TABLE OF CONTENTS

WISCONSIN STATE ELECTRICAL CODE

PROPOSED

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GENERAL REQUIREMENTS AND DEFINITIONS

CHAPTER E-1. SCOPE

E-1.01. Scope of Code.

This code shall apply as minimum fire and safety requirements for the construction, installation and maintenance of all electrical power and communication circuits and equipment including signal, radio, and lightning rod equipment; and includes rules to be observed in the operation of electrical power and communication equipment and lines.

CHAPTER E-10. GENERAL REQUIREMENTS

E-10.10. Character of Construction, Maintenance and Operation.

All electrical power and communication equipment and lines shall be of such construction, and so installed, operated, and maintained as to minimize the life and fire hazard.

E-10.11. Use of Approved Materials and Construction Methods.

(1). Materials. No materials, employed in construction covered by this code, shall be used which have not been approved by the Industrial Commission or Public Service Commission.

Exception: Materials which comply with the requirements of this code are hereby approved.

Note: It is the policy of the administrative authority to approve materials, devices, and systems which are listed as standard by the Underwriters' Laboratories if they do not conflict with the requirements of this or other state codes or the laws of the state.

(2). Methods of Installation. No methods of installing electrical materials or devices in construction covered by this code shall be used which are not

approved by the Industrial Commission or Public Service Commission.

Exception: Methods of installation which comply with the requirements of this code are hereby approved.

E-10.12. Construction, Inspection and Repairs.

All construction and equipment shall be cleaned when necessary and inspected at such intervals as experience has shown to be necessary. Any equipment or construction known to be defective so as to endanger life or property shall be promptly repaired, permanently disconnected, or isolated until repairs can be made. Construction, repairs, additions and changes to electrical equipment and conductors shall be made by qualified persons only. (See also E-121.02 and E-121.04.)

E-10.13. Application of Rules.

(1). Waiving Rules. The rules are intended to apply to all installations except as modified or waived by the proper administrative authority. They are intended to be so modified or waived in particular cases wherever any rules are shown for any reason to be impracticable or if equivalent or safer construction is secured in other ways.

(2). Application. The intent of the rules will be realized (a) by applying the rules in full to all new installations, reconstructions, alterations, and extensions, except where any rule is shown to be impracticable for special reasons or where the advantage of uniformity with existing construction is greater than the advantage of construction in compliance with the rules, providing the existing construction is reasonably safe; (b) by bringing existing installations into conformity with these rules as far as may be directed by the Industrial Commission or Public Service Commission and within the time determined by them.

(3). Penalties. The 1959 Statutes of the State of Wisconsin require:

102.57 Violations of safety provisions, penalty. Where injury is caused by the failure of the employer to comply with any statute or any lawful order of the Commission, compensation and death benefits as provided in this chapter shall be increased fifteen percent. Failure of an employer

reasonably to enforce compliance by employes with such statute or order of the commission shall constitute failure by the employer to comply with such statute or order.

102.58 Decreased compensation. Where injury is caused by the wilful failure of the employe to use safety devices where provided in accordance with any statute or lawful order of the commission and adequately maintained, and their use is reasonably enforced, by the employer, or where injury results from the employe's wilful failure to obey any reasonable rule adopted by the employer for the safety of the employe and of which the employe has notice, or where injury results from the intoxication of the employe, the compensation, and death benefit provided herein shall be reduced 15 per cent.

196.64 Utilities, liability for treble damages. If any public utility shall do or cause to be done or permit to be done any matter, act or thing prohibited or declared to be unlawful by chapter 196 or 197, or shall omit to do any act, matter or thing required to be done by it, such public utility shall be liable to the person injured thereby in treble the amount of damages sustained in consequence of such violation.

196.66 General penalty; utility responsible for agents. (1) If any public utility shall violate any provision of chapter 196 or 197, or shall do any act therein prohibited or shall fail or refuse to perform any duty enjoined upon it for which a penalty has not been provided, or shall fail, neglect or refuse to obey any lawful requirement or order made by the Commission or the municipal council or any judgment or decree made by any court upon its application, for every such violation, failure or refusal such public utility shall forfeit not less than twenty-five dollars nor more than one thousand dollars. (2) Every day during which any public utility or any officer, agent or employe thereof shall fail

to observe and comply with any order or direction of the commission or to perform any duty enjoined by Chapter 196 or 197, shall constitute a separate and distinct violation.

(4). Temporary Installations. It will sometimes be necessary to modify or waive certain of the rules in case of temporary installations or installations which are shortly to be dismantled or reconstructed. Such temporary construction may be used for a reasonable length of time provided it is under competent supervision while it or adjoining equipment is alive or if it is protected by suitable barriers or warning signs when accessible to any person, without fully complying with this code; but all such construction shall be made reasonably safe.

(5). Testing. Rooms which are used exclusively for routine or special electrical test work and, therefore, are under the supervision of a qualified person, need comply with this code only insofar as is practicable for the character of the testing done.

(6). Emergency. In case of emergency or pending decision of the administrator, the person responsible for the installation may decide as to modification or waiver of any order, subject to review by proper authority.

CHAPTER E-100. DEFINITION OF SPECIAL TERMS

E-100.02. Definitions.

General guides for this Chapter on Definitions include: (1) for simplicity, only definitions essential to the proper use of this Code are included; (2) only those terms used in two or more rules are defined in full in Chapter E-100, other definitions being defined in the individual rule where they apply; (3) wherever practical the defimitions will conform to those of the American Standards Association.

(1) Accessible: (As applied to wiring methods). Not permanently closed in by the structure or finish of the building; capable of being removed without disturbing the building structure or finish. (See "Concealed" and "Exposed").

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

(3) Administrative Authority: The Industrial and/or the Public Service Commission.

(4) Alive or Live: Electrically connected to a source of potential difference, or electrically charged so as to have a potential different from that of the earth.

Note: The term "Live" is sometimes used in place of the term "Current-Carrying" where the intent is clear, to avoid repetitions of the longer term.

(5) Antenna Conflict: See "Conflict".

(6) Appliance: Appliances are current-utilizing equipment, fixed or portable; for example, heating , cooking and small motor-operated equipment.

(7) Approved: Acceptable to the administrative authority enforcing this code. (See E-10.11).

(8) Armored Cable: Flexible metallic tubing in which the conductors have been inserted in the process of manufacture.

(9) Askarel: A synthetic non-flammable insulating liquid which, when decomposed by the electric arc, evolves only non-flammable gaseous mixtures.

(10) Authority: See "Administrative Authority".

(11) 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. (See "Non-Automatic").

(12) Branch Circuit: That portion of a wiring system extending beyond the final overcurrent device protecting the circuit.

Note: A device not approved for branch circuit protection, such as a thermal cutout or motor overload protective device, is not considered as the overcurrent device protecting the circuit.

(13) Branch Circuit-Appliance: A branch circuit supplying energy to one or more outlets to which appliances are to be connected; such circuits to have no permanently connected lighting fixtures not a part of an appliance.

(14) Branch Circuit - General Purpose: A branch circuit that supplies a number of outlets for lighting and appliances.

(15) Branch Circuit - Individual: A branch circuit that supplies only one utilization equipment.

(16) 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.

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

(18) Cable: A combination of conductors which are bound together and insulated from each other. It also includes single conductors having the same insulation and outside protective covering as commonly used in multi-conductor cables.

(19) Cable Vault: See "Manhole".

(20) Circuit: A conductor or system of conductors through which an electric current is intended to flow.

(21) Circuit-Breaker: A device designed to open, under abnormal conditions, a current-carrying circuit, without injury to itself. The term, as used in this code, applies only to the automatic type, designed to trip on a predetermined overload of current.

(22) Climbing Space: The vertical space reserved along the side of a pole structure to permit ready access for linemen to equipment and conductors located on the pole structure.

(23) Common Use: The simultaneous use of facilities by two or more agencies

supplying the same type of service.

(24) Communication Lines: See "Lines".

(25) 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.

(26) Conductor: A metallic conducting material, usually in the form of a wire or cable, suitable for carrying an electric current.

(27) Conductor - Bare: A conductor having no covering or insulation whatsoever. (See "Covered Conductor".)

(28) Conductor Conflict: See "Conflict".

(29) Conductor - Covered: A conductor having one or more layers of nonconducting materials that are not recognized as insulation under the code. (See "Conductor - Bare").

(30) Conductor - Grounding: A conductor which is used to connect the equipment or the wiring system with a grounding electrode or electrodes.

(31) Conductor - Lateral: In pole wiring work, a wire or cable extending in a general horizontal direction approximately at right angles to the general direction of the line conductors.

(32) Conductor - Line: One of the wires or cables carrying electric current, supported by poles, towers, or other structures, but not including vertical or lateral connecting wires.

(33) Conductor - Vertical: In pole wiring work, a wire or cable extending in an approximately vertical direction.

(34) Conduit: A tube especially constructed for the purpose of enclosing electrical conductors.

(35) Conduit - Flexible Metallic: A flexible raceway of circular cross-section, especially constructed for the purpose of drawing in or withdrawing of wires and cables after the conduit and its fittings are in place, and is made

of metal strip, usually of steel, with metallic corrosion resistant coating, helically wound, and with interlocking edges.

(36) Conduit - Rigid Metal: A tubular raceway with threaded ends, for electric wires and cables; if of ferrous metal, having a corrosion resistant coating on all surfaces except threads, and if of corrosion resistant material, properly identified, and in either case with a uniformly smooth interior coating of enamel or like material. Conduit may be made of mild steel tubing of circular cross-section having walls which in the various electrical trade sizes comply with the measurements set forth in Chapter E-900, Table 4. For other materials, dimensions are to be the same,

(37) Conduit - Thin-wall (Electrical Metallic Tubing): A thin-walled steel or corrosion-resistant metal raceway of circular cross-section, constructed for the purpose of pulling in or withdrawing wires after it is installed in place, coated inside and out to be corrosion resistant, and connected by means of threadless fittings. The interior diameters should be the same as for the corresponding trade sizes of rigid conduit.

(38) Conflict - Antenna: An antenna or its guy wire is at a higher level than a supply or communication conductor and approximately parallel thereto, provided the breaking of the antenna or its support will be likely to result in contact between the antenna or guy wire and the supply or communication conductors.

(39) Conflict - Conductor: A conductor is so situated with respect to a conductor of another line at a lower level that the horizontal distance between them is less than the sum of the following values:

(a) Five feet, plus

(b) One-half the difference of level between the conductors concerned, plus

(c) The value required in Tables 6, 7 and 8 of E-123.06 for horizontal separation between conductors on the same support for

the highest voltage carried by either conductor concerned.

(40) Conflict - Structure: As applied to a pole line, the line is so situated with respect to a second line that the overturning (at the ground line) of the first line will result in contact between its poles or conductors and the conductors of the second line, assuming that no conductors are broken in either line.

(a) Exceptions: Lines are not considered as conflicting under the following conditions:

1. Where one line crosses another.

2. Where two lines are on opposite sides of a highway, street or alley and are separated by a distance not less than 60 per cent of the height of the taller pole and not less than 20 feet.

(41) Connector - Pressure (Solderless): A pressure wire connector is a device which establishes the connection between two or more conductors or between one or more conductors and a terminal by means of mechanical pressure and without the use of solder.

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

(43) Cooking Unit - Counter Mounted: An assembly of one or more domestic surface heating elements for cooking purposes designed for flush mounting in, or supported by, a counter, and which assembly is complete with inherent or separately mountable controls and internal wiring. (See "Oven, Wall-Mounted.")

(44) Current - Carrying Part: A conducting part intended to be connected in an electric circuit. Non-current-carrying parts are those not intended to be so connected.

(45) Current - Limiting Overcurrent Protective Device: (See E-240.27.)

(46) 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.

(47) Dead: Free from any electrical connection to a source of potential difference and from electric charge; not having a potential different from that of the earth. The term is used only with reference to current-carrying parts which are sometimes alive.

(48) Demand Factor: Of any system or part of a system, the ratio of the maximum demand of the system, or part of the system, to the total connected load of the system, or part of the system under consideration.

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

(50) Disconnecting Means: A device, group of devices, or other means whereby the conductors of a circuit can be disconnected from their source of supply.

(51) Disconnector: A switch which is intended to open a circuit after the load has been thrown off by some other means.

Note: Manual switches designed for opening loaded circuits are usually installed in circuit with disconnectors, to provide a safe means for opening the circuit under load.

(52) Dry: See "Location - Dry".

(53) Duct: In underground work, a single tubular runway for underground cables.

(54) Dustproof: So constructed or protected that dust will not interfere with its successful operation.

(55) Dust-tight: So constructed that dust will not enter the enclosing case.

(56) Duty - Continuous: A requirement of service that demands operation at a substantially constant load for an indefinitely long time.

(57) Duty - Intermittent: A requirement of service that demands operation for alternate intervals of (a) load and no load, or (b) load and rest, or (c)

load, no load and rest.

(58) Duty - Periodic: A type of intermittent duty in which the load conditions are regularly recurrent.

(59) Duty - Short-Time: A requirement of service that demands operation at a substantially constant load for a short and definitely specified time.

(60) Duty - Varying: A requirement of service that demands operation at loads, and for intervals of time, both of which may be subject to wide variation.

Note: See table in E-430.022 for illustrations of various types of duty.

(61) Effectively Grounded: See "Grounded".

(62) Electric Sign: A fixed or portable, self-contained electrically illuminated appliance with words or symbols designed to convey information or attract attention.

(63) Electrical Metallic Tubing: See "Conduit".

(64) Electrical Supply Equipment: See "Equipment".

(65) Electrical Supply Lines: See "Lines".

(66) Electrical Supply Station: Any building, room, or separate space within which electrical supply equipment is located and the interior of which is accessible, as a rule, only to properly qualified persons.

Note: This includes generating stations and substations and generator, storage battery, and transformer rooms, but excludes manholes and isolated transformer vaults on private premises. (See "Transformer Vault".)

