATION. IF THE LEAD SHEATH IS DAMAGED, MOISTURE MAY PENETRATE THE INSULATION, PROVIDING A PATH FOR A GROUND FAULT.

FIGURE 96 SHOWS AN EXAMPLE OF A PROPERLY SUPPORTED CABLE AND AN EXAMPLE OF THE DAMAGE WHICH COULD RESULT SHOULD THE CABLE BE IMPROPERLY SUPPORTED.

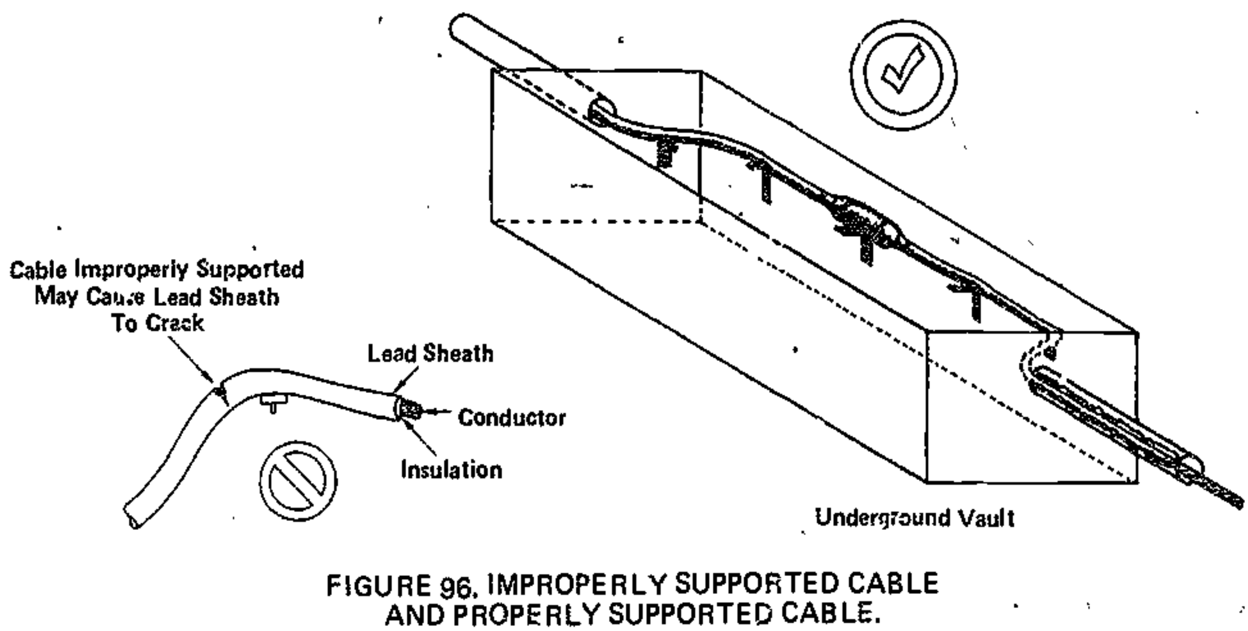


FIGURE 96. IMPROPERLY SUPPORTED CABLE
AND PROPERLY SUPPORTED CABLE.

(ii) Conductors emerging from the ground shall be enclosed in approved raceways. (See §1910.302(b)(3).)

(2) Interrupting and isolating devices.

(i) Circuit breaker installations located indoors shall consist of metal-enclosed units or fire-resistant cell-mounted units. In locations accessible only to qualified personnel, open mounting of circuit breakers is permitted. A means of indicating the open and closed position of circuit breakers shall be provided.

(ii) Fused cutouts installed in buildings or transformer vaults shall be of a type approved for the purpose. They shall be readily accessible for fuse replacement.

• (iii) A means shall be provided to completely isolate equipment for inspection and repairs. Isolating means which are not designed to interrupt the load current of the circuit shall be either interlocked with an approved circuit interrupter or provided with a sign warning against opening them under load.

• INTERRUPTING AND ISOLATING DEVICES ARE SWITCHES USED TO DISCONNECT POWER IN A CIRCUIT SO SERVICE AND MAINTENANCE WORK ON EQUIPMENT DOWN STREAM OF THE SWITCH CAN BE ACCOMPLISHED SAFELY. FIGURE 97 IS A SCHEMATIC ILLUSTRATION OF TWO ISOLATING SWITCHES USED TO DE-ENERGIZE A PIECE OF EQUIPMENT FOR MAINTENANCE AND REPAIR. IN THIS CASE, TWO SWITCHES ARE USED TO SECTIONALIZE A HIGH VOLTAGE GRID TO PREVENT BACK-FEED CURRENT

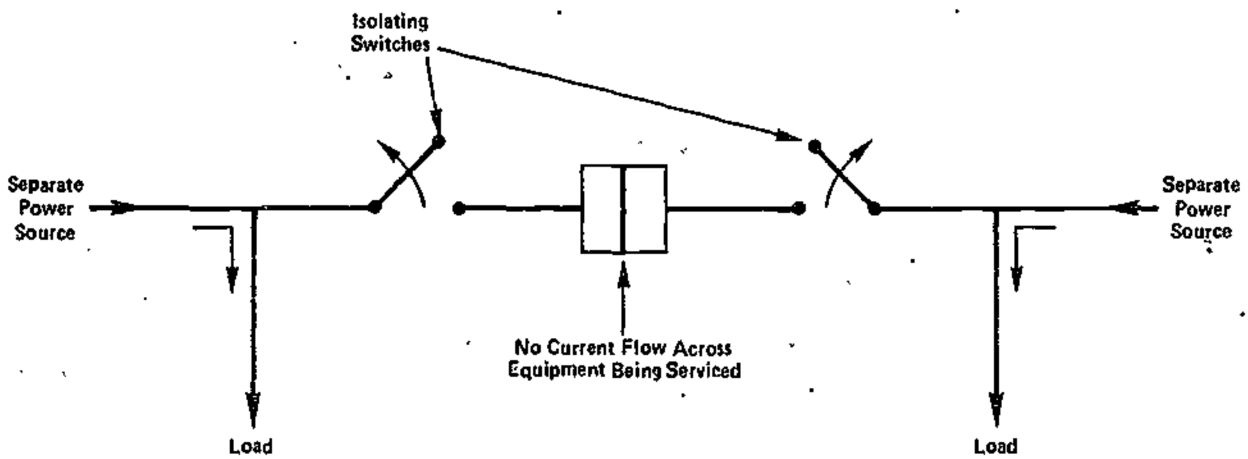


FIGURE 97. ISOLATING SWITCHES

TO THE UNIT BEING SERVICED. INTERRUPTING DEVICES THAT ARE RATED FOR HIGH VOLTAGE APPLICATION, 600 VOLTS OR MORE, INCLUDE AIR BREAK AND OIL-IMMERSED SWITCHES. THESE SWITCHES OPERATE IN AN ENCLOSURE WHICH IS FILLED WITH AIR OR OIL TO SUPPRESS ARCING AND FLASH-OVER DURING OPERATION.

ISOLATING SWITCHES INTENDED FOR USE AS LOAD-INTERRUPTING DEVICES MUST BE RATED FOR THE SHORT CIRCUIT CURRENT LOAD OF THE CIRCUIT THE INTER-

RUPT. ISOLATING SWITCHES CAN, HOWEVER, BE USED IN A CIRCUIT AND NOT BE RATED AS AN INTERRUPTING DEVICE, BUT ONLY IF CERTAIN PRECAUTIONS ARE FOLLOWED. IF THE SWITCHES ARE NOT DESIGNED TO BE OPENED UNDER LOAD, ARCING AND FLASH-OVER MAY OCCUR AND CAUSE SEVERE DAMAGE TO THE EQUIPMENT AND SERIOUS INJURY TO THE EMPLOYEE OPERATING THE SWITCH. IF AN ISOLATING MEANS IS USED BUT IS NOT DESIGNED TO INTERRUPT THE CIRCUIT WHILE THE SWITCH IS CARRYING CURRENT, IT SHALL EITHER BE INTERLOCKED WITH A RATED CIRCUIT INTERRUPTER OR BE PROVIDED WITH A SIGN WARNING AGAINST OPENING IT UNDER LOAD. IN EITHER CASE, CURRENT THROUGH THE SWITCH MUST BE STOPPED BEFORE THE NON-RATED SWITCH CAN BE OPENED.

(3) Mobile and portable equipment.

(i) Power cable connections to mobile machines. A metallic enclosure shall be provided on the mobile machine for enclosing the terminals of the power cable. The enclosure shall include provisions for a solid connection for the ground wire(s) terminal to effectively ground the machine frame. The method of cable termination used shall prevent any strain or pull on the cable from stressing the electrical connections. The enclosure shall have provision for locking so only authorized qualified persons may open it and shall be marked with a sign warning of the presence of energized parts.

(ii) Guarding live parts. All energized switching and control parts shall be enclosed in effectively grounded metal cabinets or enclosures. Circuit breakers and protective equipment shall have the operating means projecting through the metal cabinet or enclosure so these units can be reset without locked doors being opened. Enclosures and metal cabinets shall be locked so that only authorized qualified persons have access and shall be marked with a sign warning of the presence of energized parts. Collector ring assemblies on revolving-type machines (shovels, draglines, etc.) shall be guarded.

(4) Tunnel installations.

(i) Application. The provisions of this paragraph apply to installation and use of high-voltage power distribution and utilization equipment which is portable and/or mobile, such as substations, trailers, cars, mobile shovels, draglines, hoists, drills, dredges, compressors, pumps, conveyors, and underground excavators.

(ii) Conductors. Conductors in tunnels shall be installed in one or more of the following:

(a) Metal conduit or other metal raceway,
(b) Type MC cable, or
(c) Other approved multiconductor cable.

Conductors shall also be so located or guarded as to protect them from physical damage. Multiconductor portable cable may supply mobile equipment. An equipment grounding conductor shall be run with circuit conductors inside the metal raceway or inside the multiconductor cable jacket. The equipment grounding conductor may be insulated or bare.

(iii) Guarding live parts. Bare terminals of transformers, switches, motor controllers, and other equipment shall be enclosed to prevent accidental contact with energized parts. Enclosures for use in tunnels shall be drip-proof, weatherproof, or submersible as required by the environmental conditions.