(67) Enclosed: Surrounded by a case which will prevent a person from accidentally contacting live parts.

(68) Equipment: A general term including materials, fittings, devices, appliances, fixtures, apparatus, and the like, used as a part of, or in connection with, an electrical installation.

(69) Equipment - Electrical Supply: Equipment which produces, modifies, regulates, controls, or safeguards a supply of electrical energy.

(70) Equipment - Utilization: Equipment which utilizes electrical energy for mechanical, chemical, heating, lighting, testing, or similar purposes and is not a part of supply equipment, supply lines or communication lines.

(71) Explosion-Proof: Enclosed in a case which 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 it must operate at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby.

(72) Exposed: (As applied to circuits or lines). In such a position that in case of failure of supports or insulation contact with another circuit or line may result.

(73) Exposed. (As applied to live parts). A live part can be inadvertently touched or approached nearer than a safe distance by any person. It is applied to parts not suitably guarded or isolated. (See "Accessible" and "Concealed").

(74) Exposed: (As applied to wiring method). Not concealed.

(75) Externally Operable: (As applied to equipment in a case or cabinet). Capable of being operated without exposing the operator to contact with live parts.

(76) Feeder: A feeder is the circuit conductors between the service equipment, or the generator switchboard of an isolated plant, and the branch circuit overcurrent device.

(77) Fitting: An accessory such as a locknut, bushing or other part of a wiring system which is intended primarily to perform a mechanical rather than an electrical function.

(78) Flexible Metallic Tubing: See "Conduit".

(79) Garage: A building, or part of a building, which accommodates or houses self-propelled vehicles. For the purposes of this code the term vehicle includes land, air and water vehicles.

(80) General-Use Switch: See "Switch".

(81) Ground: A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and earth, or to some conducting body which serves in place of the earth.

(82) Grounded: Connected to earth or to some conducting body which serves in place of the earth.

(83) Grounded Conductor: A conductor which is intentionally grounded, either solidly or through a current limiting device.

(84) Grounded - Effectively: Permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient current-carrying capacity to prevent the building up of voltages which may result in undue hazard to connected equipment or to persons.

(85) Grounded System: A system of conductors in which at least one conductor or point (usually the middle wire, or neutral point of transformer or generator windings) is intentionally grounded, either solidly or through a current limiting device. This ground connection may be at one or more points.

(86) Grounding Conductor: See "Conductor".

(87) Guarded: Covered, shielded, enclosed or otherwise protected, by means of suitable covers, casings, barriers, rails, or screens, or by means of mats or platforms, to remove the liability of dangerous contact or approach by persons or objects to a point of danger. Wires which are insulated, but not otherwise protected, are not considered as guarded. (See "Insulated".)

(88) Guard Zone: The space at minimum clearance from guards to electrical parts where guards may be installed by workmen without definite engineering design. (See E-112.05).

(89) Handhole: An opening in an underground system into which workmen reach, but do not enter.

(90) Hazardous Locations: See Chapter E-500.

(91) Hoistway: Any shaftway, hatchway, wellhole, or other vertical opening or space in which an elevator or dumbwaiter is designed to operate.

(92) Identified: As used in Chapter E-200, the conductor or terminal to which it refers is to be recognized as grounded.

(93) Insulated: Separated from other conducting surfaces by a dielectric substance or air space permanently offering a high resistance to the passage of current and to disruptive discharge through the substance or space.

Note: When any object is said to be insulated, it is understood to be insulated in a suitable manner for the conditions to which it is subjected. Otherwise, it is, within the purpose of these rules, uninsulated. Insulating covering of conductors is one means of making the conductors insulated.

(94) Insulating: Where applied to the covering of a conductor or to clothing, guards, rods, and other safety devices, a device, when interposed between a person and current-carrying parts, protects the person making use of it against electric shock from the current-carrying parts with which the device is intended to be used. (The opposite of conducting.)

(95) Isolated: Not readily accessible to persons unless special means for access are used. (See"Exposed".)

(96) Isolated Plant: A private electrical installation deriving energy from its own generator driven by a prime mover.

(97) Isolating Switch: See "Switch".

(98) Isolation by Elevation: Elevated sufficiently so that persons may safely walk underneath. (See "Exposed".)

(99) Joint Use: The simultaneous use of facilities by two or more agencies not furnishing like services but having use for similar facilities.

(100) Lateral Conductor: See "Conductor".

(101) Lateral Working Space: The space reserved for working between conductor levels outside the climbing space, and to its right and left.

(102) Lighting Outlet: An outlet intended for the direct connection of a lampholder, a lighting fixture or a pendent cord terminating in a lampholder.

(103) Lightning Arrester: As applied to supply circuits, a device which has the property of reducing the voltage of a surge applied to its terminals, is capable of interrupting follow current if present, and restores itself to its original operating condition.

(104) Line Conductor: See "Conductor".

(105) Lines - Communication: The conductors and their supporting or containing structures which are located outside of buildings and are used for public or private signal or communication service and which operate at not exceeding 400 volts to ground or 750 volts between any two points of the circuit, and the transmitted power of which does not exceed 150 watts. When operating at less than 150 volts no limit is placed on the capacity of the system.

(a) Telephone, telegraph, railroad-signal, messenger-call, clock, fire or police alarm, community television antenna, and other systems conforming with the above are included.

(b) Lines used for signalling purposes, but not included under the above definition are considered as supply lines of the same voltage and are to be so run.

1. Exception is made under certain conditions for communication circuits used in the operation of supply lines. (See E-128.09 (1)).

(106) Lines - Electrical Supply: Those conductors and their necessary supporting or containing structures which are located entirely outside of buildings and are used for transmitting a supply of electrical energy. Electrical supply lines do not include communication lines as defined in (105) above.

(a) Does not include open wiring on buildings, in yard or similar locations where spans are less than 20 feet and all the precautions required for

stations or utilization equipment, as the case may be, are observed.

(b) Railway-signal lines of more than 400 volts to ground are always supply lines within the meaning of these rules, and those of less than 400 volts may be considered as supply lines, if so run and operated throughout.

(107) Lines - Minor Communication: Communication lines carrying not more than two circuits, used mainly for local telephone or telegraph service, or for police or fire alarm service.

(108) Location - Damp: A location subject to a moderate degree of moisture, such as some basements, some barns, some cold storage warehouses, and the like.

(109) Location - Dry: 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.

(110) Location - Wet: A location subject to saturation with water or other liquids, such as locations exposed to the weather, washrooms in garages, and like locations. Installations underground or in concrete slabs or masonry in direct contact with the earth, shall be considered as wet locations.

(111) Low-Energy Power Circuit: A circuit which is not a remote-control or signal circuit but which has the power supply limited in accordance with the requirements of Class 2 remote-control circuits. (See Chapter E-725.)

(a) Such circuits include electric door openers and circuits used in the operation of coin-operated phonographs.

(112) Low Voltage Protection: The effect of a device operative on the reduction or failure of voltage to cause and maintain the interruption of power supply to the equipment protected.

(113) Low Voltage Release: The effect of a device operative on the reduction or failure of voltage to cause the interruption of power supply to the equipment, but not preventing the re-establishment of the power supply on return of voltage.

(114) Manhole: (More accurately termed splicing chamber or cable vault). An

opening in an undergroundsystem which workmen or others may enter for the purpose of installing cables, transformers, junction boxes, and other devices, and for making connections and tests.

(115) Manual: Capable of being operated by personal intervention.

(116) Motor Circuit Switch: See "Switch".

(117) Multi-Outlet Assembly: A type of surface or flush raceway, designed to hold conductors and attachment plug receptacles, assembled in the field or at the factory.

(118) New Construction: All new electrical installations and all extensions and renewals which constitute a substantial portion of the installation.

(119) Non-Automatic: The implied action requires personal intervention for its control. (See "Automatic.")

Note: As applied to an electric controller, non-automatic control does not necessarily imply a manual controller, but only that personal intervention is necessary.

(120) Open Wire: A conductor or pair of conductors separately supported above the surface of the ground.

(121) Outlet: A point on the wiring system at which current is taken to supply utilization equipment.

(122) Outline Lighting: An arrangement of incandescent lamps or gaseous tubes to outline and call attention to certain features such as the shape of a building or the decoration of a window.

(123) Oven, Wall-Mounted: A domestic oven for cooking purposes designed for mounting in or on a wall or other surface.

(124) Panelboard: A single panel, or group of panel units, designed for assembly in the form of a single panel; including busses and with or without switches and/or automatic overcurrent protective devices for the control of light, heat, or power circuits of small individual as well as aggregate capacity;

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 Definition of "Switchboard").

(125) Permanently Grounded: See "Grounded, Effectively".

(126) Pole Face: That side of a pole on which cross arms are attached, or which is so designated by the companies owning or operating the pole.

(127) Portable Appliance: An appliance capable of being readily moved where established practice or the conditions of use make it necessary or convenient for it to be detached from its source of current by means of a flexible cord and attachment plug.

(128) Qualified Person: One familiar with the construction and operation of the apparatus and the hazards involved.

(129) Raceway: Any channel for holding wires, cables or bus bars, which is designed expressly for, and used solely for, this purpose.

Note: Raceways may be of metal or insulating material, and the term includes rigid metal conduit, flexible metal conduit, electrical metallic tubing, underfloor raceways, cellular metal floor raceways, surface metal raceways, wireways and busways.

(130) Raintight: So constructed or protected that exposure to a beating rain will not result in the entrance of water.

(131) Readily Accessible: Capable of being reached quickly for operation, renewal or inspection, 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").

(132) Receptacle Outlet: An outlet where one or more receptacles are installed.

(133) Reconstruction: Replacement of a substantial portion of an existing installation by new equipment or construction. Does not include ordinary maintenance replacements.

(134) Remote-Control Circuit: Any electrical circuit which controls any

other circuit through a relay or an equivalent device.

(135) Rural Districts: All places not urban, usually in the country, but in some cases within city limits. (See definition of "Urban Districts".)

(136) Sag:

(a) Apparent Sag at any Point: The departure of the wire at the particular point in the span from the straight line between the two points of support of the span, at 60°F., with no wind.

(b) Apparent Sag of a Span: The maximum departure of the wire in a given span from the straight line between the two points of support of the span, at 60°F., with no wind loading.

(c) Final Unloaded Sag: The sag of a conductor after it has been subjected for an appreciable period to the loading prescribed, or equivalent loading, and the loading removed.

(d) Initial Unloaded Sag: The sag of a conductor prior to the application of any external load.

(e) Maximum Total Sag: The total sag at the midpoint of the straight line joining the two points of support of the conductor.

(f) Total Sag: The distance, measured vertically, from any point of a conductor to the straight line joining its two points of support, under conditions of ice loading equivalent to the total resultant loading.

(g) Unloaded Sag: (Of a conductor at any point in a span). The distance, measured vertically, from the particular point in the conductor to a straight line between its two points of support, without any external load.

(137) Sealable Equipment: Equipment enclosed in a case or cabinet that is provided with means for 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.

(138) Sealed (Hermetic Type) Refrigeration Compressor: A mechanical

compressor consisting of a compressor and a motor, both of which are enclosed in the same sealed housing, with no external shafts nor shaft seals, the motor operating in the refrigerant atmosphere.

(139) Service: The conductors and equipment for delivering energy from the electricity supply system to the wiring system of the premises served.

(140) Service Cable: Service conductors made up in the form of cable.

(141) Service Conductors: The supply conductors which extend from the street main, or from transformers to the service equipment of the premises supplied.

(142) Service Drop: The overhead service conductors between the last pole or other aerial support and the first point of attachment to the building.

(143) 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.

(144) Service Entrance Conductors, Underground System: The service conductors between the terminals of the service equipment and the point of connection to the service lateral.

(a) Where service equipment is located outside the building walls, there may be no service-entrance conductors, or they may be entirely outside the building.

(145) Service Equipment: The necessary equipment, usually consisting of circuit-breaker or switch and fuses, and their accessories, located near point of entrance of supply conductors to a building and intended to constitute the main control and means of cut-off for the supply to that building.

(146) Service Lateral: The underground service conductors between the street main, including any risers at a pole or other structure or from transformers, and the first point of connection to the service entrance conductors in a terminal box inside or outside the building wall. Where there is no terminal box, the point of connection shall be considered to be the point of entrance of the service

conductors into the building.

(147) Service Raceway: The rigid metal conduit, electrical metallic tubing, or other raceway, that encloses service entrance conductors.

(148) Setting: (Of Circuit-Breaker). The value of the current at which it is set to trip.

(149) Shall: Is used to indicate requirements.

(150) Should: Is used to indicate recommendations, or that which is advised but not required. In general, recommendations have the form of fine-print notes or paragraphs supplementing the preceding text.

(151) 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.

(152) Sign: See "Electric Sign".

(153) Signal Circuit: Any electrical circuit which supplies energy to an appliance which gives a recognizable signal.

(a) Such circuits include circuits for door bells, buzzers, code-calling systems, signal lights, and the like.

(154) Span Length: The horizontal distance between two adjacent supporting points of a conductor.

(155) Special Permission: The written consent of the Industrial or Public Service Commission.

(156) Structure Conflict: See "Conflict".

(157) Substantial: So constructed and arranged as to be of adequate strength and durability for the service to be performed under the prevailing conditions.

(158) Switches:

(a) General Use Switch: A switch intended for use as a switch in general distribution and branch circuits. It is rated in amperes and is capable of inter-

rupting its rated current at its rated voltage.

(b) 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 Code.

(c) AC General Use Snap Switch: A form of general use snap switch suitable only for use on alternating current circuits for controlling the following:

1. Resistive and inductive loads (including electric discharge lamps) not exceeding the ampere rating at the voltage involved.

2. Tungsten filament lamp loads not exceeding the ampere rating at 120 volts.

3. Motor loads not exceeding 80 per cent of the ampere rating of the switches at the rated voltage.

Note: All AC general use snap switches are marked "AC" in addition to their electrical rating.