(iv) Disconnecting means. A disconnecting means that simultaneously opens all ungrounded conductors shall be installed at each transformer or motor location.

(v) Grounding and bonding. All nonenergized metal parts of electric equipment and metal raceways and cable sheaths shall be effectively grounded and bonded to all metal pipes and rails at the portal and at intervals not exceeding 1000 feet throughout the tunnel.

(b) Emergency power systems.

(1) Scope. The provisions for emergency systems apply to circuits, systems, and equipment intended to supply power for illumination and special loads, in the event of failure of the normal supply.

(2) Wiring methods. Emergency circuit wiring shall be kept entirely independent of all other wiring and equipment and may not enter the same raceway, cable, box, or cabinet as other wiring except either where common circuit elements suitable for the purpose are required, or for transferring power from the normal to the emergency source.

- WIRING METHODS FOR EMERGENCY POWER SYSTEMS

EMERGENCY CIRCUIT WIRING MUST BE COMPLETELY INDEPENDENT OF AND PHYSICALLY SEPARATED FROM ALL OTHER WIRING AND EQUIPMENT. SUCH WIRING MUST NOT ENTER RACEWAYS, BOXES, CABLES, OR CABINETS THAT CONTAIN OTHER WIRING. THIS ENSURES THAT ANY FAULT ON THE NORMAL WIRING CIRCUITS WILL NOT AFFECT THE PERFORMANCE OF THE EMERGENCY SYSTEM.

THERE ARE TWO EXCEPTIONS TO THIS REQUIREMENT. FIRST, WHERE POWER IS TRANSFERRED FROM THE NORMAL SOURCE TO THE EMERGENCY SOURCE, THE TRANSFER SWITCH REQUIRES CIRCUIT WIRING FROM BOTH SOURCES TO ENTER THE SAME BOX OR CABINET. SECOND, IF COMMON CIRCUIT ELEMENTS IN EQUIPMENT ARE SUITABLE FOR EMERGENCY AND NORMAL LIGHTING PURPOSES, BOTH SYSTEMS MAY OCCUPY THE SAME ENCLOSURE. FOR EXAMPLE, THE JUNCTION BOX FOR A LIGHTED EXIT SIGN, WHICH IS SUPPLIED UNDER NORMAL CONDITIONS BY A REGULAR BRANCH CIRCUIT, MAY ALSO CONTAIN EMERGENCY SYSTEM CONDUCTORS. SEE FIGURE 98.

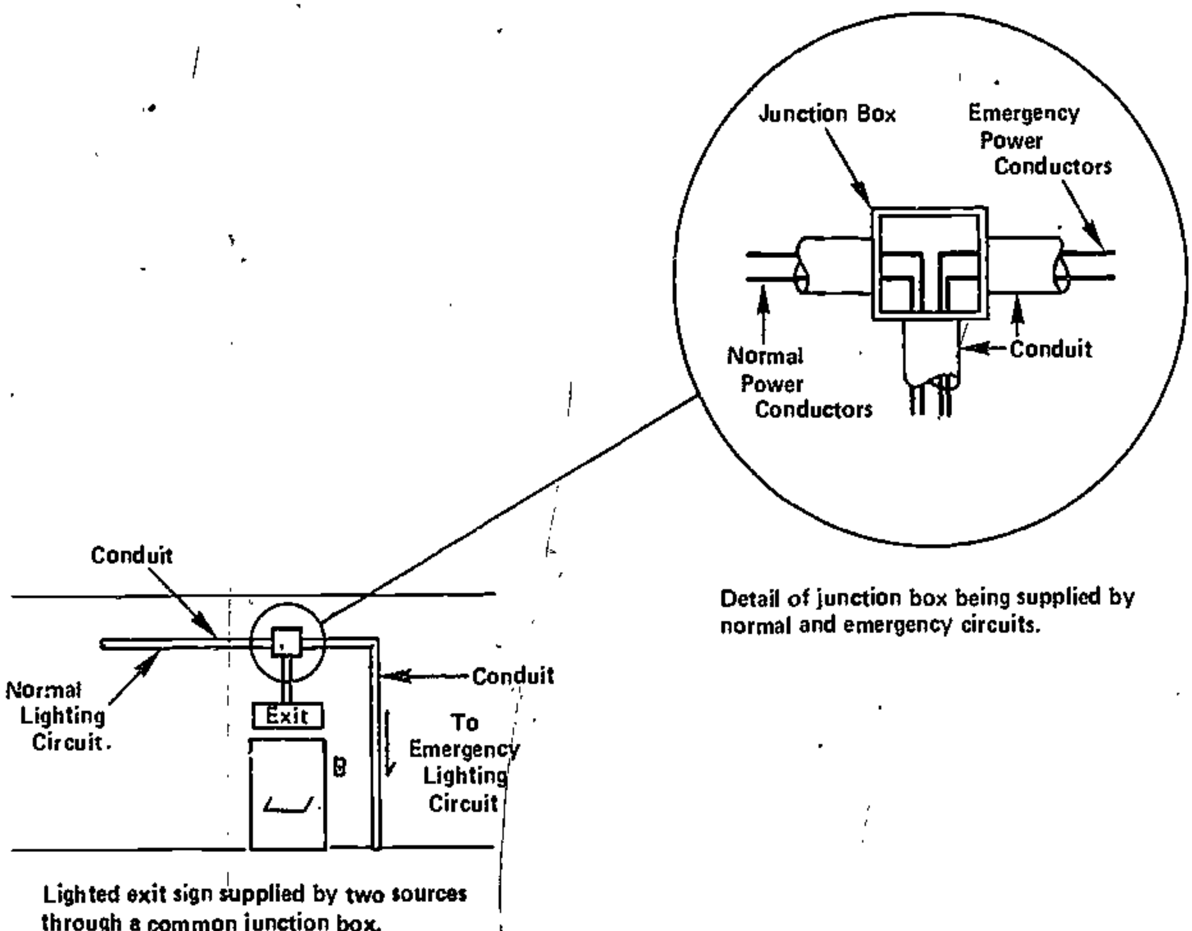


FIGURE 98. NORMAL AND EMERGENCY LIGHTING CIRCUITS WHERE PERMITTED IN A COMMON JUNCTION BOX

(3) Emergency illumination. Where emergency lighting is necessary, the system shall be so arranged that the failure of any individual lighting element, such as the burning out of a light bulb, cannot leave any space in total darkness.

(c) Class 1, Class 2, and Class 3 remote control, signaling, and power-limited circuits.

(1) Classification. Class 1, Class 2, or Class 3 remote control, signaling, or power-limited circuits are characterized by their usage and electrical power limitation which differentiates them from light and power circuits. These circuits are classified in accordance with their respective voltage and power limitations as summarized in paragraphs (c)(1)(i) through (c)(1)(iii) of this section.

(i) Class 1 circuits.

(a) A Class 1 power-limited circuit is supplied from a source having a rated output of not more than 30 volts and 1000 volt-amperes.

(b) A Class 1 remote control circuit or a Class 1 signaling circuit has a voltage which does not exceed 600 volts; however, the power output of the source need not be limited.

(ii) Class 2 and Class 3 circuits.

(a) Power for Class 2 and Class 3 circuits is limited either inherently (in which no overcurrent protection is required) or by a combination of a power source and overcurrent protection.

(b) The maximum circuit voltage is 150 volts AC or DC for a Class 2 inherently limited power source, and 100 volts AC or DC for a Class 3 inherently limited power source.

(c) The maximum circuit voltage is 30 volts AC and 60 volts DC for a Class 2 power source limited by overcurrent protection, and 150 volts AC or DC for a Class 3 power source limited by overcurrent protection.

(iii) The maximum circuit voltages in paragraphs (c)(1)(i) and (c)(1)(ii) of this section apply to sinusoidal AC or continuous DC power sources, and where wet contact occurrence is not likely.

- CLASS 1, CLASS 2, AND CLASS 3 REMOTE CONTROL, SIGNALING, AND POWER-LIMITED CIRCUITS

CLASS 1 CIRCUITS

CLASS 1 POWER-LIMITED CIRCUITS ARE SUPPLIED FROM A POWER SOURCE THAT HAS A RATED OUTPUT OF NOT MORE THAN 30 VOLTS AND A POWER LIMITATION OF 1,000 VOLT-AMPS. CLASS 1 POWER-LIMITED CIRCUITS HAVE A CURRENT LIMITER ON THE POWER SOURCE THAT SUPPLIES THEM. THIS LIMITER IS AN OVERCURRENT PROTECTION DEV . HAT RESTRICTS THE AMOUNT OF SUPPLY CURRENT TO THE CIRCUIT IN THE EVENT OF AN OVE" ' OAD, SHORT CIRCUIT OR GROUND FAULT. THESE CLASS 1 CIRCUITS MAY BE SUPPLIED FROM A TRANSFORMER OR OTHER TYPE OF POWER SUPPLY SUCH AS GENERATORS OR BATTERIES. SEE FIGURE 99.

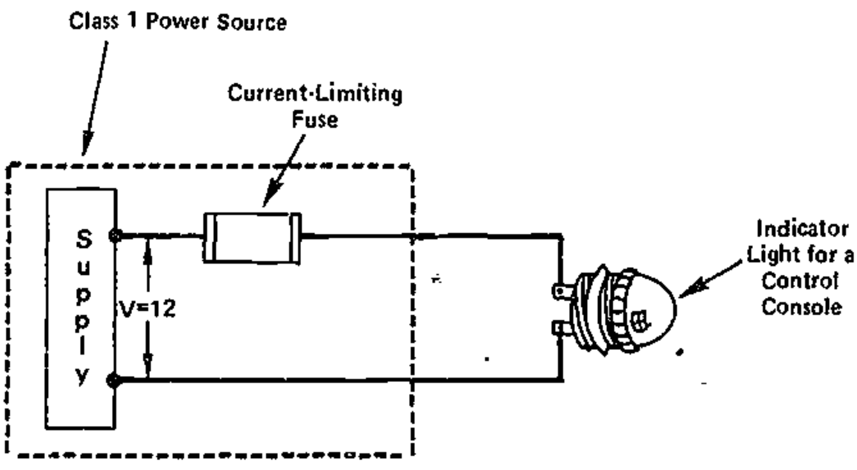


FIGURE 99. EXAMPLE OF A CLASS 1 POWER-LIMITED CIRCUIT

CLASS 1 REMOTE CONTROL OR SIGNALING CIRCUITS ARE PERMITTED TO OPERATE AT UP TO 600 VOLTS AND HAVE NO LIMITATION ON THE POWER RATING OF THE SOURCE. CLASS 1 SYSTEMS GENERALLY MUST MEET MOST WIRING REQUIREMENTS FOR POWER AND LIGHT CIRCUITS. CLASS 1 REMOTE CONTROL CIRCUITS ARE COM-

MONLY USED IN MOTOR CONTROLLERS THAT OPERATE MECHNICAL PROCESSES, ELEVATORS, CONVEYORS, AND EQUIPMENT THAT IS CONTROLLED FROM ONE OR MORE REMOTE LOCATIONS. CLASS 1 SIGNALING CIRCUITS ARE USED IN NURSES' CALL SYSTEMS IN HOSPITALS, ELECTRIC CLOCKS, BANK ALARM SYSTEMS, AND FACTORY CALL SYSTEMS. SEE FIGURE 100.

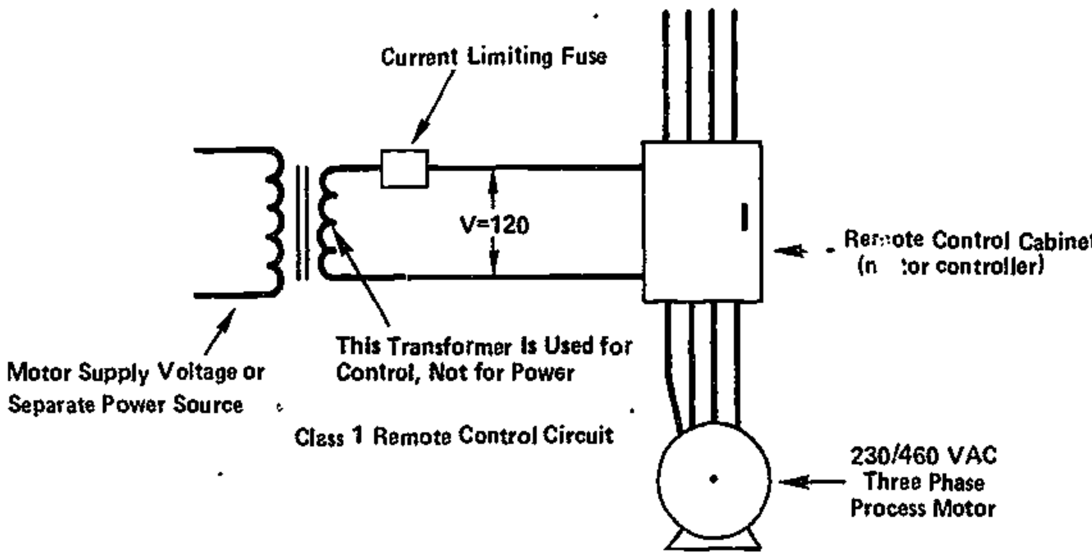


FIGURE 100. EXAMPLE OF A CLASS 1 REMOTE CONTROL CIRCUIT

CLASS 2 AND CLASS 3 CIRCUITS

THE POWER FOR CLASS 2 AND CLASS 3 CIRCUITS MUST BE INHERENTLY LIMITED, WHICH REQUIRES NO OVERCURRENT PROTECTION, OR MUST BE LIMITED BY COMBINING A POWER SOURCE AND OVERCURRENT PROTECTION. THESE CIRCUITS CAN BE INHERENTLY LIMITED BY POWER-LIMITED TRANSFORMERS THAT HAVE HIGH IMPEDENCE WINDINGS TO LIMIT POWER OUTPUT. BATTERIES ALSO ARE COMMON POWER SOURCES THAT ARE INHERENTLY LIMITING.

HEATING SYSTEM THERMOSTATS ARE COMMONLY CLASS 2 SYSTEMS. FIGURE 101 SHOWS A CURRENT-LIMITING 24-VOLT, CLASS 2 CIRCUIT FOR A BOILER THERMOSTAT CONTROL.

THE MAJORITY OF SMALL BELL, BUZZER, AND ANNUNCIATOR SYSTEMS ARE CLASS 2 CIRCUITS. CLASS 2 ALSO INCLUDES SMALL INTERCOMMUNICATING TELEPHONE SYSTEMS IN WHICH THE VOICE CIRCUIT IS SUPPLIED BY A BATTERY AND THE RINGING CIRCUIT BY A TRANSFORMER.

CLASS 2 AND 3 SYSTEMS DO NOT REQUIRE THE SAME WIRING METHODS AS POWER, LIGHT AND CLASS 1 SYSTEMS; HOWEVER A 2" SEPARATION IS REQUIRED BETWEEN THESE SYSTEMS.

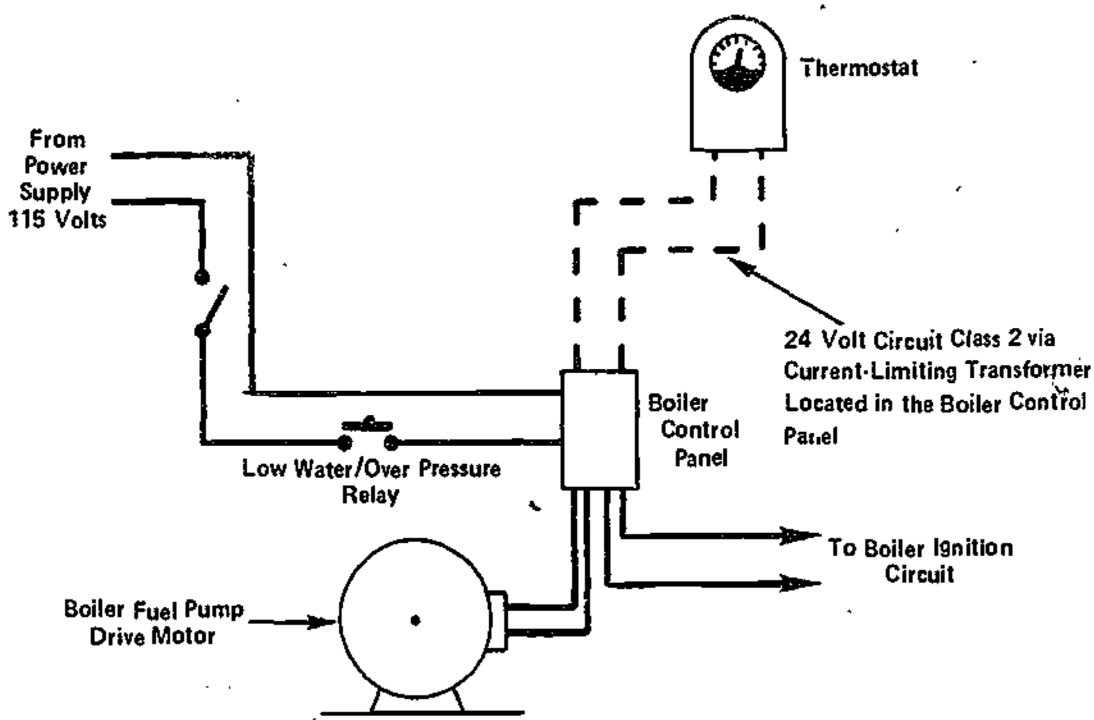


FIGURE 101. THERMOSTAT CONTROL CIRCUIT, CLASS 2

TABLE 10 PRESENTS A COMPARISON OF CLASS 1, CLASS 2, AND CLASS 3 CIRCUITS, INCLUDING COMMON USES.

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TABLE 10. COMPARISON OF CLASS 1, 2, AND 3 REMOTE CONTROL, SIGNALING, AND POWER-LIMITED CIRCUITS

	COMMON AC/DC SOURCE	POWER LIMITING DEVICE	MAXIMUM** POWER OUTPUT (VOLT-AMPERES)	VOLTAGE** LIMITATION (VOLTS)	COMMON USES
CLASS 1 CIRCUITS					
POWER LIMITED	AC OR DC	OVERCURRENT DEVICE	1,000	30	
REMOTE CONTROL AND SIGNALING CIRCUITS	AC OR DC	OVERCURRENT DEVICE	NO POWER LIMITATIONS	600	REMOTE MOTOR CONTROL CIRCUITS BANK ALARM SYSTEMS CALL SYSTEMS IN HOSPITALS
CLASS 2 CIRCUITS					
INHERENTLY LIMITED	AC OR DC	TRANSFORMER WITH HIGH RESISTANCE WINDINGS	100*	150	OIL BURNER CONTROL CIRCUIT SMALL BELL, BUZZER, OR ANNUNCIATOR SYSTEM
OVERCURRENT DEVICE LIMITED	AC	OVERCURRENT DEVICE	250	30	SMALL INTERCONNECTED TELEPHONE SYSTEMS
	DC	OVERCURRENT DEVICE	250	60	
CLASS 3 CIRCUITS					
INHERENTLY LIMITED	AC OR DC	TRANSFORMER WITH HIGH RESISTANCE WINDINGS	100*	100	
OVERCURRENT DEVICE LIMITED	AC OR DC	OVERCURRENT DEVICE	250	150	

* MAXIMUM NAMEPLATE RATING OF POWER SOURCE

** NOTE: MAXIMUM POWER OUTPUT AND VOLTAGE LIMITATIONS CONTAINED IN THIS TABLE ARE AT DIFFERENT CIRCUIT VOLTAGES. BOTH POWER OUTPUT AND VOLTAGE LIMITATION MUST BE SATISFIED. FOR MORE INFORMATION REFER TO ARTICLE 725 OF THE NATIONAL ELECTRICAL CODE.

1910.308(c)(1)(iii)

(2) Marking. A Class 2 or Class 3 power supply unit shall be durably marked where plainly visible to indicate the class of supply and its electrical rating. (See §1910.302(b)(3).)

(d) Fire protective signaling systems. (See §1910.302(b)(3).)

(1) Classifications. Fire protective signaling circuits shall be classified either as non-power limited or power limited.

(2) Power sources. The power sources for use with fire protective signaling circuits shall be either power limited or nonlimited as follows:

(i) The power supply of non-power-limited fire protective signaling circuits shall have an output voltage not in excess of 600 volts.