(d) AC-DC General Use Snap Switch: A form of general use snap switch suitable for use on either direct or alternating current circuits for controlling the following:

1. Resistive loads not exceeding the ampere rating at the voltage involved.

2. Inductive loads not exceeding one-half the ampere rating at the voltage involved, except that switches having a marked horsepower rating are suitable for controlling motors not exceeding the horsepower rating of the switch at the voltage involved.

3. Tungsten filament lamp loads not exceeding the ampere rating at 125 volts, when marked with the letter "T".

Note: AC-DC general use snap switches are not generally marked AC-DC, but are always marked with their electrical rating.

(e) Isolating Switch: A switch intended for isolating an electric

circuit from its source of power. It has no interrupting rating and is intended to be operated only after the circuit has been opened by some other means.

(f) 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.

(159) Switchboard: A large single panel, frame, or assembly of panels on which are mounted, on the face or back or both, switches, overcurrent and other protective devices, buses, and usually instruments. Switchboards are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets. (See "Panelboard").

(160) Tags: Tags or other markers of distinctive appearance, indicating that men are at work on the equipment or lines so designated.

(161) Tension:

(a) Final Unloaded Conductor Tension: The longitudinal tension in a conductor after the conductor has been stretched by the application for an appreciable period, and subsequent release, of the heavy loading of ice and wind, and temperature decrease, specified in these rules (or equivalent loading).

(b) Initial Conductor Tension: The longitudinal tension in a conductor prior to the application of any external load.

(162) Thermal Cutout: An overcurrent protective device which contains a heater element in addition to and affecting a renewable fusible member which opens the circuit. It is not designed to interrupt short circuits.

(163) Thermal Protection: (As applied to motors). The words "Thermal Protection" appearing on the name plate of a motor indicate that the motor is provided with a thermal protector.

(164) Thermal Protector: (As applied to motors). An inherent overheating protective device which is responsive to motor current and temperature and which, when properly applied to a motor, protects the motor against dangerous overheating

due to overload or failure to start.

(165) Transformer Vault: An isolated fire-resistant enclosure, either above or below ground, in which transformers and related equipment are installed and which is not continuously attended during operation.

(166) Urban District: Thickly settled area, whether inside city limits or not.

(167) Utilization Equipment: See "Equipment".

(168) Vapor-Tight: So enclosed that vapor will not enter the enclosure.

(169) Ventilated: Provided with a means to permit circulation of the air sufficiently to remove an excess of heat, fumes, or vapors.

(170) Vertical Conductor: See "Conductor".

(171) Voltage:

(a) Voltage of a Circuit: The greatest effective difference of potential between any two conductors of the circuit concerned.

(b) Voltage to Ground in Grounded Circuits: The voltage between the given conductor and that point or conductor of the circuit which is grounded.

(c) Voltage to Ground in Ungrounded Circuits: The greatest voltage between the given conductor and any other conductor of the circuit.

Note 1: Where one circuit is directly connected to another circuit of higher voltage (as in the case of auto-transformers), both are considered of the higher voltage, unless the circuit of lower voltage is effectively grounded.

Note 2. When the term "Volts" or "Voltage" is used without qualification, it means the voltage between conductors if no grounded conductor capable of carrying load is present. If such a grounded conductor is present, "Volts" or "Voltage" means volts to ground.

(172) Watertight: So constructed that moisture will not enter the enclosing case.

(173) Weatherproof: So constructed or protected that exposure to the

weather will not interfere with its successful operation.

(a) Weatherproof (As applied to the protective covering on a conductor): A covering made up of braids of fibrous material which are thoroughly saturated with a dense moisture-proof compound after they have been placed on the conductor, or an equivalent protective covering designed to withstand weather conditions.

(174) Wet; (See "Location - Wet").

PART 4

PROTECTION OF BUILDINGS AND STRUCTURES AGAINST LIGHTNING

CHAPTER E-160.

SCOPE, DEFINITIONS, ETC.

E-160.01. Scope and Purpose.

(1) The rules of this part of the code apply to the protection against lightning of buildings and other property, with the exception of property devoted to the production, storage and transportation of flammable liquids and gases, explosives manufacturing buildings and magazines and electrical lines and equipment.

(2) The purpose is the prevention of fire loss and other damages from lightning by directing attention to the available means of protection which are believed to be effective.

E-160.02. Interpretation and Exceptions.

(1) This code shall be liberally construed. In cases of practical difficulty or unnecessary hardships exceptions from its literal requirements may be made if equivalent protection is otherwise secured.

(2) It is not intended that this code shall be interpreted as recommending the protection of every class of property to which it applies, but shall constitute the standard where economic or other considerations make it appear that protection is necessary or desirable.

E-160.03. Mandatory and Advisory Requirements.

The word "shall" where used is to be understood as mandatory and the word "should" as advisory. "May" is used in the permissive sense.

E-160.04. Terms and Definitions.

(1) Air Terminal: The combination of elevation rod, and brace, or footing placed on upper portions of structures, together with tip or point if used.

(2) Conductor: The portion of a protective system designed to carry the current of a lightning discharge from air terminal to ground.

(3) Branch Conductor: A conductor which branches off at an angle from a continuous run of conductor.

(4) Cable: A number of wires twisted or braided to form a conductor.

(5) Copper-clad Steel: Steel with a coating of copper welded to it as distinguished from copper-plated or copper-sheathed material.

(6) Down Conductor: The vertical portion of a run of conductor which ends at the ground.

(7) Elevation Rod: The vertical portion of a conductor in an air terminal by means of which it is elevated above the object to be protected.

Fastener:
(8)/ A device used to secure the conductor to the structure which supports it.

(9) Ground Connection: A buried body of metal with its surrounding soil and a connecting conductor which together serve to bring an object into electrical continuity with the earth.

(10) Metal-roofed Building: A building with a roof made of or covered with metal.

(11) Metal-clad Building: A building with sides made of or covered with metal.

(12) Point: The pointed piece of metal used at the upper end of the elevation rod to receive a lightning discharge.

(13) Roof Conductor: The portion of the conductor above the eaves running along the ridge, parapet, or other portion of the roof.

CHAPTER E-161.

LIGHTNING PROTECTION FOR ORDINARY BUILDINGS

E-161.01 to E-161.04, inclusive, hereunder apply more particularly to buildings of the ordinary types which have roofs of slate, tile, or other non-conducting material. E-161.05 sets forth modification to the rules preceding it which may be made for the case of buildings which are roofed, or roofed and clad, with metal. Grounding and interconnection of metals are included in E-161.06 to E-161.08, while Chapter E-162 is to be referred to when buildings are equipped with spires, steeples, flag poles or towers.

E-161.01. Conductors.

(1) Materials. The materials of which protective systems are made shall be relatively resistant to corrosion or shall be acceptably protected against corrosion. No combination of materials shall be used that forms an electrolytic couple of such nature that in the presence of moisture corrosion is accelerated, but where moisture is permanently excluded from the junction of such metals contact between them is not objectionable.

(a) The following list of materials comprises those commonly used for protective systems, or parts of protective systems, and with their accompanying specifications constitute materials to be regarded as standard for the purposes of this rule.

1. Copper. Where copper is used it shall be of the grade ordinarily required for commercial electrical work, generally designated as being of 98 per cent conductivity when annealed.

2. Alloys. Where alloys of metals are used they shall be substantially as resistant to corrosion as copper under similar conditions.

3. Copper-clad Steel. Where copper-clad steel is used, the copper covering shall be permanently and effectively welded to the steel core, and the proportion of copper shall be such that the conductance is not less than 30 per

cent of the conductance of an equivalent cross-section of solid copper.

4. Galvanized Steel. Where steel is used it shall be thoroughly protected against corrosion by a zinc coating which will satisfactorily withstand the standard test of the American Society for Testing Materials for galvanized coatings.

Note: The importance of resistance to corrosion of lightning-conductor materials should be emphasized at this point because corrosion, either soil or atmospheric, leads to deterioration and consequent impairment of the initial degree of reliability of a system and should be forestalled wherever possible. In this connection, there are several combinations of metals, and alloys of metals, that do not lead to marked corrosion when placed in contact in the presence of moisture, whereas others do, and while it is not practicable to give here a list of such combinations, manufacturers and purchasers of lightning conductors are cautioned to use only those that have been shown by experience or adequate tests to be free from objectionable features. It may also be pointed out that atmospheric conditions in certain sea-coast sections of the United States, notably the South Atlantic and Gulf coasts, are known to be destructive to galvanized steel, and in such regions galvanized steel should be used with caution, a preference being given to copper. Copper is also to be preferred where corrosive gases are encountered, but it needs to be reinforced with a lead covering under exceptional conditions, such as are found near the tops of smokestacks. (See E-164.02 (5).)

5. Aluminum. Where aluminum is used, care should be taken not to use it in contact with the ground or elsewhere where it will rapidly deteriorate, and precautions should be observed at connections with dissimilar metals. Cable conductors shall be of electrical conductor grade aluminum.

(2) Form and Size.

(a) The following sub-sections give minimum sizes and weights for main and branch conductors. Conductors used for bonding and inter-connecting metallic bodies to the main cable, and which will not normally be required to carry the

main lightning current, may be reduced in size.

(b) Conductors for inter-connection to domestic water systems, steam or hot water heating systems, or other metallic masses having a low resistance to ground shall be full size, since in the event of a direct stroke the major portion of the discharge current may flow to ground over such a system.

1. Copper Cable. Copper cable conductors shall weigh not less than 187.5 lb. per M ft. The size of any wire of a cable shall be not less than No. 17 AWG (0.045 inch).

2. Copper Tube, Copper Solid Section and Copper-Clad Steel. Tube, or solid section conductors of copper or copper-clad steel shall weigh not less than 187.5 lb. per M ft. The thickness of any tube wall shall be not less than No. 20 AWG (0.032 inch). The thickness of any copper ribbon or strip shall be not less than No. 16 AWG (0.051 inch).

3. Galvanized-Steel. Galvanized-steel conductors shall have a net weight of steel of not less than 320 lb. per M ft. and a zinc coating of not less than 2 ounces per square foot of galvanized surface. The thickness of any tube wall, web or ribbon before galvanizing shall be not less than No. 17, U. S. Standard Sheet Gage (0.056 inch) and the diameter of any wire of a cable before galvanizing shall be not less than No. 14 Steel Wire Gage (0.080 inch).

4. Aluminum.

a. Aluminum cable conductors shall weigh not less than 95 pounds per thousand feet and the size of any wire of the cable shall be not less than No. 14 AWG (0.064 inch). Aluminum conductors for bonding and interconnecting metallic bodies to the main cable shall be at least the equivalent in strength and cross-sectional area of a No. 4 AWG (0.204 inch) aluminum wire. Aluminum strip conductors for interconnecting metallic bodies to the main conductor cable, if void of perforations, shall be not less than No. 14 AWG (0.064 inch) in thickness and at least $\frac{1}{2}$ inch wide. If perforated, the strip shall be as much wider as the diameter of the perforations. Aluminum strip for connecting exposed water pipes shall be

not less than No. 12 AWG (0.080 inch) in thickness and at least 1½ inch wide.

b. Aluminum connectors shall be not less than No. 12 AWG (0.080 inch) in thickness and of the same design and dimensions required for stamped copper connectors.

c. Aluminum tubular points shall be not less than 5/8 inch O. D., No. 16 AWG (0.050 inch) wall thickness and of the same lengths as required for copper points. Solid aluminum points shall be not less than ½ inch in diameter and of the same lengths as required for copper points.

d. Aluminum air terminal supports (for points and elevation rods), when stamped, shall be not less than No. 14 AWG (0.064 inch) in thickness and of the same design and dimensions required for copper supports.

e. Cast aluminum parts (fasteners, clamps, connectors, fixtures, etc.), shall be of the same designs and dimensions required for copper alloy fittings and equivalent in strength and conductivity.

f. Copper, copper-covered and copper alloy fixtures and fittings shall not be used for the installation of aluminum lighting protection systems. Aluminum, galvanized iron or aluminum alloy fixtures and fittings are the only types permitted, except for ground connections as provided in the next paragraph.

Note: The use of aluminum materials for direct grounding of aluminum systems of lightning protection is not acceptable and they should never be buried in earth. Galvanized iron ground rods, leads and clamps are satisfactory for grounding aluminum systems. Copper or copper-covered ground rods and leads may be employed, provided the clamps for connecting the aluminum down conductors to the copper or copper-covered grounding equipment are types specially designed for making the connection between the two dissimilar metals. The connection of the aluminum down conductors to the grounding equipment shall be made at a point not less than one foot above ground line. Protecting the connection from mechanical injury and displacement by the use of suitable guards is required.

(3) Joints.

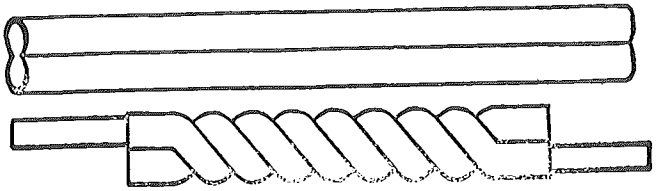
(a) General. Joints in conductors shall be as few in number as practicable and where they are necessary they shall be mechanically strong and well made and provide ample electrical contact. The latter requirement is to be regarded as met by a contact area not less than double the conducting cross-sectional area of the conductor.

Note: The following suggestions are offered in regard to the construction of joints in conductors.

1. Sections of cable conductor are preferably connected together by unravelling 6 inches or more of the ends and making a solderless wrapped joint. An alternative is found in couplings of malleable metal No. 14 AWG (0.064 inch) in thickness, three inches in length, and of semi-tubular form with projections on the interior which, when the coupling is crimped, become embedded in the cable.

2. Sections of tube conductor may be connected together by dowel-type screw joints with the dowels secured to the tube by rivets or by screw sleeve couplings.

3. Lengths of circular cross-section conductor may be connected together by the Western Union Joint with or without solder, McIntire Sleeves, or by screw couplings. Lengths of rectangular cross-section conductors (ribbon) may be connected together by overlapping and riveting.



McIntire Sleeve Joint
Above: Sleeve. Below: Completed Joint

4. Lengths of star-section conductor may be connected together by means of screw joints formed from lugs of metal crimped over or formed on the end of the conductor.

5. Branch conductors are best connected to main conductors by joints similar to those used in main conductors, except that they may be in T or Y form.

6. Elevation rods are best attached to cables by means of crimped joints of malleable metal, similar to those described in the first paragraph of this note, except that they should be in Tee form, and connect to the elevation rod by means of a dowel or screw coupling.

7. Elevation rods on forms of conductor other than cable may be attached in the same manner as branch rods, or by an equivalent means.

(b) Mechanical Strength. On structures exceeding 60 feet in height, joints shall be so constructed that their mechanical strength in tension as shown by laboratory tests is not less than 50 per cent of that of the smallest of the several sections of conductor which are joined together.

(c) Electrical Resistance. Joints shall be so made that they have an electrical resistance not in excess of that of two feet of conductor.

(4) Fasteners.

(a) Conductors shall be securely attached to the building or other object upon which they are placed. Fasteners in general shall be substantial in construction, not subject to breakage and shall be, with the nails, screws, or other means by which they are fixed, of the same material as the conductor, or of such nature that there will be no serious tendency towards electrolytic corrosion in the presence of moisture because of contact between the different parts.

(b) Fasteners shall be so spaced as to give adequate support to the conductor, generally not over four feet apart.

Note 1. The firmness with which conductors are attached goes far toward determining their period of usefulness and security. Insecure facteners

not only lead to a reduction of the protective values of an installation but detract from its appearance and necessitate repeated repairs.

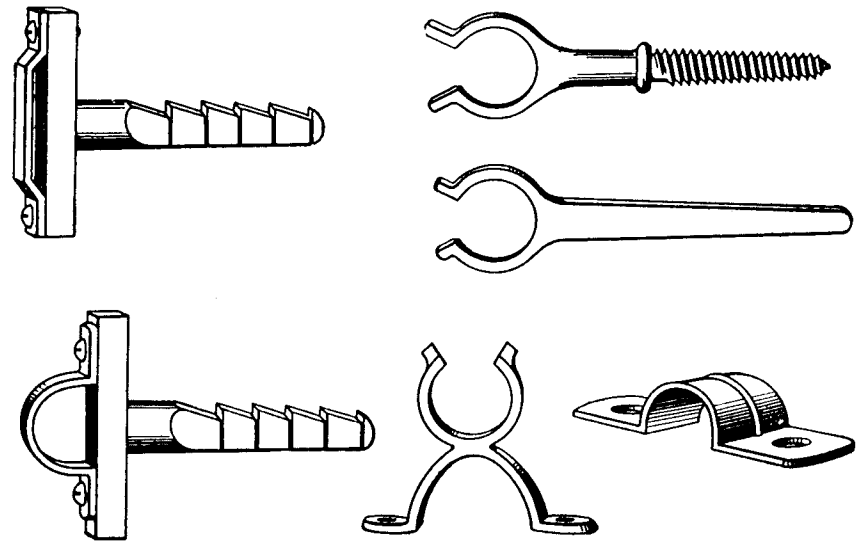
Note 2. Conductors may be secured to wood surfaces by means of metal bands or straps, screw-shank fasteners, or an equivalent means. Strap or band fasteners should be made, if of copper, from sheet metal not less than No. 20 AWG (0.032 inch) in thickness and not less than 3/8 inch wide; or if of aluminum, from sheet metal not less than No. 16 AWG (0.050 inch) in thickness and not less than $\frac{1}{2}$ inch wide; with screw or nail holes surrounded by an ample width of material. Screw-shank fasteners should be provided with a fork of substantial construction which can be closed by bending. The screw-shank itself should be at least the equivalent in size of a No. 10 wood screw 1.5 inches long.

Note 3. Conductors may be secured to brick and stone surfaces by means of screw-shank fasteners in the form of an expansion screw, by drive-shank fasteners having the shank ridged or barbed to grip the hole when driven, or by fan-shank fasteners to be laid in the walls as they are built.

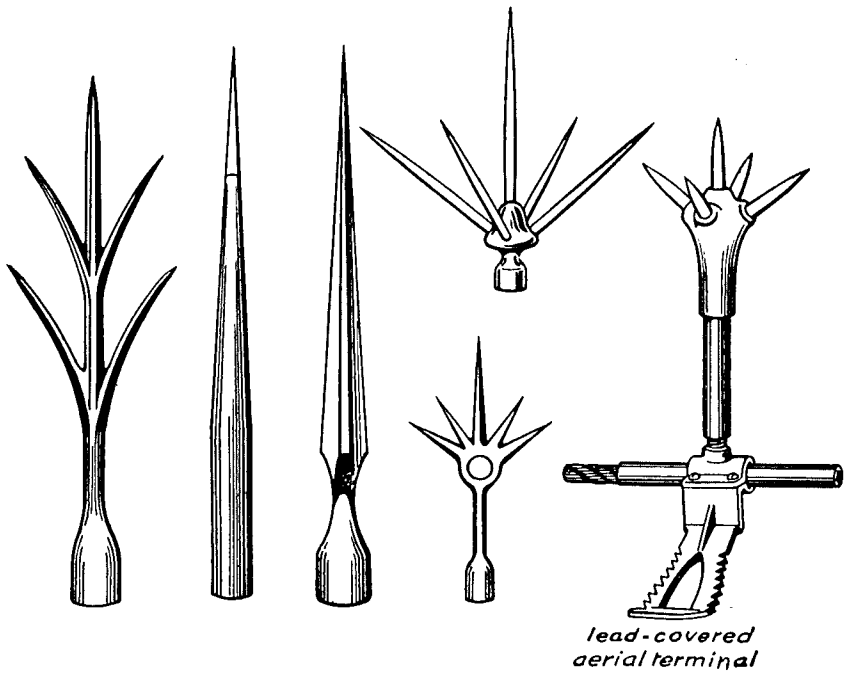
Note 4. Either the expansion screw or drive-shank should be not less than 3/8 inch in diameter and 2 inches in length, or of a type that will withstand a pull of at least 100 pounds. The fan-shank should be approximately $\frac{1}{2}$ inch wide at its narrowest place, 1/10 inch thick and 3 inches long.

Note 5. Where screws are used they should be not smaller than No. 6, 3/4 inch long. Nails should be not smaller in size than 4d standard. Copper-clad nails may be used with copper fasteners and galvanized nails with galvanized fasteners.

Note 6. Fasteners may also be leaded into masonry or brick work.



Fasteners and Supports



Air Terminals

E-161.02. Points and Elevation Rods.

(1) Attachment of Points. Separate points are not required, but if used shall be of substantial construction and be securely attached to the elevation rods by screw or slip joints. The conducting cross-sectional area of the base shall be at least equivalent to the conducting cross-sectional area of the elevation rod.

(2) Elevation Rods.

(a) Size. Elevation rods shall be at least the equivalent in weight and stiffness of a copper tube having an outside diameter of 5/8 inch and a wall thickness of No. 20 AWG (0.032 inch).

(b) Form. Elevation rods may be of any form of solid or tubular cross-section.

(c) Height. The height of an elevation rod shall be such as to bring the tip not less than ten inches above the object to be protected.

Note: On flat surfaces a greater height than ten inches is desirable but the height need not exceed five feet. In most cases the proper height for an elevation rod between the limits just mentioned will depend upon the character of the object to be protected. The proper height may also be taken as depending somewhat on the contour of the object being protected; a spire, for instance, does not require so high an elevation rod as a silo having a peaked but much less sloping roof.

(3) Braces for Elevation Rods.

(a) Use. Elevation rods shall be amply secured against overturning either by attachment to the object to be protected or by means of substantial tripod or other braces which shall be permanently and rigidly attached to the building.

(b) Materials. The material from which braces are constructed shall be at least the equivalent in strength and stiffness of one-fourth inch round

iron, and with the nails or screws used in erecting, shall comply with the requirements of "E-161.01(1) Materials)" as to resistance to corrosion or protection against corrosion.

(c) Form and Construction. Braces shall be assembled by means of riveted joints or other joints of equivalent strength. Preference should be given to tripod or 4-legged braces and when in place the feet should be spread until the distance between them approximates one-third the height of the brace.

(d) Guides. Where elevation rods are more than 24 inches high, braces shall have guides for holding the elevation rod at two points located approximately as follows: The lower at a distance above the foot of the rod equal to 1/3 of its height, the upper at a distance above the lower equal to 1/4 the height of the rod.

Note 1. Where elevation rods are 24 inches high or less, braces with a single guide may be used, holding the rod approximately midway of its height. Ten-inch elevation rods may be braced by means of substantial footings.

Note 2. Where elevation rods are to be attached to house chimneys they can be secured either by means of expansion screw fasteners or a band surrounding the chimney. On horizontal masonry or brick work, holes may be drilled and the rod set in cement. On woodwork lag-screws or strap fasteners may be used. Bracing in each case may be accomplished according to circumstances, but it is important that a good mechanical job be done to prevent overturning of the air terminal by the wind.

E-161.03. Prevention of Deterioration.

(1) General. Precaution shall be taken in every instance to provide against any undue tendency towards deterioration due to local conditions.

(2) Corrosion.

(a) Where any part of a protective system is exposed to the direct action of chimney gases or other corrosive gases , it shall be protected by a continuous covering of lead 1/16 inch or more in thickness.

(b) Aluminum parts, including fasteners and anchors, shall be protected from direct contact with concrete or mortar wherever such concrete or mortar is wet or damp, or may become intermittently wet or damp.

(3) Mechanical Injury. Where any part of a protective system is exposed to mechanical injury it shall be protected by covering it with molding or tubing preferably made of wood or non-magnetic material. If metal tubing is used the conductor shall be electrically connected to it at its upper end.

(4) Use of Ornaments. The use of small ornaments such as glass balls attached to elevation rods is not objectionable but elevation rods shall not be made to support vanes or ornaments having in any plane a wind-resistance area in excess of 20 square inches.

Note: Twenty square inches of area as a maximum for an ornament represents approximately the wind resistance area of a 5-inch glass ball. Where heavy or large ornaments are desired they should be provided with a separate support.

E-161.04. Air Terminals and Conductors.

(1) General. Air terminals shall be provided for all structural parts that are likely to receive, and be damaged by, a stroke of lightning.

(2) Projections. In the case of projections such as gables, chimneys, and ventilators, the air terminal shall be placed on, or attached to, the object to be protected where practicable, otherwise within two feet of it.

(3) Ridges, Parapets, and Edges of Flat Roofs. Along ridges, parapets, and edges of flat roofs, air terminals shall be spaced at intervals not exceeding 25 feet.

(4) Metal Projections and Parts of Buildings. Metal projections and parts of buildings such as ventilators, smokestacks, and other objects, that are likely to receive, but not be appreciably damaged by, a stroke of lightning, need not be provided with air terminals, but shall be securely bonded to the lightning conductor with metal of the same weight per unit length as the main conductor.

Note 1. Parts of structures most likely to be struck by lightning are those which project above surrounding parts such as chimneys, ventilators, flagpoles, towers, water-tanks, spires, steeples, deck-railings, shaft-houses, gables, skylights, dormers, ridges and parapets.

Note 2. The edge of the roof is the part most likely to be struck on flat-roofed buildings. On large flat and gently sloping roofs it is desirable to erect air terminals at points of intersection of lines dividing the surface into rectangles not exceeding 50 feet in length.

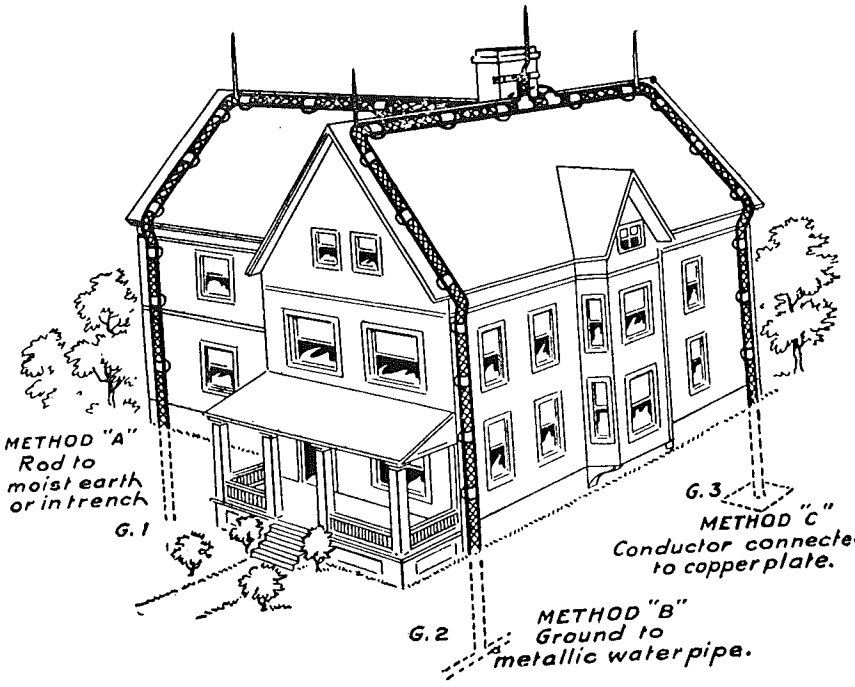
Note 3. In parts of some buildings relatively thin layers of brick, stone, tile or similar masonry material have been laid on top of structural steel. Lightning then has to break through the brick, stone, etc., to reach the steel, and this may result in fragments of brick, stone, etc., being thrown down into the street. Such construction should be avoided, but where already existing, the situation may be improved by covering the masonry with a metallic sheathing, which in turn is connected to the lightning protective system.