(ii) The power for power-limited fire protective signaling circuits shall be either inherently limited, in which no overcurrent protection is required, or limited by a combination of a power source and overcurrent protection.

• (3) Non-power-limited conductor location. Non-power-limited fire protective signaling circuits and Class 1 circuits may occupy the same enclosure, cable, or raceway provided all conductors are insulated for maximum voltage of any conductor within the enclosure, cable, or raceway. Power supply and fire protective signaling circuit conductors are permitted in the same enclosure, cable, or raceway only if connected to the same equipment.

• NON-POWER-LIMITED CONDUCTOR LOCATION

NON-POWER-LIMITED FIRE PROTECTIVE SIGNALING CIRCUITS MAY INCLUDE CIRCUITS THAT ARE PART OF A CENTRAL STATION SIGNALING SYSTEM, A SPRINKLER WATER FLOW ALARM, OR A LOCAL FIRE ALARM IN A BUILDING. VOLTAGES FOR THESE CIRCUITS RANGE UP TO 600 VOLTS. THESE CIRCUITS ARE PERMITTED TO BE LOCATED IN THE SAME ENCLOSURE, CABLE, OR RACEWAY AS CLASS 1 CIRCUITS IF THE INSULATION ON ALL OF THE WIRES WITHIN THAT ENCLOSURE ARE RATED FOR THE HIGHEST VOLTAGE OF ANY CONDUCTOR THEREIN.

POWER SUPPLY CONDUCTORS ARE NOT USUALLY PERMITTED IN THE SAME ENCLOSURE, CABLE, OR RACEWAY AS FIRE PROTECTIVE CONDUCTORS BECAUSE A FAULT OR OVERCURRENT CONDITION IN THE POWER SUPPLY CONDUCTOR COULD DAMAGE THE FIRE PROTECTIVE CIRCUITS. THIS WOULD CAUSE THE FIRE PROTECTIVE SIGNAL CIRCUIT TO MALFUNCTION AND PERHAPS NOT TRANSMIT A NEEDED ALARM OR FIRE SIGNAL. HOWEVER, POWER SUPPLY CONDUCTORS AND FIRE PROTECTIVE SIGNALING CIRCUITS MAY OCCUPY THE SAME ENCLOSURE IF THEY ARE CONNECTED TO THE SAME EQUIPMENT.

- (4) Power-limited conductor location. Where open conductors are installed, power-limited fire protective signaling circuits shall be separated at least 2 inches from conductors of any light, power, Class 1, and non-power-limited fire protective signaling circuits unless a special and equally protective method of conductor separation is employed. Cables and conductors of two or more power-limited fire protective signaling circuits or Class 3 circuits are permitted in the same cable, enclosure, or raceway. Conductors of one or more Class 2 circuits are permitted within the same cable, enclosure, or raceway with conductors of power-limited fire protective signaling circuits provided that the insulation of Class 2 circuit conductors in the cable, enclosure, or raceway is at least that needed for the power-limited fire protective signaling circuits.

- POWER-LIMITED CONDUCTOR LOCATION

SINCE POWER-LIMITED CONDUCTORS ARE USUALLY LIGHT GAUGE WIRE WITH LOW VOLTAGE RATING AND OPERATE AT LOWER VOLTAGES AND POWER RATINGS THAN CLASS 1 CIRCUITS, POWER CIRCUITS, AND NON-POWER-LIMITED CIRCUITS, SPECIAL MEASURES MUST BE TAKEN TO KEEP THESE CONDUCTORS PHYSICALLY SEPARATE. GENERALLY, THE POWER-LIMITED CIRCUIT CONDUCTORS MUST BE SEPARATED FROM THESE OTHER CIRCUITS BY AT LEAST 2 INCHES. HOWEVER, THE DIFFERENT CIRCUITS MAY BE CLOSER: 1) IF THE LIGHT, POWER, CLASS I, OR NONPOWER-LIMITED CIRCUIT IS IN A RACEWAY OR IN A SHEATHED, METAL-CLAD, OR TYPE UF CABLE, OR 2) IF THE POWER-LIMITED CIRCUIT CONDUCTORS ARE SEPARATED FROM THE OTHER CIRCUITS BY A NONCONDUCTOR, SUCH AS PORCELAIN TUBES OR FLEXIBLE TUBING, IN ADDITION TO THE CONDUCTOR INSULATION.

BECAUSE OF THE DIFFERING OPERATING VOLTAGES AND INSULATION LEVELS OF POWER-LIMITED SIGNALING CIRCUITS, THEIR CONDUCTORS ARE ONLY PERMITTED TO BE LOCATED WHERE NOT SUBJECT TO DAMAGE OR INTERFERENCE FROM OTHER TYPES OF CIRCUITS. CLASS 3 CIRCUITS AND POWER-LIMITED FIRE PROTECTIVE SIGNAL CIRCUITS OPERATE AT SIMILAR VOLTAGES AND POWER LEVELS. THEREFORE, THE CONDUCTORS AND CABLES OF TWO OR MORE POWER-LIMITED FIRE PROTECTIVE SIGNALING CIRCUITS OR CLASS 3 CIRCUITS MAY OCCUPY THE SAME ENCLOSURE. HOWEVER, POWER-LIMITED FIRE PROTECTIVE SIGNALING CIRCUITS AND CLASS 2 CIRCUITS DIFFER IN OPERATING VOLTAGES AND INSULATION, AND THEY ARE PERMITTED IN THE SAME ENCLOSURE ONLY WHEN THE INSULATION OF THE CLASS 2 CONDUCTORS IS COMPARABLE TO THAT OF THE FIRE PROTECTIVE CIRCUIT. SEE FIGURE 102.

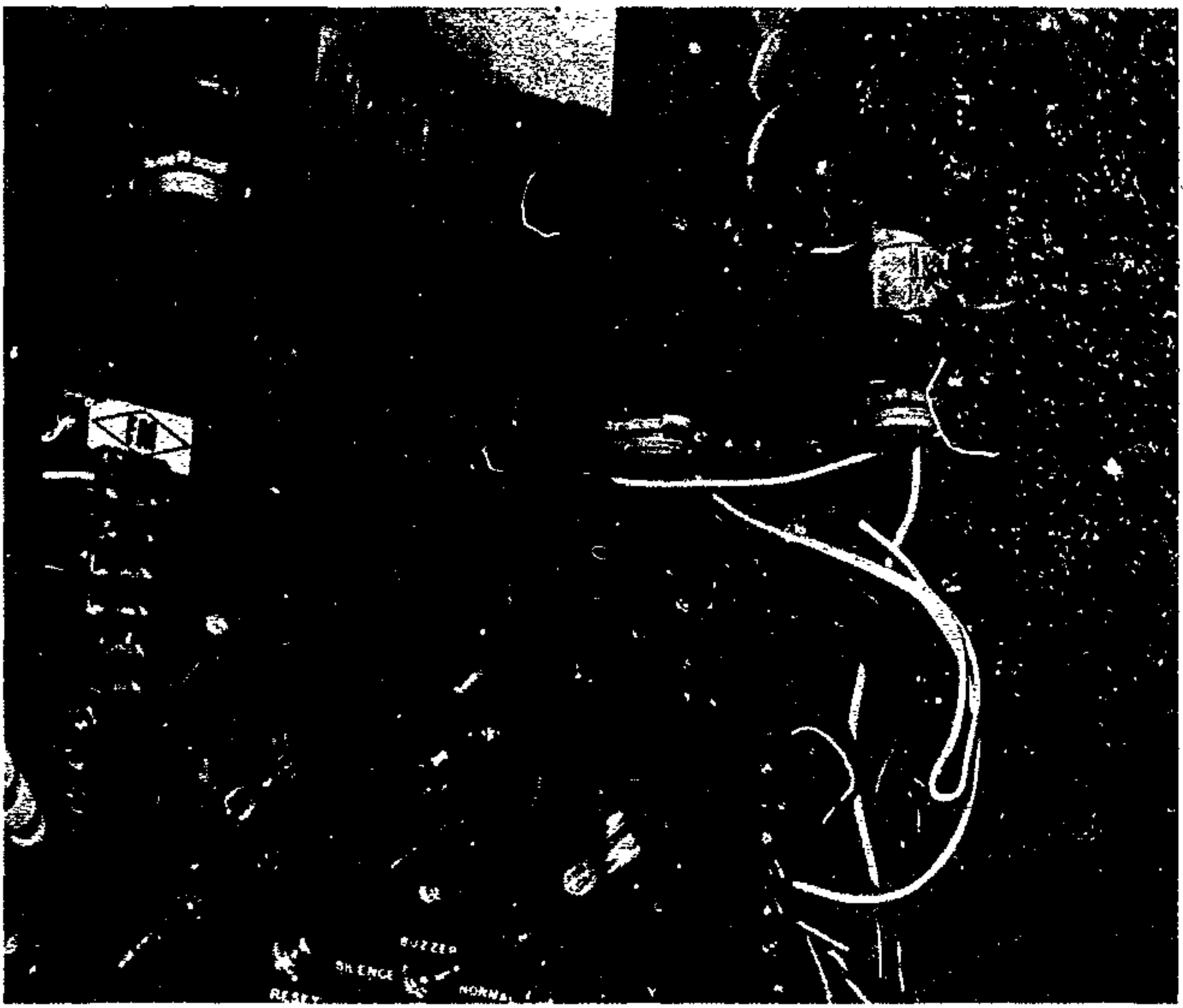


FIGURE 102. FIRE PROTECTION SIGNALING CIRCUIT CONDUCTORS

- (5) Identification. Fire protective signaling circuits shall be identified at terminal and junction locations in a manner which will prevent unintentional interference with the signaling circuit during testing and servicing. Power-limited fire protective signaling circuits shall be durably marked as such where plainly visible at terminations.

- IDENTIFICATION

IDENTIFICATION FOR FIRE PROTECTIVE SIGNALING CIRCUITS IS REQUIRED SO THAT THESE SYSTEMS ARE NOT INTERFERED WITH DURING MAINTENANCE OPERATIONS. BECAUSE THESE ARE ESSENTIAL SYSTEMS, THIS REQUIREMENT IS INTENDED TO PROTECT SIGNALING CIRCUITS WHILE WORK IS BEING PERFORMED ON OTHER SYSTEMS OR WHILE THE SIGNALING CIRCUIT ITSELF IS BEING SERVICED,

AVOIDING DAMAGE TO THE CIRCUIT AND FALSE ALARMS. SEE FIGURE 103. THIS FIRE ALARM SYSTEM IS IDENTIFIED.