(5) Coursing of Conductors. Conductors shall in general be coursed over the roofs and down the corners and sides of buildings in such a way as to constitute as nearly as local conditions will permit, an enclosing network.

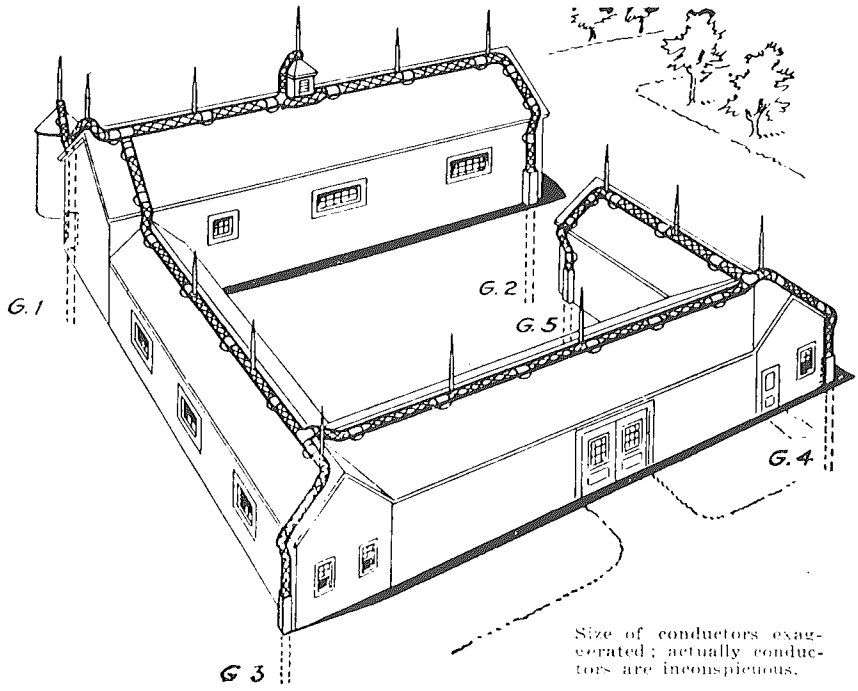
(6) Roof Conductors.

(a) Roof conductors shall be coursed along contours, such as ridges, parapets and edges of flat roofs, and where necessary over flat surfaces, in such a way as to join each air terminal to all the rest.

(b) Roof conductors surrounding decks, flat surfaces, and flat roofs, shall be connected to form a closed loop.



Typical Installation on Large Dwelling
(Size of Conductors exaggerated in the drawing)



Typical Installation on Barn Group

(7) Down Conductors. Down conductors shall preferably be coursed over the extreme outer portions of buildings, such as corners, due consideration being given to the best places for making ground connections, and to the location of air terminals.

(8) Obstructions. Horizontal conductors shall be coursed around chimneys, ventilators, and similar obstructions in a horizontal plane and without abrupt turns.

(9) Bends. No bend in a conductor which embraces a portion of a building such as an eave, shall have a radius of less than 8 inches. The angle of any turn shall not exceed 90° and conductors shall everywhere preserve a downward or approximately horizontal course.

E-161.05. Metal-roofed and Metal-clad Buildings.

The materials and equipment required by this rule for the protection of metal-roofed or metal-roofed and clad buildings, shall comply with the requirements of E-161.01 to E-161.04, inclusive.

(1) Metal not Continuous. Buildings which are roofed, or roofed and clad, with metal in the form of sections insulated from one another, or so applied that they are not in electrical contact, shall be treated in the same manner as are buildings composed of non-conducting materials.

(2) Metal Continuous.

When buildings are roofed or roofed-and-clad, with all-metal sheets made electrically continuous by means of an interlocking or other contact acceptable to the administrative authority, or by bonding, the following modifications may be made to the requirements of E-161.02 to E-161.08, inclusive.

(a) Air terminals need be provided only on chimneys, ventilators, gables, and other projections, such as are likely to receive and be damaged by a stroke of lightning. Projections that are likely to receive, but not be damaged by a stroke of lightning need not be provided with air terminals, but shall be

securely bonded to the roof.

(b) Roof conductors may be dispensed with, and elevation rods, if used connected to the roof by soldered joints, or securely bolted joints, having an area of contact of not less than 3 square inches. If the roof metal is in small sections connection shall be made to at least four of the sections.

(c) Down conductors shall be connected to the edges of roofs, or to the lower edges of metal siding, by soldered or bolted joints having an area of contact of at least three square inches. If the metal is in small sections, connection shall be made to at least four of the sections.

(d) The roof metal should have adequate thickness (See E-171.02) to prevent a hole being burned in the metal in case of a direct stroke to the roof, which could cause a fire if flammable material were stored below.

(3) Metal Roof Not Electrically Continuous with Metal Siding. The siding shall be connected to the roof at each corner, and down conductors shall be connected to the lower part of metal siding, in the manner specified in (2) above, with a connection between roof and siding directly above the down conductor in every case, and the down conductor grounded as specified in E-161.08.

E-161.06. Number of Down Conductors.

(1) Minimum. There shall be not less than two down conductors on any type of buildings, and these shall be run so as to be as widely separated as practicable. The following rules shall apply as to additional down conductors.

Note: In deciding upon the location and number of down conductors it should be kept in mind that it is very desirable to have at least two paths in parallel, and well separated, from the foot or near the foot of each air terminal to ground. This causes a stroke upon any air terminal to find a divided path the impedance of which is less than that offered by a single path and affords increased protection. The obstruction, or impedance, offered to the passage of the stroke is nearly in inverse proportion to the number of parallel paths if they are well separated.

(2) Rectangular Structures.

(a) On rectangular structures having gable, hip, or gambrel roofs, and exceeding 110 feet in length, there shall be at least one additional down conductor for each additional 50 feet of length, or fraction thereof.

(b) On rectangular structures having French, flat, or sawtooth roofs, and exceeding three hundred feet in perimeter, there shall be at least one additional down conductor for each additional 100 feet of perimeter or fraction thereof.

(3) Irregular-shaped Structures.

(a) On an ell or T-shaped structure there shall be at least one additional down conductor; on an H-shaped structure at least two additional down conductors; and on a wing-built structure at least one additional down conductor for each wing.

(b) On irregular-shaped structures the total number of down conductors shall in every case be sufficient to make the average distance between them along the perimeter not greater than 100 feet.

(4) Structures Exceeding 60 Feet in Height. On structures exceeding 60 feet in height there shall be at least one additional down conductor for each additional 60 feet of height, or fraction thereof, except that the application of this rule shall not cause down conductors to be placed about the perimeter of a structure at intervals of less than 50 feet.

(5) Metal-roofed and Metal-clad Buildings. The number of down conductors and ground connections for metal-roofed and metal-clad buildings shall be determined in the same manner as for buildings composed of non-conducting materials, i.e. according to the requirements of (1), (2), (3) and (4) above.

(6) Dead Ends. Additional down conductors shall be installed where necessary to avoid "dead ends", or branch conductors ending at air terminals, which exceed 16 feet in length, except that single down conductors descending flagpoles, spires, and similar structures which are adjuncts of buildings shall not be regarded as

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(5) Metal-roofed and Metal-clad Buildings. The number of down conductors and ground connections for metal-roofed and metal-clad buildings shall be determined in the same manner as for buildings composed of non-conducting materials, i.e. according to the requirements of (1), (2), (3) and (4) above.

(6) Dead Ends. Additional down conductors shall be installed where necessary to avoid "dead ends", or branch conductors ending at air terminals, which exceed 16 feet in length, except that single down conductors descending flagpoles, spires, and similar structures which are adjuncts of buildings shall not be regarded as

"dead ends" but shall be treated as air terminals.

Note 1. Dead ends arise where an air terminal is placed on the peak of a dormer, or in some similar situation, and in the interest of economy is connected only to the nearest conductor, which usually is at the nearest ridge. A stroke on such an air terminal must traverse a single conductor until it reaches the ridge conductor where the path divides. The foregoing rule allows 16 feet for the length of this single conductor. Where greater lengths are encountered the conductor must be extended from the air terminal to ground.

Note 2. It is advisable to install additional down conductors at places along runs of roof conductors where the roof conductor descends into low places between parts of buildings as it may in the case of an H-shaped structure where the end wings are higher than the connecting portion.

E-161.07. Interconnection of Metallic Masses.

(1) Interconnection or Grounding. Metallic masses about buildings which are a permanent portion of the structure, or are permanently installed within or about it, shall, with the exception of those of comparatively small size, be made a part of the lightning-conductor system by interconnection with it, or be independently grounded, or both, depending upon their location with respect to the lightning conductors and their surroundings as more fully described in paragraphs (2) to (8) inclusive of this rule.

Note: The object of interconnecting the metal parts of a building with the conductor is to prevent the damage from side flashes that has been found to occur, especially in the case of rather extensive metal objects that are nearby. The main principle to be observed in the prevention of such damage is to pick out on a building the places where side flashes are most likely to occur and provide metallic paths for them.

(2) Exterior Bodies of Metal. Metal situated wholly on the exterior of buildings shall be electrically connected to the conductor at its upper (or nearest) end, and if of considerable length, shall be grounded or electrically connect-

ed to the conductor at its lower (or farthest) end.

Note: Exterior bodies of metal include ornamental ridges, ventilators, roofs, valleys, gutters, down spouts, and structural iron. Connecting these into the lightning conductor system not only serves to prevent side flashes that cause damage, but makes the system a nearer approach to an enclosing network.

(3) Interior Bodies of Metal. Metal situated wholly in the interior of buildings which at any point comes within 6 feet of a lightning conductor, or metal connected thereto, shall be electrically interconnected with it, and if of considerable size or length shall be grounded at its lower or farther extremity within the building.

Note: Interior bodies of metal include radiators, piping systems, tanks, stationary machinery, stanchions, and various forms of structural metal. In general, experience has shown that side flashes are not likely to occur to bodies of metal of ordinary size located more than 6 feet from a conductor, whereas those that are nearer are likely to receive side flashes which may damage a building or set fire to it. Very long or very large bodies of metal may, however, be a menace at more than 6 feet. The side flashing to these nearby bodies is eliminated by interconnection but the rise of potential due to dynamic discharge is not, so interior grounding becomes necessary. Unless there are water pipes or their equivalent that may be used for interior grounding purposes there may be danger to persons and livestock about dwelling houses and barns. On this account where water pipes are not available it is advisable to avoid as far as practicable the necessity for interconnection of interior bodies of metal by keeping conductors more than 6 feet away from them - the farther the better.

(4) Metal Bodies Projecting Through Sides and Roofs.

(a) Metal which projects through roofs, or through sides of buildings above the second floor, shall be bonded to the nearest conductor at the point where it emerges from the building and be grounded at its lower or extreme end

within the building.

(b) Metal which projects through the sides of buildings below the second floor shall be treated as though it were wholly within the building.

Note: Metal projections through roofs and sides of buildings generally consist of soil pipes, metal flues, over-flow pipes of hot-water heating systems and isolated gravity-type water systems, hayfork tracks and ventilators. Hayfork tracks may be taken care of by connecting both ends to the conductor.

(5) Interconnection of Metals on or Within Metal-Roofed and Metal-Clad Buildings.

(a) All parts of metal roofs, or roofs and sides, shall be securely bonded together.

(b) All interior metal parts or contents of considerable size or extent that are a permanent portion of a structure or are permanently installed within it, shall be independently grounded, and if within 6 feet of sides or roof or a down conductor shall be connected thereto.

Note: The necessity for interconnecting and grounding the metal contents of metal-roofed and metal-clad buildings arises from the fact that in the event of a discharge the potential of the metal covering, even though grounded, changes sufficiently with respect to nearby objects to cause side flashes, especially where the distance to be covered by the flash is short. Side flashes from the metal coverings of buildings are likely to be especially destructive or dangerous because of the large electrostatic capacity involved. The chances for such side flashes should be particularly considered in all buildings housing dusty operations, as flour mills. Care should be taken to ground ventilators projecting downward from roofs.

(6) Metallic Bodies to be Independently Grounded. Metallic bodies having any dimension exceeding five feet, and situated wholly within buildings, and which do not at any point come within 6 feet of a lightning conductor or metal connected

thereto shall be independently grounded.

Note: It is generally safest to ground all metal within buildings that does not come close enough to a conductor to require interconnection with it, using an independent ground connection of any of the usual types, for the reason that it prevents sparks from accumulated static charges and from induction due to dynamic discharges.

(7) Substitution for Regular Conductors. Extended metal parts of buildings shall not be substituted for regular conductors, except where they are permanently electrically continuous, and have a conducting cross-sectional area at least double that of the lightning conductor that would otherwise be used.

Note: In some cases of monumental structures and others where heavy and extensive metal parts are available they may well be used in place of conductors to avoid expense and sacrifice of appearance, there being no difference whether they are on the interior or exterior of the structure where used for down conductors.

(8) Size of Interconnecting and Bonding Wires. For bonding, interconnecting and independent grounding of metallic masses the conductor used shall be at least the equivalent in strength and conducting cross-sectional area of a No. 6 AWG copper wire, except where full-size lightning conductor is required by E-161.04(4).

E-161.08. Ground Connections.

(1) Number. A ground connection shall be provided for each down conductor, preference being given to metal water pipes and other large underground metallic structures.

(2) Distribution. Ground connections (and down conductors) shall be placed at as uniform intervals about a building as practicable, and grouping of ground connections on one side of a building avoided.

(3) Moisture. In making ground connections advantage should be taken of all permanently moist places where practicable, although such places should be avoided if wet with waste water which contains chemical substances especially corrosive to

the metal with which the ground connection is made.

Note: Chemical substances especially corrosive to lightning conductor material are not ordinarily encountered in practice. They would usually be found about factories engaged in chemical processes.

(4) Permanency. Ground connections shall in every case be thoroughly and permanently made, with due regard to the character of the surrounding soil.

(5) Waterpipe Grounds. Where a metallic waterpipe enters a building at least one down conductor shall be connected to it, preferably at a point immediately outside of the foundation wall, by means of a substantial clamp to which the conductor can be attached by bolts or solder.

(6) Grounding Electrodes in Deep Soil. Where the soil is moist clay, or other soil of similar character as to electrical resistivity, artificial grounding electrodes may be made by extending the rod itself into the ground a distance of not less than 10 feet. Where the soil is largely sand, gravel, or stones, more extensive artificial grounding electrodes shall be made by adding metal in the form of driven rods or pipes, or strips, plates, or lengths of conductor buried in trenches as in (7). Where a grounding electrode consists of a driven rod or pipe, the length of the electrode shall be permanently marked upon it at the top.

(7) Grounding Electrodes in Shallow Soil. Where bed rock is near the surface, ground connections may be made by digging trenches radially from the building and burying in them the lowest ends of the down conductors or their equivalent in the form of metal strips or wires. Where the soil is very dry or will not permit digging to a depth of more than one foot, in addition to the conductors laid radially, a similar conductor shall be buried which encircles the structure to be protected and connects all of the down conductors together.

(8) Trenches. Trenches shall be long enough to accommodate 12 feet of conductor when laid straight, but need not be more than 3 feet in depth.

Note 1. Properly made ground connections are essential to the effective

functioning of a lightning-conductor system and every effort should be made to provide ample contact with the earth. This does not necessarily mean that the resistance of the ground connection must be low, but rather that the distribution of metal in the earth or upon its surface in extreme cases, shall be such as to permit the dissipation of a stroke of lightning without damage.

Note 2. Low resistance is, of course, desirable, but not essential, as may be shown by the extreme case on the one hand of a building resting on moist clay soil, and on the other by a building resting on bare solid rock. In the first case if the soil is of normal resistivity or from 200 to 5000 ohm-centimeters, the resistance of a ground connection made by extending the conductor 10 feet into the ground will be from 20 to 50 ohms, and two such ground connections on a small rectangular building have been found by experience to be sufficient. Under these favorable conditions providing adequate means for collecting and dissipating the energy of a flash without serious chance of damage is a simple and comparatively inexpensive matter.

Note 3. In the second case it would be impossible to make a ground connection in the ordinary sense of the term because most kinds of rock are insulating, or at least of high resistivity, and in order to obtain the effect of grounding other and more elaborate means are necessary. The most effective means would be an extensive wire network laid on the surface of the rock surrounding the building, after the manner of counterpoise to a radio antenna, to which the down conductors, could be connected. The resistance to earth at some distant point of such an arrangement would be high but at the same time the potential distribution about the building would be substantially the same as though it were resting on conducting soil and the resulting protective effect also substantially the same.

Note 4. In general, the extent of the grounding arrangements will depend upon the character of the soil, ranging from simple extension of the conductor into the ground where the soil is deep and of high conductivity, to an elaborate buried net-

work where the soil is very dry or of very poor conductivity. Where a network is required it should be buried if there is soil enough to permit it, as this adds to its effectiveness. Its extent will be determined largely by the judgment of the person planning the installation with due regard to the minimum requirements of this rule, which is intended to cover the ordinary run of cases that are likely to be encountered in practice, keeping in mind that as a rule the more extensive the underground metal available the more effective the protection.

Note 5. Some essential features of good practice in grounding for protection against lightning are as follows:

1. Where practicable each artificial ground connection should extend or have a branch which extends below and at least two feet away from the foundation walls of the building, as otherwise there is a chance of the wall being damaged.

2. The metal composing the ground connection should make contact with the soil from the surface downwards, for if contact is made below the surface there may be flashing at the surface with danger of burning off the conductor.

3. During a stroke of lightning on a system of conductors the grounding electrodes are to be thought of as the points through which the heavy current flows between the air terminals and the surface of the earth about the building and should, therefore, be distributed with the view of carrying this flow of current in the most advantageous manner. This will be generally realized by placing them at the outer extremities, such as the corners, and avoiding as far as possible the necessity for current flow under the building.

E-161.09. Radio Installations and Wires Entering Buildings.

(1) Wires Entering Buildings. Wires entering buildings shall conform to requirements of the latest edition of the Wisconsin State Electrical Code which are applicable.

(2) Metal Radio Masts on Buildings. Metal radio masts on buildings shall be bonded to the nearest lightning conductor.

(3) Wooden Radio Masts. Wooden radio masts which extend more than 6 feet above the ridge or highest parts of the building on which they are placed shall be treated in the same manner as flag poles.

E-161.10. Concealed Installations.

(1) Full Conductor Systems.

(a) The same requirements as for exposed systems apply to concealed systems. Conductors are coursed the same except that they may be under the roofing material, under the roof, behind the exterior wall facing or between the studs of walls.

(b) Groundingsmay be carried to the exterior at or below grade level and then made in the conventional manner according to soil conditions encountered. Groundings may also be placed in the basement below the basement slab but on outside walls only. Such groundings below basement slabs should be avoided at interior locations in the structure due to the fact that the soil in such locations will usually be dry.

(c) Chimney points and chimney conductors may be built into the masonry of the chimney or may be attached to the exterior of the chimney and then carried through the roof to the interior main conductor.

(d) Approved fittings and flashings shall be employed in making all through roof and through wall connections. Particular care should be employed on concealed installations to insure common grounding of all extended metallic parts such as the electric system, water system, furnace pipes or ducts, gas pipes, soil pipes, metal lathing, foil insulation, etc.

(2) Structural Steel Systems.

(a) The structural steel framework of a building may be utilized as the main conductor of a lightning protection system provided it is electrically continuous or is made electrically continuous by bonding of non-electrically continuous sections. The electrical continuity may be measured by a comparison of ohms

resistance to ground at ground level and at the top and other elevations of the structure. Electrically continuous reinforcing rods may also be considered as structural steel.

(b) Air terminals may be individually bonded to the framework through the roof or parapets or they may be joined together with an exterior conductor which shall be bonded to the framework in not less than the same number of places as there are groundings for the structure.

(c) Groundings shall be made from approximately every other steel column, around the perimeter, and in no case shall they average more than 60 feet apart.

(d) All bondings of air terminals, connecting conductors, and grounding tails shall be made to the steel with bonding plates having a surface contact of not less than 8 square inches. They shall be bolted, welded, brazed or securely clamped to a cleaned section of the steel.

(e) If the grounding locations are dry, such as in sand, gravel, or rock, a counterpoise, interconnected with each of the individual ground terminals shall be installed.

CHAPTER E-162

MISCELLANEOUS STRUCTURES

E-162.01. Spires, Steeples, and Flag Poles.

(1) General. The materials, equipment and ground connections required by the rules of this Chapter for the protection of spires, steeples, and flag poles, shall comply with the requirements of Chapter E-161.

(2) Air Terminals. A single air terminal may be used, which elevates the tip a distance of not less than 10 inches above the uppermost point of the structure.

(3) Down Conductors. A single down conductor may be used, which, if the structure is isolated, shall be extended directly to a ground connection. If the structure is an adjunct of a building and near or touching the perimeter, the down conductor shall be extended directly to a ground connection, but shall also be connected to the lightning-conductor system on the building. If it is set well within the perimeter the descending conductor shall be connected to the nearest roof conductor.

(4) Interconnection of Metals. Bells, clocks, structural iron, and other metallic masses shall be connected to the down conductor. If the length of a metallic body is comparable to the height of the structure, connection shall be made at the upper and lower extremities; otherwise connection may be made at the nearest point.

(5) Grounding of Metallic Spires and Flag Poles. Spires and flag poles composed entirely of or covered entirely with metal and resting on foundations of non-conducting material with the top so constructed as to receive a stroke of lightning without appreciable damage, need not be provided with air terminals or down conductors, but shall be grounded or connected to the nearest lightning conductor, or both, according as the structure is isolated, set within the perimeter of a building or near it, respectively.

Note: On spires and steeples exceeding 100 feet in height it is advisable to use more massive conductors and fastenings than on ordinary types of buildings in order to resist the extradordinary conditions found on tall structures.

E-162.02. Water Towers, Silos, and Similar Structures.

(1) General. The materials, equipment, and ground connections required by the rules of this chapter for the protection of water towers, silos, and similar structures, shall comply with the requirements of Chapter E-161.

Note: On structures exceeding 100 feet in height it is advisable to use more massive conductors and fastenings than on ordinary buildings in order to resist the extraordinary conditions found on tall structures, especially with regard to temperature effects and loading which may lead to alternate expansion and contraction.

(2) Air Terminals. The number and location of air terminals shall in general comply with the requirements of E-161.04, except that on silos and other towers having roofs ending in a peak a single air terminal may be regarded as sufficient.

(3) Conductors. Where more than one air terminal is used they shall be connected together by a conductor which forms a closed loop about the structure near the top, or passes over it, as the contour of the roof may require. From this, or from the single air terminal if but one is used, at least two down conductors shall be extended directly to ground connections on opposite sides, if the structure is isolated. If it is an adjunct of a building, near or touching the perimeter, one down conductor shall be extended directly to a ground connection while the other may be connected to the lightning conductor system on the building. If it is set well within the perimeter both down conductors may be connected to the lightning-conductor system on the building. If the height of the structure exceeds 100 feet the down conductors should be cross-connected midway between top and bottom.

(4) Interconnection of Metals. All metallic bodies of considerable size or extent, whether exterior or interior, shall be connected to the down conductors.

If their length is comparable to the height of the structure they shall be connected to the down conductors at both ends; otherwise connection may be made at the nearest point.

Note: Metal objects about towers which are comparable in length with the height of the structure, consist usually of stairways, elevator guides, and drain pipes carrying water from the roof.

(5) Grounding of Metal Towers and Water Tanks. Towers and tanks composed entirely of or covered entirely with metal and resting on foundations of non-conducting material, with the uppermost portion so constructed as to receive a stroke of lightning without appreciable damage, shall be grounded by means of two earth terminals on opposite sides of the structure.

E-162.03. Grain Elevators.

(1) General. The rules contained in Chapter E-161, except as modified by E-162.03(2) and E-162.03(3), shall apply to grain elevators, and to other structures in which combustible dusts may be produced in quantities sufficient to form explosive or ignitable mixtures with air or in which such dusts may accumulate on ledges or other surfaces in quantities sufficient to sustain smouldering fire.

(2) Conductors. Roof conductors and down conductors shall be of copper or aluminum cable conforming to E-161.01.

Note: Due to the physical deformation of such structures through cycles of loading and unloading, it is necessary that conductors have sufficient flexibility to guard against breakage.

(3) Interconnection of Metallic Masses. Interconnection of metallic masses shall conform to E-161.07, except that all interior metallic masses having any dimension greater than 5 feet, and all metallic masses except those of comparatively small size, which are within 6 feet of grounded metallic masses including lightning conductors and metal connected thereto, shall be interconnected with each other and with the lightning conductors. Interconnected networks of interior

metallic masses shall have at least one interior ground connection in addition to the lightning conductor grounds.

CHAPTER E-163

BUILDINGS CONTAINING BALED FLAMMABLE MATERIALS

It has been found that lightning flashes occurring in the immediate vicinity of cotton or other fibrous materials of a flammable nature baled with metal ties may cause secondary discharges between the ties of sufficient intensity to cause ignition. To prevent fires of this type a greater degree of shielding is required than is afforded by the ordinary system of lightning rods. The required condition is inherent or readily realized in all-metal or metal-covered buildings, but in the case of other types made of non-conducting materials the nearest practicable approach to the necessary degree of shielding is found in a grounded network of sufficiently small mesh covering the roof. It has been found experimentally that the shielding effect of a network of given mesh increases with the height above the shielded object, also that the shielding effect decreases as the size of the mesh is increased. A mesh of 6 feet is a fair mean value if placed on or a few feet above the roof .

E-163.01. Methods and Materials.

The materials, equipment and ground connections required by the rules of this chapter shall comply with the requirements of Chapters E-161 and E-162.

E-163.02. Metal-Roofed and Metal-Clad Buildings.

Metal-roofed and metal-clad buildings shall be treated in the same manner as required in Chapter E-161, rule E-161.05.

E-163.03. Buildings of Non-Conducting Materials.

The effect of an electrostatic shield may be obtained by constructing on or above the roof a network of wires or cables and grounding it about the perimeter at the same intervals as required for metal-roofed buildings.

CHAPTER E-164

SMOKESTACKS AND CHIMNEYS

E-164.01. Metal Smokestacks.

(1) Metal smokestacks need no protection against lightning other than that afforded by their construction, except that they shall be properly grounded. If the construction of the foundation is not such as to provide ample electrical connection with the earth, ground connections shall be provided similar to those required for stacks made of materials other than metal as provided in E-164.02(7).

(2) Metal guy wires and cables shall be grounded at their lower ends.

Note: Metal guy wires or cables attached to steel anchor rods set in earth may be considered as sufficiently well grounded. Only those set in concrete or attached to buildings or non-conducting supports need attention.

E-164.02. Brick, Hollow-Tile, and Concrete Stacks.

Where stacks of brick, hollow tile, concrete, or other material liable to damage by lightning are to be protected the following rules shall apply.

(1) Conductors.

(a) Conductors shall be of copper of the grade required for commercial electrical work, generally designated as having 98 per cent conductivity when annealed.

(b) The weight of the conductor shall be not less than 6 ounces per linear foot.

(c) The size of any wire in a cable shall be not less than No. 15 AWG (0.057 inch).

(d) The thickness of any tube wall shall be not less than No. 15 AWG (0.057 inch).

(e) The thickness of any web or ribbon shall be not less than No. 12 AWG (0.080 inch).

(2) Fasteners.

(a) Fasteners shall be of copper or copper alloy substantially as resistant to corrosion as the conductor itself, and must be strongly constructed.

Each fastener must have a sufficiently tight grip to support its corresponding length of conductor.

(b) Fasteners shall be spaced close enough to give ample support to the conductor, generally not over 4 feet apart.