FOR POWER-LIMITED FIRE PROTECTIVE SIGNALING CIRCUITS, THE MARKING MUST INDICATE THAT THE CIRCUIT IS A POWER-LIMITED FIRE PROTECTIVE SIGNALING CIRCUIT. THIS RULE IS INTENDED TO ENSURE THAT THE POWER-LIMITED FIRE CIRCUITS, WHICH OPERATE AT LOWER POWER AND VOLTAGE LEVELS, ARE NOT CONFUSED WITH OTHER CIRCUITS OPERATING AT HIGHER VOLTAGES.

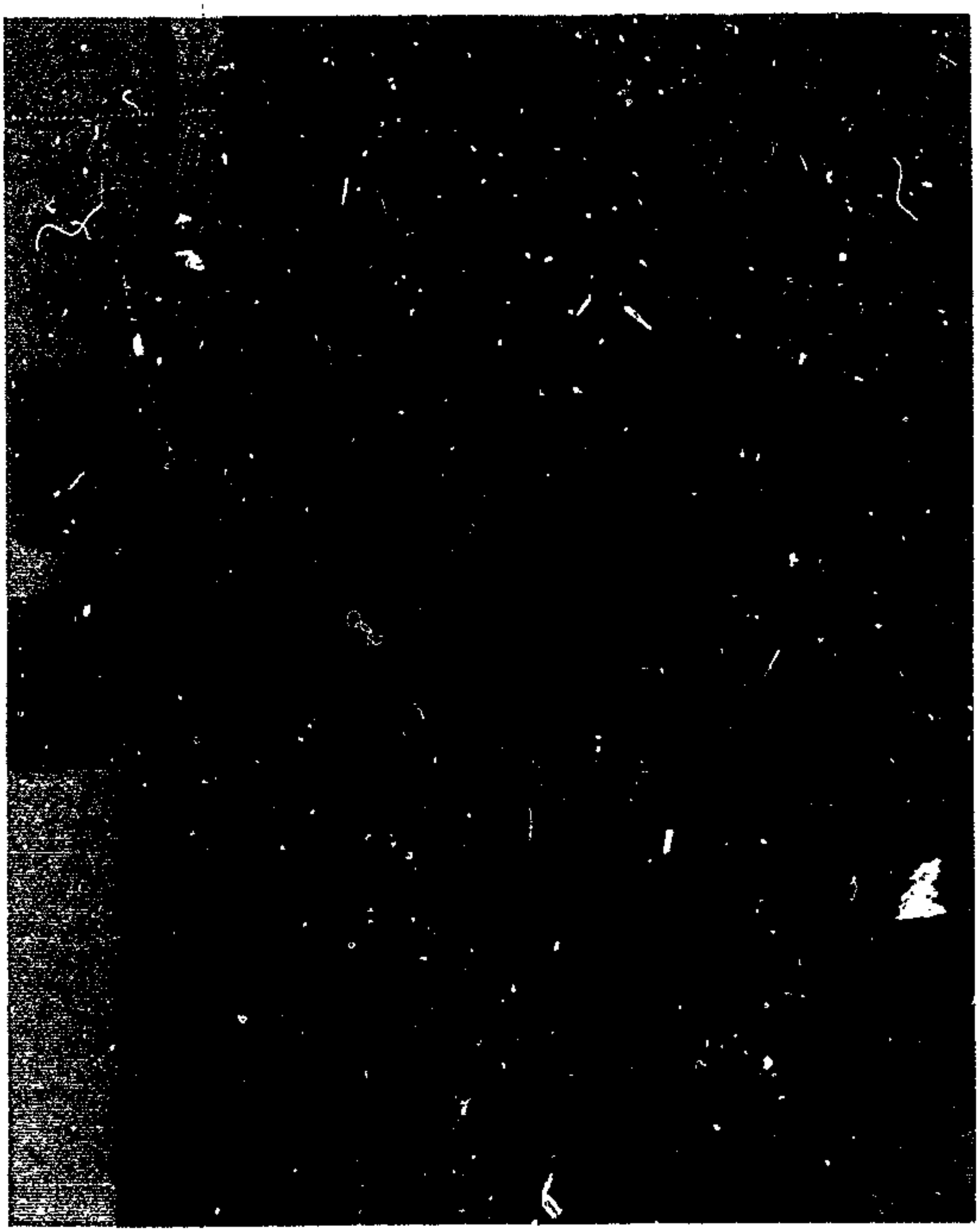


FIGURE 103. FIRE PROTECTIVE SIGNALING PANELS IDENTIFYING FIRE ALARM CIRCUITS

(e) Communications systems.

(1) Scope. These provisions for communication systems apply to such systems as central-station-connected and non-central-station-connected telephone circuits, radio and television receiving and transmitting equipment, including community antenna television and radio distribution systems, telegraph, district messenger, and outside wiring for fire and burglar alarm, and similar central station systems. These installations need not comply with the provisions of §§1910.303 through 1910.308(d).

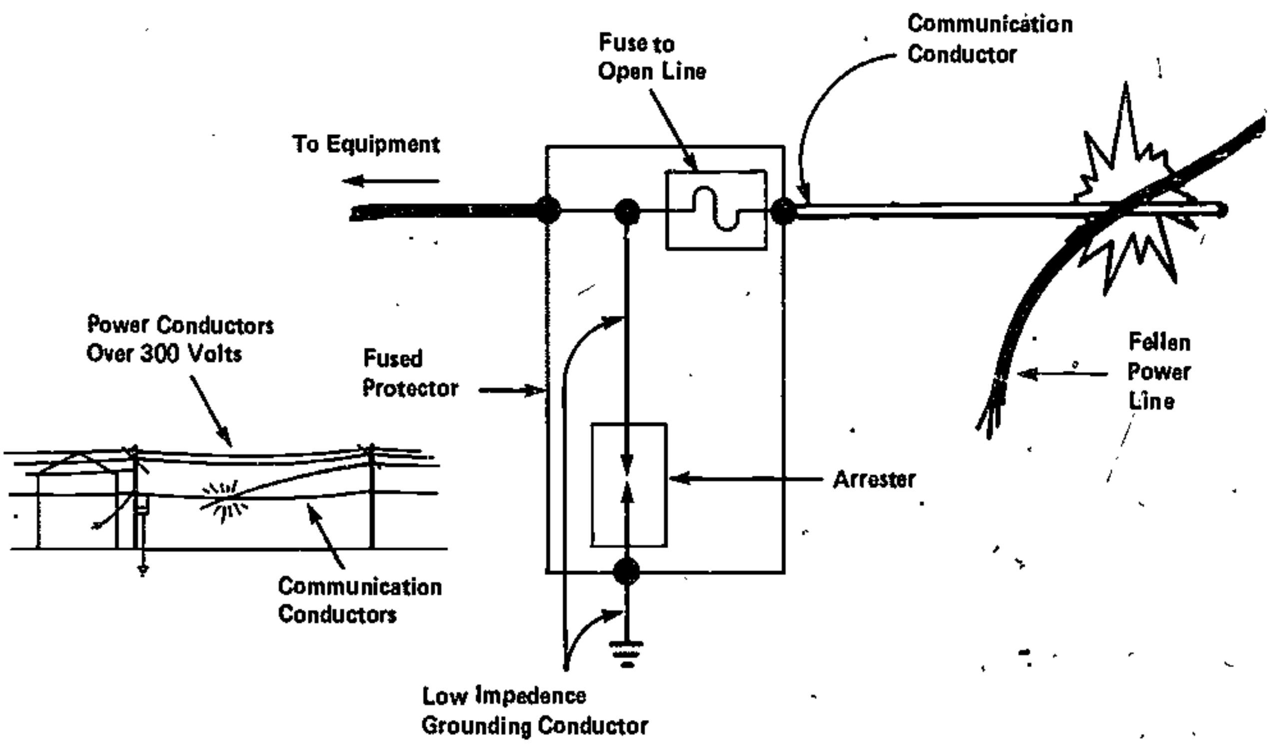
(2) Protective devices.

(i) Communication circuits so located as to be exposed to accidental contact with light or power conductors operating at over 300 volts shall have each circuit so exposed provided with a protector approved for the purpose.

- COMMUNICATION SYSTEMS — PROTECTIVE DEVICES

COMMUNICATION CIRCUITS THAT ARE NEAR LIGHT AND POWER CONDUCTORS THAT OPERATE AT OVER 300 VOLTS MUST BE PROVIDED WITH A PROTECTIVE DEVICE THAT WILL STOP CURRENT FLOW FROM THE POWER LINES THROUGH THE COMMUNICATION LINES. FUSED ARRESTERS ON EACH COMMUNICATION LINE ARE COMMONLY USED PROTECTIVE DEVICES. IF HIGH VOLTAGE POWER LINES ON POLES COME DOWN IN A STORM AND ACCIDENTALLY CONTACT THE COMMUNICATION LINES THAT SHARE THE SAME POLE, THESE PROTECTIVE DEVICES WILL NOT ALLOW THE HIGH VOLTAGE TO BE IMPRESSED ON THE COMMUNICATION CIRCUIT. PROTECTORS ARE REQUIRED BY THE NATIONAL ELECTRICAL CODE TO BE LOCATED AS NEAR AS PRACTICABLE TO THE POWER CONDUCTORS AND INSIDE, ON, OR ADJACENT TO THE BUILDINGS BEING SERVICED.

FIGURE 104 ILLUSTRATES PROTECTION FROM ACCIDENTAL CONTACT WITH POWER LINES OPERATING AT OVER 300 VOLTS WITH A LOW IMPEDANCE PROTECTIVE GROUNDING CONDUCTOR, AND ARRESTER.



SHOULD A POWER LINE OPERATING AT OVER 300 VOLTS ACCIDENTALLY CONTACT THE COMMUNICATION CONDUCTOR, THE PROTECTIVE ARRESTER WILL ALLOW THE EXCESS CURRENT TO TRAVEL TO GROUND INSTEAD OF ALONG THE COMMUNICATION CONDUCTOR. THE FUSE WILL THEN OPEN THE CIRCUIT TO EQUIPMENT

FIGURE 104. PROTECTION OF COMMUNICATION SYSTEM FROM ACCIDENTAL CONTACT WITH POWER CONDUCTORS

(ii) Each conductor of a lead-in from an outdoor antenna shall be provided with an antenna discharge unit or other suitable means that will drain static charges from the antenna system.