(3) Air Terminals.

(a) Air terminals shall be strongly constructed of the same grade of material as the conductor, or may be made of stainless steel, monel metal, or other equally corrosion-resistant metal; and shall be uniformly distributed about the rim of the stack at intervals not exceeding 8 feet.

(b) The height above the rim shall be not less than 30 inches.

(c) They shall be secured to the top of the stack by means of expansion bolts or fan shank fasteners of substantial construction. The air terminals shall be electrically connected together by means of a metal ring or band which forms a closed loop about two feet below the top of the chimney. If there is a metal crown the air terminals should be connected thereto.

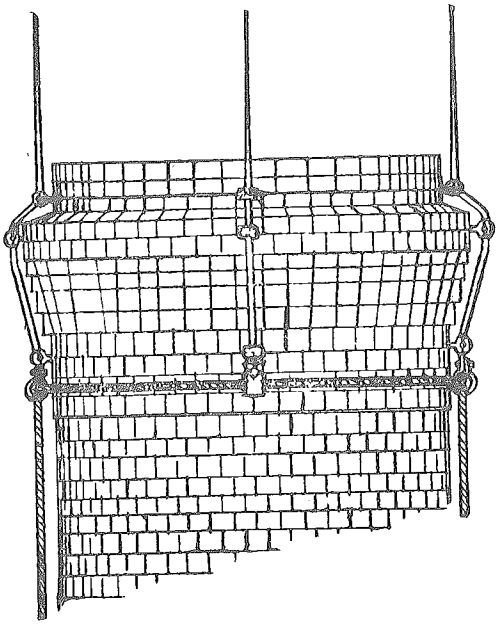
(4) Down Conductors.

(a) At least two down conductors shall be provided on opposite sides of the stack, leading from the ring or crown at the top to the ground.

(b) On stacks exceeding 160 feet in height the down conductors shall be cross-connected approximately midway between top and bottom. Where a metal ladder is continuous from the rim to the ground, and the vertical members have a combined cross-section not less than twice that specified in E-161.01 (2) (c), such members may be utilized as down conductors.

(5) Lead Covering. In order to prevent corrosion by gases, copper air terminals, conductors, and fasteners within 25 feet of the top of the stack shall have a continuous covering of lead at least 1/16 inch thick.

(6) Joints. Joints in conductors must be as few as practicable and of such construction as to show by laboratory tests a strength in tension of at least 50



Typical Arrangement at Top of Stack

per cent of that of the conductor.

(7) Ground Connections.

(a) Ground connections may be made in the manner prescribed for buildings (See E-161.08).

(b) If there is a water pipe nearby connection shall be made to it by means of a substantial clamp.

(8) Protection Against Machanical Injury.

(a) Down conductors near the ground shall be protected against mechanical injury by means of wood molding or other non-magnetic material.

(b) If metal tubing is used for protective purposes the down conductor shall be electrically connected to it at its upper end.

(9) Metal Linings. Where stacks have a metal lining extending part way up the lining shall be connected to the rod at its upper end and grounded at the bottom.

E-164.03. Reinforced-Concrete Stacks.

(1) Reinforcing Metal. Stacks consisting partly or entirely of reinforced concrete shall comply with the requirements of E-164.02, and in addition the reinforcing metal shall be electrically connected together and shall be electrically connected to the down conductors at the top and bottom of the concrete.

Note: In existing stacks whose reinforcement may not be electrically continuous, it is recommended that additional connections be made at points where the reinforcing rods are accessible.

(2) Joints. Joints between iron or steel and copper, within 25 feet of the chimney top shall be protected against corrosion by being coated with lead or imbedded in the concrete.

E-164.04. Vents Emitting Explosive Dusts, Vapors or Gases.

(1) Air terminals on capped or hooded vents emitting explosive dusts, vapors or gases should extend not less than five (5) feet above the opening.

(2) When explosive dusts, gases or vapors are emitted under forced draft

from open stacks, the air terminals should extend not less than fifteen (15) feet above the vent opening.

CHAPTER E-165

HANGARS, BALLOONS AND AIRSHIPS

E-165.01. Prevention of Damage to Hangars.

Where buildings housing aircraft are to be protected against lightning the following rules shall apply.

Note: Buildings for the housing of aircraft require special attention in regard to protection against lightning because of the hazardous nature of their contents, and in the case of buildings for housing rigid airships, because of their great height and area. Permanent structures are usually all-steel, steel over wood frames, or asbestos on either wood or steel. For the protection of all-steel structures it is considered sufficient to ground the framework (as indicated in paragraph (8) below), but for the protection of buildings of other forms of construction more extensive measures are necessary.

(1) Materials. Materials used for the purposes of this chapter shall comply with the requirements of E-161.01 (1) "Materials".

(2) Conductors. Conductors shall comply with the requirements of E-161.01 (2).

Note: It is recommended that where existing conditions are especially severe with respect to weather or other causes, as may be the case with very large buildings for the housing of air craft, more massive conductors be used than required by E-161.01 (2).

(3) Construction and Installation. The construction and installation of conductors where used shall comply with E-161.01 (3) and (4), E-161.02 and E-161.03.

(4) Structures with Steel Frames. Where protection is provided for buildings with steel frames, all parts of which are securely bonded together, the air terminals may be connected to the steel frame at the nearest point and other conductors between air terminals and ground omitted. Where such connection is made the

connecting conductor shall comply with the requirements of E-161.01 (2), as to weight, and shall be secured in electrical contact with the frame by means of bolts and nuts. The steel frame shall be grounded as provided in E-165.01 (8).

(5) Construction of Air Terminals. Air terminals shall be strongly constructed and shall be securely attached and braced against overturning.

Note 1. The following construction is suggested for air terminals on the roofs of steel-frame buildings. The elevation rod may consist of a length of "extra strong" galvanized-steel pipe not less than 0.75 inch internal diameter, or an equivalent aluminum, copper or copper-alloy tube, threaded at both ends, one to receive a threaded solid point 6 inches in length, and the other an attachment for securing the elevation rod to the roof. By "equivalent" is meant of equivalent strength and conductivity.

Note 2. This attachment should consist of a pair of wooden blocks bolted to the outer and inner surfaces of the wood sheathing and cut to fit the roof and afford horizontal parallel surfaces for mounting floor flanges. The roof and blocks should be drilled through at the hub of the flanges and the tube screwed through both flanges in a vertical position. The roofing should be laid on around the outer wooden block and copper or aluminum flashing applied.

(6) Height of Air Terminal.

(a) Where air terminals are placed on projections the height shall be such as to bring the tip not less than 10 inches above the object to be protected. Where air terminals are placed near projections there shall be at least 4 inches of additional height above the object to be protected for each foot of separation.

(b) Where air terminals are spaced 25 feet or less apart on roof ridges or flat surfaces the height shall not be less than 4 feet 10 inches. For each additional foot of separation above 25 feet there shall be an increase in height of not less than 2 inches.

(c) Where air terminals are placed in rectangular arrangement as in (7)

the height shall be determined by the longest side of the rectangle.

(7) Location of Air Terminals. Air terminals shall be provided for all structural parts that are likely to receive, and be damaged by, a stroke of lightning.

(a) In the case of projections the air terminal shall be placed on the object to be protected where practicable, otherwise it shall be attached to the roof as near by as practicable.

(b) Along ridges, parapets, and edges of both flat and pitched roofs, air terminals shall be erected at intervals not exceeding 25 feet.

(c) Flat and sloping surfaces, except as indicated below, shall be divided into rectangles having sides not exceeding 50 feet in length by drawing lines parallel to the edges of the roof, and air terminals erected at the intersection of these lines.

(d) On gambrel roofs only the portion above the breaks need be considered and is to be treated as a pitched roof.

(e) On mansard roofs only the flat portion need be considered and is to be treated as a flat roof.

(8) Ground Connections. Ground connections for lightning conductors shall comply with E-161.08.

Where the frame of the building is of steel it shall be permanently and effectively grounded as follows:

(a) If there is a water-pipe system entering the structure the frame shall be bonded to it at the point of entrance with a conductor secured to the pipe by means of a substantial clamp with a lug, and to the frame with a bolt and nut. In addition, artificial grounds shall be provided for the steel pedestals, columns, or roof trusses, at not less than half of the footings, and distributed as uniformly about the perimeter as practicable.

(b) If there is no water-pipe system available, an artificial ground

shall be provided at each footing.

(c) Where the soil is deep, artificial grounds may be made by extending the grounding conductor into the soil a distance of at least 10 feet, by driving a pipe or rod to a depth at least 8 feet, or by burying to a depth of at least 6 feet a metal plate having an area of at least 4 square feet.

(d) Where the soil is shallow, grounds may be made by digging trenches radially from the building and burying in them a length of grounding conductor, or its equivalent in the form of a metal strip. In addition, a trench should be dug surrounding the building and a conductor laid in it which connects all of the grounding conductors together.

(e) Conductor for grounding purposes shall conform to E-165.01 (2) above.

(f) Where galvanized-steel pipes are used they shall be standard "extra strong" and have a nominal internal diameter of not less than 0.75 inch.

(g) Where copper strips or plates are used they shall have a thickness of not less than No. 14 AWG (0.064 inch).

(h) Grounding conductors shall be attached to buried electrodes by means of soldered, riveted, welded, or bolted joints, and to the frame with bolts and nuts.

(i) Trenches for grounding purposes must be long enough to accommodate 12 feet of conductor when laid straight but need not be more than 3 feet in depth.

(9) Interconnection of Metals.

(a) Exterior metallic bodies such as roof flashings and down spouts shall be securely bonded to the lightning-conductor system. In the case of steel-frame buildings they shall be securely bonded to the frame, and all parts of the frame shall be securely bonded together.

(b) Interior metallic bodies, such as piping systems and machinery, shall be independently grounded and if within 10 feet of a lightning conductor shall be securely bonded thereto. In the case of steel-frame buildings, all interior metallic bodies within 10 feet of the walls shall be securely bonded to the frame.

(c) Where water pipes are available they shall be used in preference to other means for grounding interior bodies of metal. Where artificial grounds are necessary they shall be constructed in compliance with E-161.08.

(d) For all bonding, interconnecting and grounding purposes the conductor used shall be at least the equivalent in strength and conducting cross-sectional area of a No. 6 AWG copper wire except where full-size lightning conductor is otherwise required. (See E-161.07 and notes.)

(10) Spark Prevention. Each structure, after its protective system is installed, shall be examined by competent authority with a view of determining whether all possible interior sources of sparks from a stroke of lightning on the building have been eliminated. If it appears that gaps between adjacent bodies of metal or between bodies of metal and ground, are likely to give rise to sparks, suitable bonds or ground connections shall be installed in such a manner as permanently and effectively to prevent them.

E-165.02. Prevention of Damage to Airships.

To prevent damage from lightning and accumulation of static electricity, balloons and airships shall be treated as follows:

(1) Captive Balloons. Captive balloons shall be grounded through the metal cable and winch by means of a pipe or rod driven 6 feet in the ground, or its equivalent in metal buried in a trench.

(2) Free Balloons and Airships. Free balloons and airships shall be provided with an effective grounding wire which is to be dropped just previous to landing, and a good ground contact made for carrying off such electrical charges as may have been accumulated by them while in the air.

(3) Interconnection of Metallic Parts. All metal parts of lighter-than-air craft shall be interconnected so that any charge that may accumulate may be distributed rather than remain concentrated.

CHAPTER E-166

SHIPS

E-166.01. Vessels to be Protected.

Vessels shall be protected as indicated below irrespective of the geographical area in which they operate.

E-166.02. Radio Antennas.

Radio antennas shall be provided with means for grounding during electrical storms.

E-166.03. Vessels with Steel Hulls and Steel Masts.

If there is metallic contact between steel hulls and steel masts no further protection against lightning is necessary.

E-166.04. Vessels of Other than Steel Construction.

The grounding of radio antennas constitutes sufficient protection for vessels of other than steel construction, except where wooden masts or spars are employed, in which case all metal fittings such as trucks and bands shall be effectively and permanently grounded by means of 1 x 1/32 inch copper strips secured to spars by brass screws and led to the nearest grounded metal-hull structure. Similar grounding of metal fittings at the extremities of wooden masts and spars constitutes adequate protection where no radio antenna is installed.

E-166.05. Metal Standing Rigging and Jacob's Ladders.

Where metal standing rigging and Jacob's ladders are installed they shall be effectively grounded at the lower ends in all cases (i. e. whether the vessel is equipped with a radio antenna or not) except where such rigging or Jacob's ladders are broken up into insulated sections not over 10 feet in length for radio purposes by means of suitable insulators, in which case grounding at the lower ends is not necessary. Grounding shall be carried out by means of stranded wire shunts 1/4 inch in diameter, around dead eyes, lanyards, shackles, rigging screws, thimbles, etc., these shunts to be stranded, laid around the bright rigging, then parcelled

and sewed.

E-166.06. Ground Connections.

In vessels having a steel hull, the hull itself constitutes an adequate ground. In vessels having wooden hulls, ground connection shall be made by means of a copper plate not less than 36 square feet in area secured to the outside of the hull below the light water line.

CHAPTER E-167

TREES

The protection of trees against lightning has been done on an increasing scale during the last few years, especially trees of historical interest or of unusual value. The rules of this chapter for the installation of lightning conductors on trees are based on what appears to be the best information obtainable.

E-167.01. Methods and Materials.

Where it appears desirable to protect trees against lightning the following rules shall apply:

(1) Conductors. Conductors may be copper, copper-clad steel, aluminum or galvanized-iron and shall conform to the requirements of E-161.01.

(2) Coursing of Conductors. In general a single conductor shall be run from the highest part of the tree along the trunk to a ground connection. If the tree is forked, branch conductors shall be extended to the highest parts of the principal limbs. If the tree is very large two down conductors maybe run on opposite sides of the trunk and interconnected near the top.