(3) Conductor location.

(i) Outside of buildings.

(a) Receiving distribution lead-in or aerial-drop cables attached to buildings and lead-in conductors to radio transmitters shall be so installed as to avoid the possibility of accidental contact with electric light or power conductors.

(b) The clearance between lead-in conductors and any lightning protection conductors may not be less than 6 feet.

(ii) On poles. Where practicable, communication conductors on poles shall be located below the light or power conductors. Communications conductors may not be attached to a crossarm that carries light or power conductors.

(iii) Inside of buildings. Indoor antennas, lead-ins, and other communication conductors attached as open conductors to the inside of buildings shall be located at least 2 inches from conductors of any light or power or Class 1 circuits unless a special and equally protective method of conductor separation, approved for the purpose, is employed.

(4) Equipment location. Outdoor metal structures supporting antennas, as well as self-supporting antennas such as vertical rods or dipole structures, shall be located as far away from overhead conductors of electric light and power circuits of over 150 volts to ground as necessary to avoid the possibility of the antenna or structure falling into or making accidental contact with such circuits.

(5) Grounding.

(i) Lead-in conductors. If exposed to contact with electric light and power conductors, the metal sheath of aerial cables entering buildings shall be grounded or shall be interrupted close to the entrance to the building by an insulating joint or equivalent device. Where protective devices are used, they shall be grounded in an approved manner.

- LEAD-IN CONDUCTOR GROUNDING

WHERE AERIAL COMMUNICATION CONDUCTORS ENTER BUILDINGS AND ARE LOCATED NEAR LIGHT AND POWER CONDUCTORS, THE METAL SHEATH COVERING THESE CABLES MUST BE EFFECTIVELY GROUNDED OR ITS CONTINUITY MUST BE INTERRUPTED BEFORE REACHING THE BUILDING. EITHER METHOD WILL PREVENT THE PRESENCE OF POWER LINE VOLTAGE ON EQUIPMENT IN CASE A POWER LINE ACCIDENTALLY CONTACTS THE COMMUNICATION CONDUCTORS. IN ADDITION, PROTECTIVE DEVICES OR ARRESTERS MUST ALSO BE PROPERLY GROUNDED BECAUSE OF UNUSUAL CURRENT SURGES AND POWER LEVELS THAT MAY OCCUR. PROPER GROUNDING INCLUDES GROUNDING ELECTRODE CONDUCTORS HAVING APPROVED INSULATION, BEING NOT SMALLER THAN NO. 18 COPPER, BEING RUN IN STRAIGHT LINES, BEING PROTECTED FROM PHYSICAL DAMAGE, BEING CONNECTED TO THE BUILDING GROUNDING ELECTRODE SYSTEM OR EQUIVALENT AT THE NEAREST ACCESSIBLE LOCATION, AND BEING CONNECTED WITH BOLTED CLAMPS OR BONDED.

(ii) Antenna structures. Masts and metal structures supporting antennas shall be permanently and effectively grounded without splice or connection in the grounding conductor.

(iii) Equipment enclosures. Transmitters shall be enclosed in a metal frame or grill or separated from the operating space by a barrier, all metallic parts of which are effectively connected to ground. All external metal handles and controls accessible to the operating personnel shall be effectively grounded. Unpowered equipment and enclosures shall be considered grounded where connected to an attached coaxial cable with an effectively grounded metallic shield.

DEFINITIONS

DEFINITIONS

§1910.399 Definitions Applicable to this Subpart

(a) Definitions applicable to §§1910.302 through 1910.330.

(1) Acceptable. An installation or equipment is acceptable to the Assistant Secretary of Labor, and approved within the meaning of this Subpart S:

(i) If it is accepted, or certified, or listed, or labeled, or otherwise determined to be safe by a nationally recognized testing laboratory, such as, but not limited to, Underwriters' Laboratories, Inc. and Factory Mutual Engineering Corp.; or

(ii) With respect to an installation or equipment of a kind which no nationally recognized testing laboratory accepts, certifies, lists, labels, or determines to be safe, if it is inspected or tested by another Federal agency, or by a State, municipal, or other local authority responsible for enforcing occupational safety provisions of the National Electrical Code, and found in compliance with the provisions of the National Electrical Code as applied in this Subpart; or

(iii) With respect to custom-made equipment or related installations which are designed, fabricated for, and intended for use by a particular customer, if it is determined to be safe for its intended use by its manufacturer on the basis of test data which the employer keeps and makes available for inspection to the Assistant Secretary and his authorized representatives.

(2) Accepted. An installation is "accepted" if it has been inspected and found by a nationally recognized testing laboratory to conform to specified plans or to procedures of applicable codes.

(3) Accessible. (As applied to wiring methods.) Capable of being removed or exposed without damaging the building structure or finish, or not permanently closed in by the structure or finish of the building. (See "concealed" and "exposed.")

(4) Accessible. (As applied to equipment.) Admitting close approach; not guarded by locked doors, elevation, or other effective means. (See "Readily accessible.")

(5) Ampacity. Current-carrying capacity of electric conductors expressed in amperes.

(6) Appliances. Utilization equipment, generally other than industrial, normally built in standardized sizes or types, which is installed or connected as a unit to perform one or more functions such as clothes washing, air conditioning, food mixing, deep frying, etc.

(7) Approved. Acceptable to the authority enforcing this Subpart. The authority enforcing this Subpart is the Assistant Secretary of Labor for Occupational Safety and Health. The definition of "acceptable" indicates what is acceptable to the Assistant Secretary of Labor, and therefore approved within the meaning of this Subpart.

(8) Approved for the purpose. Approved for a specific purpose, environment, or application described in a particular standard requirement.
Suitability of equipment or materials for a specific purpose, environment or application may be determined by a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation as part of its listing and labeling program. (See "Labeled" or "Listed.")

(9) Armored cable. Type AC armored cable is a fabricated assembly of insulated conductors in a flexible metallic enclosure.

(10) Askarel. A generic term for a group of nonflammable synthetic chlorinated hydrocarbons used as electrical insulating media. Askarels of various compositional types are used. Under arcing conditions the gases produced, while consisting predominantly of noncombustible hydrogen chloride, can include varying amounts of combustible gases depending upon the askarel type.

(11) Attachment plug (Plug cap)(Cap). A device which, by insertion in a receptacle, establishes connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle.

(12) Automatic. Self-acting, operating by its own mechanism when actuated by some impersonal influence, as, for example, a change in current strength, pressure, temperature, or mechanical configuration.

(13) Bare conductor. See "Conductor."

(14) Bonding. The permanent joining of metallic parts to form an electrically conductive path which will assure electrical continuity and the capacity to conduct safely any current likely to be imposed.

(15) Bonding jumper. A reliable conductor to assure the required electrical conductivity between metal parts required to be electrically connected.

(16) Branch circuit. The circuit conductors between the final over-current device protecting the circuit and the outlet(s).

(17) Building. A structure which stands alone or which is cut off from adjoining structures by fire walls with all openings therein protected by approved fire doors.

(18) Cabinet. An enclosure designed either for surface or flush mounting, and provided with a frame, mat, or trim in which a swinging door or doors are or may be hung.

(19) Cable tray system. A cable tray system is a unit or assembly of units or sections, and associated fittings, made of metal or other non-combustible materials forming a rigid structural system used to support cables. Cable tray systems include ladders, troughs, channels, solid bottom trays, and other similar structures.

(20) Cablebus. Cablebus is an approved assembly of insulated conductors with fittings and conductor terminations in a completely enclosed, ventilated, protective metal housing.

(21) Center pivot irrigation machine. A center pivot irrigation machine is a multi-motored irrigation machine which revolves around a central pivot and employs alignment switches or similar devices to control individual motors.

(22) Certified. Equipment is "certified" if it (a) has been tested and found by a nationally recognized testing laboratory to meet nationally recognized standards or to be safe for use in a specified manner, or (b) is of a kind whose production is periodically inspected by a nationally recognized testing laboratory, and (c) it bears a label, tag, or other record of certification.

(23) Circuit breaker.

(i) (600 volts nominal, or less). A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without injury to itself when properly applied within its rating.

(ii) (Over 600 volts, nominal). A switching device capable of making, carrying, and breaking currents under normal circuit conditions, and also making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions, such as those of short circuit.

(24) Class I locations. Class I locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitible mixtures. Class I locations include the following:

(i) Class I, Division 1. A Class I, Division 1 location is a location:

(a) In which hazardous concentrations of flammable gases or vapors may exist under normal operating conditions; or

(b) In which hazardous concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or

(c) In which breakdown or faulty operation of equipment or processes might release hazardous concentrations of flammable gases or vapors, and might also cause simultaneous failure of electric equipment.

NOTE: This classification usually includes locations where volatile flammable liquids or liquefied flammable gases are transferred from one container to another; interiors of spray booths and areas in the vicinity of spraying and painting operations where volatile flammable solvents are used; locations containing open tanks or vats of volatile flammable liquids; drying rooms or compartments for the evaporation of flammable solvents; locations containing fat and oil extraction equipment using volatile flammable solvents; portions of cleaning and dyeing plants where flammable liquids are used; gas generator rooms and other portions of gas manufacturing plants where flammable gas may escape; inadequately ventilated pump rooms for flammable gas or for volatile flammable liquids; the interiors of refrigerators and freezers in which volatile flammable materials are stored in open, lightly stoppered, or easily ruptured containers; and all other locations where ignitible concentrations of flammable vapors or gases are likely to occur in the course of normal operations.

(ii) Class I, Division 2. A Class I, Division 2 location is a location:

(a) In which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the hazardous liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or

(b) In which hazardous concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operations of the ventilating equipment; or

(c) That is adjacent to a Class I, Division 1 location, and to which hazardous concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided.

NOTE: This classification usually includes locations where volatile flammable liquids or flammable gases or vapors are used, but which would become hazardous only in case of an accident or of some unusual operating condition. The quantity of flammable material that might escape in case of accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that merit consideration in determining the classification and extent of each location.

Piping without valves, checks, meters, and similar devices would not ordinarily introduce a hazardous condition even though used for flammable liquids or gases. Locations used for the storage of flammable liquids or of liquefied or compressed gases in sealed containers would not normally be considered hazardous unless also subject to other hazardous conditions.

Electrical conduits and their associated enclosures separated from process fluids by a single seal or barrier are classed as a Division 2 location if the outside of the conduit and enclosures is a nonhazardous location.

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

(i) Class II, Division 1. A Class II, Division 1 location is a location:

(a) In which combustible dust is or may be in suspension in the air under normal operating conditions, in quantities sufficient to produce explosive or ignitible mixtures; or

(b) Where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitible mixtures to be produced, and might also provide a source of ignition through simultaneous failure of electric equipment, operation of protection devices, or from other causes, or

(c) In which combustible dusts of an electrically conductive nature may be present.

NOTE: This classification may include areas of grain handling and processing plants, starch plants, sugar-pulverizing plants, malting plants, hay-grinding plants, coal pulverizing plants, areas where metal dusts and powders are produced or processed, and other similar locations which contain dust producing machinery and equipment (except where the equipment is dust-tight or vented to the outside). These areas would have combustible dust in the air, under normal operating conditions, in quantities sufficient to produce explosive or ignitible mixtures. Combustible dusts which are electrically nonconductive include dusts produced in the handling and processing of grain and grain products, pulverized sugar and cocoa, dried egg and milk powders, pulverized spices, starch and pastes, potato and woodflour, oil meal from beans and seed, dried hay, and other organic materials which may produce combustible dusts when processed or handled. Dusts containing magnesium or aluminum are particularly hazardous and the use of extreme caution is necessary to avoid ignition and explosion.

(ii) Class II, Division 2. A Class II, Division 2 location is a location in which:

(a) Combustible dust will not normally be in suspension in the air in quantities sufficient to produce explosive or ignitible mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus; or

(b) Dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment, and dust accumulations resulting therefrom may be ignitible by abnormal operation or failure of electrical equipment or other apparatus.

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

(26) Class III locations. Class III locations are those that are hazardous because of the presence of easily ignitible fibers or flyings but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitible mixtures. Class III locations include the following:

(i) Class III, Division 1. A Class III, Division 1 location is a location in which easily ignitible fibers or materials producing combustible flyings are handled, manufactured, or used.
NOTE: Such locations usually include some parts of rayon, cotton, and other textile mills; combustible fiber manufacturing and processing plants; cotton gins and cotton-seed mills; flax-processing plants; clothing manufacturing plants; woodworking plants, and establishments; and industries involving similar hazardous processes or conditions.
Easily ignitible fibers and flyings include rayon, cotton (including cotton linters and cotton waste), sisal or henequen, istle, jute, hemp, tow, cocoa fiber, oakum, baled waste kapok, Spanish moss, excelsior, and other materials of similar nature.

(ii) Class III, Division 2. A Class III, Division 2 location is a location in which easily ignitible fibers are stored or handled, except in process of manufacture.

(27) Collector ring. A collector ring is an assembly of slip rings for transferring electrical energy from a stationary to a rotating member.

(28) Concealed. Rendered inaccessible by the structure or finish of the building. Wires in concealed raceways are considered concealed, even though they may become accessible by withdrawing them. [See "Accessible. (As applied to wiring methods.)"]

(29) Conductor.
(i) Bare. A conductor having no covering or electrical insulation whatsoever.
(ii) Covered. A conductor encased within material of composition or thickness that is not recognized as electrical insulation.
(iii) Insulated. A conductor encased within material of composition and thickness that is recognized as electrical insulation.

(30) Conduit body. A separate portion of a conduit or tubing system that provides access through a removable cover(s) to the interior of the system at a junction of two or more sections of the system or at a terminal point of the system. Boxes such as FS and FD or larger cast or sheet metal boxes are not classified as conduit bodies.

(31) Controller. A device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.

(32) Cooking unit, counter-mounted. A cooking appliance designed for mounting in or on a counter and consisting of one or more heating elements, internal wiring, and built-in or separately mountable controls. (See "Oven, wall-mounted.")

(33) Covered conductor. See "Conductor."

(34) Cutout. (Over 600 volts, nominal.) An assembly of a fuse support with either a fuseholder, fuse carrier, or disconnecting blade. The fuseholder or fuse carrier may include a conducting element (fuse link), or may act as the disconnecting blade by the inclusion of a nonfusible member.

(35) Cutout box. An enclosure designed for surface mounting and having swinging doors or covers secured directly to and telescoping with the walls of the box proper. (See "Cabinet.")

(36) Damp location. See "Location."

(37) Dead front. Without live parts exposed to a person on the operating side of the equipment.

(38) Device. A unit of an electrical system which is intended to carry but not utilize electric energy.

(39) Dielectric heating. Dielectric heating is the heating of a nominally insulating material due to its own dielectric losses when the material is placed in a varying electric field.
(40) Disconnecting means. A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.
(41) Disconnecting (or Isolating) switch. (Over 600 volts, nominal.) A mechanical switching device used for isolating a circuit or equipment from a source of power.
(42) Dry location. See "Location."
(43) Electric sign. A fixed, stationary, or portable self-contained, electrically illuminated utilization equipment with words or symbols designed to convey information or attract attention.
(44) Enclosed. Surrounded by a case, housing, fence or walls which will prevent persons from accidentally contacting energized parts.
(45) Enclosure. The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts, or to protect the equipment from physical damage.
(46) Equipment. A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like, used as a part of, or in connection with, an electrical installation.
(47) Equipment grounding conductor. See "Grounding conductor, equipment."
(48) Explosion-proof apparatus. Apparatus enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor which 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 which operates at such an external temperature that it will not ignite a surrounding flammable atmosphere.
(49) Exposed. (As applied to live parts.) Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts not suitably guarded, isolated, or insulated. (See "Accessible and "Concealed.")
(50) Exposed. (As applied to wiring methods.) On or attached to the surface or behind panels designed to allow access. [See "Accessible. (As applied to wiring methods.)"]
(51) Exposed. (For the purposes of §1910.308(e), Communications systems.) Where the circuit is in such a position that in case of failure of supports or insulation, contact with another circuit may result.
(52) Externally operable. Capable of being operated without exposing the operator to contact with live parts.
(53) Feeder. All circuit conductors between the service equipment, or the generator switchboard of an isolated plant, and the final branch-circuit overcurrent device.
(54) Fitting. An accessory such as a locknut, bushing, or other part of a wiring system that is intended primarily to perform a mechanical rather than an electrical function.
(55) Fuse. (Over 600 volts, nominal.) An overcurrent protective device with a circuit opening fusible part that is heated and severed by the passage of overcurrent through it. A fuse comprises all the parts that form a unit capable of performing the prescribed functions. It may or may not be the complete device necessary to connect it into an electrical circuit.
(56) Ground. A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.
(57) Grounded. Connected to earth or to some conducting body that serves in place of the earth.

(58) Grounded, effectively (Over 600 volts, nominal.) Permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient ampacity that ground fault current which may occur cannot build up to voltages dangerous to personnel.

(59) Grounded conductor. A system or circuit conductor that is intentionally grounded.

(60) Grounding conductor. A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

(61) Grounding conductor, equipment. The conductor used to connect the non-current-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor and/or the grounding electrode conductor at the service equipment or at the source of a separately derived system.

(62) Grounding electrode conductor. The conductor used to connect the grounding electrode to the equipment grounding conductor and/or to the grounded conductor of the circuit at the service equipment or at the source of a separately derived system.

(63) Ground-fault circuit-interrupter. A device whose function is to interrupt the electric circuit to the load when a fault current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.

(64) Guarded. Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach to a point of danger or contact by persons or objects.

(65) Health care facilities. Buildings or portions of buildings and mobile homes that contain, but are not limited to, hospitals, nursing homes, extended care facilities, clinics, and medical and dental offices, whether fixed or mobile.

(66) Heating equipment. For the purposes of §1910.306(g), the term "heating equipment" includes any equipment used for heating purposes if heat is generated by induction or dielectric methods.

(67) Hoistway. Any shaftway, hatchway, well hole, or other vertical opening or space in which an elevator or dumbwaiter is designed to operate.

(68) Identified. Identified, as used in reference to a conductor or its terminal, means that such conductor or terminal can be readily recognized as grounded.

(69) Induction heating. Induction heating is the heating of a nominally conductive material due to its own I^2R losses when the material is placed in a varying electromagnetic field.

(70) Insulated conductor. See "Conductor."

(71) Interrupter switch. (Over 600 volts, nominal.) A switch capable of making, carrying, and interrupting specified currents.

(72) Irrigation machine. An irrigation machine is an electrically driven or controlled machine, with one or more motors, not hand portable, and used primarily to transport and distribute water for agricultural purposes.

(73) Isolated. Not readily accessible to persons unless special means for access are used.

(74) Isolated power system. A system comprising an isolating transformer or its equivalent, a line isolation monitor, and its ungrounded circuit conductors.

(75) Labeled. Equipment is "labeled" if there is attached to it a label, symbol, or other identifying mark of a nationally recognized testing laboratory which, (a) makes periodic inspections of the production of such equipment, and (b) whose labeling indicates compliance with nationally recognized standards or tests to determine safe use in a specified manner.

(76) Lighting outlet. An outlet intended for the direct connection of a lampholder, a lighting fixture, or a pendant cord terminating in a lampholder.

(77) Listed. Equipment is "listed" if it is of a kind mentioned in a list which, (a) is published by a nationally recognized laboratory which makes periodic inspection of the production of such equipment, and (b) states such equipment meets nationally recognized standards or has been tested and found safe for use in a specified manner.

(78) Location.

(i) Damp location. Partially protected locations under canopies, marquees, roofed open porches, and like locations, and interior locations subject to moderate degrees of moisture, such as some basements, some barns, and some cold-storage warehouses.

(ii) Dry location. A location not normally subject to dampness or wetness. A location classified as dry may be temporarily subject to dampness or wetness, as in the case of a building under construction.

(iii) Wet location. Installations underground or in concrete slabs or masonry in direct contact with the earth, and locations subject to saturation with water or other liquids, such as vehicle-washing areas, and locations exposed to weather and unprotected.

(79) Medium voltage cable. Type MV medium voltage cable is a single or multiconductor solid dielectric insulated cable rated 2000 volts or higher.

(80) Metal-clad cable. Type MC cable is a factory assembly of one or more conductors, each individually insulated and enclosed in a metallic sheath of interlocking tape, or a smooth or corrugated tube.

(81) Mineral-insulated metal-sheathed cable. Type MI mineral-insulated metal-sheathed cable is a factory assembly of one or more conductors insulated with a highly compressed refractory mineral insulation and enclosed in a liquid-tight and gas-tight continuous copper sheath.

(82) Mobile X-ray. X-ray equipment mounted on a permanent base with wheels and/or casters for moving while completely assembled.

(83) Nonmetallic-sheathed cable. Nonmetallic-sheathed cable is a factory assembly of two or more insulated conductors having an outer sheath of moisture resistant, flame-retardant, nonmetallic material. Nonmetallic sheathed cable is manufactured in the following types:

(i) Type NM. The overall covering has a flame-retardant and moisture-resistant finish.

(ii) Type NMC. The overall covering is flame-retardant, moisture-resistant, fungus-resistant, and corrosion-resistant.

(84) Oil (filled) cutout. (Over 600 volts, nominal.) A cutout in which all or part of the fuse support and its fuse link or disconnecting blade are mounted in oil with complete immersion of the contacts and the fusible portion of the conducting element (fuse link), so that arc interruption by severing of the fuse link or by opening of the contacts will occur under oil.

(85) Open wiring on insulators. Open wiring on insulators is an exposed wiring method using cleats, knobs, tubes, and flexible tubing for the protection and support of single insulated conductors run in or on buildings, and not concealed by the building structure.

(86) Outlet. A point on the wiring system at which current is taken to supply utilization equipment.

(87) Outline lighting. An arrangement of incandescent lamps or electric discharge tubing to outline or call attention to certain features such as the shape of a building or the decoration of a window.

(88) Oven, wall-mounted. An oven for cooking purposes designed for mounting in or on a wall or other surface and consisting of one or more heating elements, internal wiring, and built-in or separately mountable controls. (See "Cooking unit, counter-mounted."

(89) Overcurrent. Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload (see definition), short circuit, or ground fault. A current in excess of rating may be accommodated by certain equipment and conductors for a given set of conditions. Hence the rules for overcurrent protection are specific for particular situations.

(90) Overload. Operation of equipment in excess of normal, full load rating, or of a conductor in excess of rated ampacity which, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload. (See "Overcurrent.")

(91) Panelboard. A single panel or group of panel units designed for assembly in the form of a single panel; including buses, automatic overcurrent devices, and with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front. (See "Switchboard.")

(92) Permanently installed decorative fountains and reflection pools. Those that are constructed in the ground, on the ground, or in a building in such a manner that the pool cannot be readily disassembled for storage and are served by electrical circuits of any nature. These units are primarily constructed for their aesthetic value and not intended for swimming or wading.

(93) Permanently installed swimming pools, wading and therapeutic pools. Those that are constructed in the ground, on the ground, or in a building in such a manner that the pool cannot be readily disassembled for storage whether or not served by electrical circuits of any nature.

(94) Portable X-ray. X-ray equipment designed to be hand-carried.

(95) Power and control tray cable. Type TC power and control tray cable is a factory assembly of two or more insulated conductors, with or without associated bare or covered grounding conductors under a nonmetallic sheath, approved for installation in cable trays, in raceways, or where supported by a messenger wire.

(96) Power fuse. (Over 600 volts, nominal.) See "Fuse."

(97) Power-limited tray cable. Type PLTC nonmetallic-sheathed power limited tray cable is a factory assembly of two or more insulated conductors under a nonmetallic jacket.

(98) Power outlet. An enclosed assembly which may include receptacles, circuit breakers, fuseholders, fused switches, buses and watt-hour meter mounting means; intended to supply and control power to mobile homes, recreational vehicles or boats, or to serve as a means for distributing power required to operate mobile or temporarily installed equipment.

(99) Premises wiring system. That interior and exterior wiring, including power, lighting, control, and signal circuit wiring together with all of its associated hardware, fittings, and wiring devices, both permanently and temporarily installed, which extends from the load end of the service drop, or load end of the service lateral conductors to the outlet(s). Such wiring does not include wiring internal to appliances, fixtures, motors, controllers, motor control centers, and similar equipment.

(100) Qualified person. One familiar with the construction and operation of the equipment and the hazards involved.

(101) Raceway. A channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in this subpart. Raceways may be of metal or insulating material, and the term includes rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquidtight flexible metal conduit, flexible metallic tubing, flexible metal conduit, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways.

(102) Readily accessible. Capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. (See "Accessible.")

(103) Receptacle. A receptacle is a contact device installed at the outlet for the connection of a single attachment plug. A single receptacle is a single contact device with no other contact device on the same yoke. A multiple receptacle is a single device containing two or more receptacles.

(104) Receptacle outlet. An outlet where one or more receptacles are installed.

(105) Remote-control circuit. Any electric circuit that controls any other circuit through a relay or an equivalent device.

(106) Sealable equipment. Equipment enclosed in a case or cabinet that is provided with a means of sealing or locking so that live parts cannot be made accessible without opening the enclosure. The equipment may or may not be operable without opening the enclosure.

(107) Separately derived system. A premises wiring system whose power is derived from generator, transformer, or converter winding and has no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system.

(108) Service. The conductors and equipment for delivering energy from the electricity supply system to the wiring system of the premises served.

(109) Service cable. Service conductors made up in the form of a cable.

(110) Service conductors. The supply conductors that extend from the street main or from transformers to the service equipment of the premises supplied.

(111) Service drop. The overhead service conductors from the last pole or other aerial support to and including the splices, if any, connecting to the service-entrance conductors at the building or other structure.

(112) Service-entrance cable. Service-entrance cable is a single conductor or multi-conductor assembly provided with or without an overall covering, primarily used for services and of the following types:

(i) Type SE, having a flame-retardant, moisture-resistant covering, but not required to have inherent protection against mechanical abuse.

(ii) Type USE, recognized for underground use, having a moisture-resistant covering, but not required to have a flame-retardant covering or inherent protection against mechanical abuse. Single-conductor cables having an insulation specifically approved for the purpose do not require an outer covering.

(113) Service-entrance conductors, overhead system. The service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop.

(114) Service entrance conductors, underground system. The service conductors between the terminals of the service equipment and the point of connection to the service lateral. Where service equipment is located outside the building walls, there may be no service-entrance conductors, or they may be entirely outside the building.

(115) Service equipment. The necessary equipment, usually consisting of a circuit breaker or switch and fuses, and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cutoff of the supply.

(116) Service raceway. The raceway that encloses the service-entrance conductors.

(117) Shielded nonmetallic-sheathed cable. Type SNM, shielded non-metallic-sheathed cable is a factory assembly of two or more insulated conductors in an extruded core of moisture-resistant, flame-resistant nonmetallic material, covered with an overlapping spiral metal tape and wire shield and jacketed with an extruded moisture-, flame-, oil-, corrosion-, fungus-, and sunlight-resistant nonmetallic material.

(118) Show window. Any window used or designed to be used for the display of goods or advertising material, whether it is fully or partly enclosed or entirely open at the rear and whether or not it has a platform raised higher than the street floor level.

(119) Sign. See "Electric Sign."

(120) Signaling circuit. Any electric circuit that energizes signaling equipment.

(121) Special permission. The written consent of the authority having jurisdiction.

(122) Storable swimming or wading pool. A pool with a maximum dimension of 15 feet and a maximum wall height of 3 feet and is so constructed that it may be readily disassembled for storage and reassembled to its original integrity.

(123) Switchboard. A large single panel, frame, or assembly of panels which have switches, buses, instruments, overcurrent and other protective devices mounted on the face or back or both. Switchboards are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets. (See "Panelboard.")

(124) Switches.

(i) General-use switch. A switch intended for use in general distribution and branch circuits. It is rated in amperes, and it is capable of interrupting its rated current at its rated voltage.

(ii) General-use snap switch. A form of general-use switch so constructed that it can be installed in flush device boxes or on outlet box covers, or otherwise used in conjunction with wiring systems recognized by this subpart.

(iii) Isolating switch. A switch intended for isolating an electric circuit from the source of power. It has no interrupting rating, and it is intended to be operated only after the circuit has been opened by some other means.

(iv) Motor-circuit switch. A switch, rated in horsepower, capable of interrupting the maximum operating overload current of a motor of the same horsepower rating as the switch at the rated voltage.

(125) Switching devices. (Over 600 volts, nominal.) Devices designed to close and/or open one or more electric circuits. Included in this category are circuit breakers, cutouts, disconnecting (or isolating) switches, disconnecting means, interrupter switches, and oil (filled) cutouts.

(126) Transportable X-ray. X-ray equipment installed in a vehicle or that may readily be disassembled for transport in a vehicle.

(127) Utilization equipment. Utilization equipment means equipment which utilizes electric energy for mechanical, chemical, heating, lighting, or similar useful purpose.

(128) Utilization system. A utilization system is a system which provides electric power and light for employee workplaces, and includes the premises wiring system and utilization equipment.

(129) Ventilated. Provided with a means to permit circultion of air sufficient to remove an excess of heat, fumes, or vapors.

(130) Volatile flammable liquid. A flammable liquid having a flash point below 38 degrees C (100 degrees F) or whose temperature is above its flash point.
(131) Voltage (of a circuit). The greatest root-mean-square (effective) difference of potential between any two conductors of the circuit concerned.
(132) Voltage, nominal. A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (as 120/240, 480Y/277, 600, etc.). The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment.
(133) Voltage to ground. For grounded circuits, the voltage between the given conductor and that point or conductor of the circuit that is grounded; for ungrounded circuits, the greatest voltage between the given conductor and any other conductor of the circuit.
(134) Watertight. So constructed that moisture will not enter the enclosure.
(135) Weatherproof. So constructed or protected that exposure to the weather will not interfere with successful operation. Rainproof, raintight, or watertight equipment can fulfill the requirements for weatherproof where varying weather conditions other than wetness, such as snow, ice, dust, or temperature extremes, are not a factor.
(136) Wet location. See "Location."
(137) Wireways. Wireways are sheet-metal troughs with hinged or removable covers for housing and protecting electric wires and cable and in which conductors are laid in place after the wireway has been installed as a complete system.

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