(a) The conductors should be extended as close as practicable to the highest part of the tree.

(3) Attachment of Conductors. Conductors shall be securely attached to the tree in such a way as to allow for continued growth of the trunk, and for swaying in the wind, without danger of breakage.

Note 1. A suitable method is to place loose girdles of wire encased in flexible tubing about the tree and attach the conductors to them. As the tree grows it is necessary to loosen the girdles from time to time to prevent checking of the flow of sap.

Note 2. Another method is to use screw-shank fasteners of the same metal as conductors which hold the conductor at a distance of about 2 inches from the trunk. With growth the fasteners become embedded and are replaced with others.

Note 3. To allow for swaying of the tree in the wind the conductor should be attached with an appreciable amount of slack between points of support.

(4) Ground Connections. Grounds for conductors on trees shall be made as follows: From each conductor, descending the trunk of the tree, extend three or more radial conductors in trenches 12 inches deep, spaced at equal intervals about the base where practicable, to a distance of 10 to 25 feet, depending upon the size of the tree. If the roots are very extensive the radial conductors may well be extended more than 25 feet. It is desirable as a further protective measure to connect the outer ends of the radial conductors together with a conductor which encircles the tree at the same depth as the radial conductors. In very dry soil the network should be supplemented with driven pipes, rods, or buried plates at its outer extremities.

Note: The object of the shallow network is to pick up the ground current accompanying a lightning flash near the surface and at a distance from the trunk rather than among the roots, which are as susceptible to damage as the top.

CHAPTER E-168

LIVESTOCK IN FIELDS

(1) The information on this subject is limited, but the best obtainable has been made use of in formulating the following rules. On account of the nature of the exposure it is not possible, of course, to eliminate the hazard entirely, but

it is believed that if these rules are applied it can be much reduced.

(2) The loss of live stock by lightning is caused in large measure by herds drifting against ungrounded wire fences during thunderstorms and receiving a sufficient discharge to kill them, either from accumulated static electricity or from a stroke on the fence itself. The fences that give rise to the most trouble of this kind are those constructed with posts of poorly conducting material, such as wood or concrete. Fences built with metal posts set in earth are as safe from lightning as it is possible to make them, especially if the electrical continuity is broken as provided hereafter. Breaking the electrical continuity is very useful in that it prevents a lightning stroke from affecting the entire length of a fence, as it may if the stroke is direct and the fence continuous, even though grounded.

(3) Isolated trees in pastures where stock congregate seeking shade are also a source of loss. In pastures where shade is available from wooded areas of considerable size, isolated trees should be removed, or should be protected by suitable rodding as described in E-168.03 below.

E-168.01. Grounding of Wire Fences.

Where it appears desirable or necessary to mitigate the danger from wire fences constructed with posts of non-conducting material the following rules shall apply:

(1) Iron Posts. Ground connections may be made by inserting at intervals galvanized-iron posts, such as are ordinarily used for farm fencing, and attaching in electrical contact all of the wires of the fence. If the ground is normally dry the intervals between metal posts shall not exceed 150 feet. If the ground is normally damp they may be placed 300 feet apart.

(2) Iron Pipe. A less expensive ground connection than (1) may be made by driving a length of 1/2 or 3/4 inch galvanized-iron pipe beside the fence and attaching the wires by ties of galvanized-iron wire. The spacing shall be the same as for the posts under (1) above.

(3) Depth of Grounds. Pipes or posts shall be extended into the ground at least 3 feet.

E-168.02. Breaking Continuity of Fence.

In addition to grounding the fence its electrical continuity shall be broken by inserting insulating material in breaks in the wires at intervals of about 1000 feet. These insertions may be in the form of fence panels of wood or lengths of insulating material to the ends of which the wires can be attached. Such lengths of insulating material may consist of strips of wood 2 x 2 x 24 inches, or their equivalent as far as insulating properties and mechanical strength are concerned.

E-168.03. Trees.

Where a tree is isolated and the vicinity is much frequented by livestock, the danger from lightning can be reduced by installing a single conductor extending from the top of the tree, to a distance of at least 6 feet into the ground.

PROTECTION OF STRUCTURES CONTAINING FLAMMABLE LIQUIDS AND GASES

Introduction

Reduction of Damage.

Certain types of structures used for the storage of flammable liquids and gases are essentially self-protecting against damage due to lightning strokes. Protection of a greater or less degree may be secured in the case of others through the installation of various types of protective equipment, such as rods, masts, overhead ground wires, and by other means.

Rules E-160.01 through E-168.03 relate to the protection of buildings and miscellaneous property against lightning damage. Because of the nature of contents of the structures considered in the following, extra precautions must be taken. In these structures a small spark that would ordinarily cause little if any damage might cause the complete destruction of the structure due to explosion of its contents.

Fundamental Principles of Protection.

Protection of structures and their contents from lightning involves the following principles:

(1) The storage of flammable liquids and gases in all-metal structures, essentially gastight.

(2) The closure or protection of vapor or gas openings against entrance of flame.

(3) The maintenance of containers in good condition, so far as potential hazards are concerned.

(4) The avoidance, so far as possible, of the accumulation of flammable air-vapor mixtures about such structures.

(5) The avoidance of spark gaps between metallic conductors at points where there may be an escape or accumulation of flammable vapors or gases.

(6) The location of structures not inherently self-protecting in positions of lesser exposure with regard to lightning. Elevated positions should be avoided.

(7) In connection with structures not inherently self-protecting, the establishment of zones of protection through use of grounded rods, masts, or the equivalent.

CHAPTER E-170

SCOPE, EXCEPTIONS, ETC.

E-170.01. Scope and Purpose.

(1) This code applies to the protection of structures containing flammable liquids and gases from lightning or electric discharges. It applies particularly to structures containing alcohol, benzol, petroleum, petroleum products, turpentine, and other liquids which produce flammable air-vapor mixtures at atmospheric temperatures.

(2) This code is primarily intended to give fundamental information as to the kind of structures most suitable for the protection of their contents from lightning or electric discharges and to indicate ways of protecting such structures as are not inherently self-protecting.

(3) This code is concerned only with the prevention of fires or explosions from electric discharges and is not concerned with means of extinguishing fires when once started.

E-170.02. Interpretation and Exceptions.

This code shall be liberally construed. Exceptions from its literal requirements may be made if equivalent protection is otherwise secured. It is not intended that this code be interpreted as recommending the protection of the class of property to which it applies, but it shall constitute the standard where economic or other considerations make it appear that protection is necessary or desirable.

E-170.03. Mandatory and Advisory Requirements.

The word "shall" where used is to be understood as mandatory and the word "should" as advisory. The word "may" is used in the permissive sense.

E-170.04. Terms and Definitions.

The following terms and definitions apply specifically to the structures, materials, and contents involved in rules E-170.01 through E-171.07:

(1) Vapor Openings. These are openings through a tank shell or roof above the surface of the stored liquid. Such openings may be provided for tank breathing, tank gaging, fire fighting, or other operating purposes.

(2) Flame Protection of Vapor Openings. Self-closing gage hatches, vapor seals, pressure-vacuum breather valves, flame arresters, or other reasonably effective means to minimize the possibility of flame entering the vapor space of a tank. Where such a device is used, the tank is said to be "flameproofed".

(3) Cage. A system of wires or cables forming an essentially continuous mesh or network over a structure and roof, including the necessary conductors that are connected to the structure and to an adequate ground.

(4) Cone of Protection. The cone of protection provided by a grounded lightning rod or mast is that space adjacent to the rod or mast that is substantially immune to direct strokes of lightning. When overhead ground wires are used, the space protected is called a zone of protection or protected zone.

(5) Flash Point. Flash point is the minimum temperature at which a liquid will give off vapor in sufficient amount to form a flammable air-vapor mixture that can be ignited under specified conditions.

(6) Gastight. Structures so constructed that gas or air can neither enter nor leave the structure except through vents or piping provided for the purpose.

(7) Spark Gap. As used in this code, the term "spark gap " means any short air space between two conductors electrically insulated from or remotely electrically connected to each other.

(8) Flammable Vapors. The vapors given off from a flammable liquid at and

above its flash point.

(9) Flammable Air-vapor Mixtures. When flammable vapors are mixed with air in certain proportions, the mixture will burn rapidly when ignited. The combustion range for ordinary petroleum products, such as gasoline, is from 1½ to 6 per cent of vapor by volume, the remainder being air.

CHAPTER E-171

PROTECTIVE MEASURES

E-171.01. Conductors, Air Terminals, and Ground Connectors.

Conductors for protective systems shall be selected as to material, form, and size in accordance with rules E-160.01 through E-168.03. Details as to air terminals, down conductors, interconnection of metallic masses, and ground connections are also given in rules E-160.01 through E-168.03. Connections to ground and interconnections between metallic bodies should be as short and direct as possible.

E-171.02. Sheet Steel.

Experience in the petroleum industry demonstrates that the use of 3/16 inch steel roof sheets on tanks has been adequate. Sheet metal substantially less than 3/16 inch in thickness may be punctured by severe strokes and should be protected by suitable air terminals.

E-171.03. Rods, Masts, and Overhead Ground Wires.

(1) The cone of protection of a grounded rod or mast of conducting material is conventionally taken as the space enclosed by a cone, which has its apex at the highest point of the rod or mast and a radius at the base which bears a relation to the height. This relation depends upon the height of the cloud above the earth relative to the height of the rod or mast. A radius of base HM equal to the height of the rod or mast in important cases, or up to twice the height in less important cases, has been found to be substantially immune to direct strokes of lightning. No part of the structure to be protected should extend outside of the cone of

protection (Figure A). If more than one rod or mast is used, the shielded region between them is somewhat greater than the total of the shielded regions of all of the rods or masts considered individually.

(2) Masts separate from the structure to be protected should be a minimum of six feet from the protected structure, and the clearance should be increased by one foot for every ten feet of structure height above fifty feet to prevent side flashes. The masts shall be thoroughly grounded and connected at ground level to the grounding system of the structure to be protected.

(3) Where a suitable underground metallic water pipe serves the structure, the water pipe is ordinarily the common grounding electrode for all services and facilities which require grounding at the structure. If there is no water pipe or if the water pipe is not accessible, the separate grounding electrodes of the various services and facilities shall be bonded together and to the masts. If such separate grounding electrodes are not accessible, the minimum separation between the mast and the structure shall be increased to 10 feet for mast ground resistance of 10 ohms or less. As an alternative, a buried grounding conductor around the outside of the structure may be used and bonded to the mast ground to avoid larger separations.

(4) The zone of protection of overhead ground wires is conventionally taken as a triangular prism or wedge. One-half of the base of the wedge (HM) equal to the height of lowest point of the overhead ground wire in important cases, or up to twice the height in less important cases, has been found to be satisfactory (Figure B). The supporting masts should have a clearance from the protected structure as under E-171.03 (2). Ground wires should be of a size as indicated under E-160.01. The material selected should be non-corrosive for the conditions existing at the site, and the rules of E-160.01 should be observed.

(5) The minimum clearance between the overhead ground wires and the highest projection on the protected structure shall be six feet. For each ten feet of

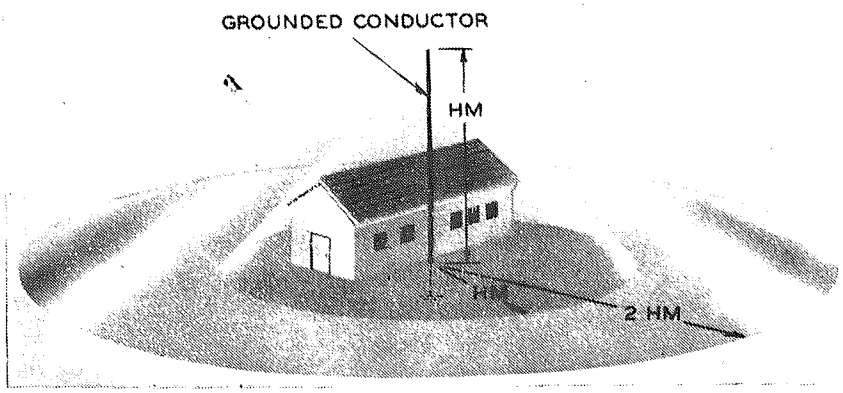


Figure A.

Cone of Protection Provided by a Vertical Grounded Conductor.

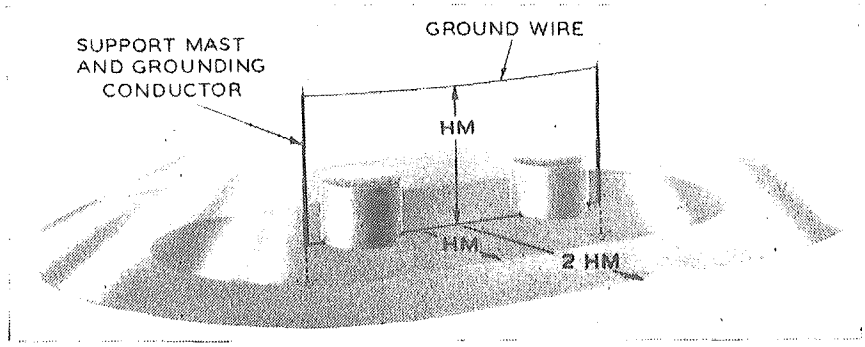


Figure B. HM = Height of Mast.

Zone of Protection Provided by a Horizontal Aerial Ground Wire.

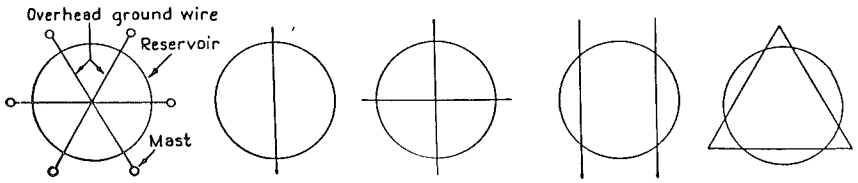


Figure C.

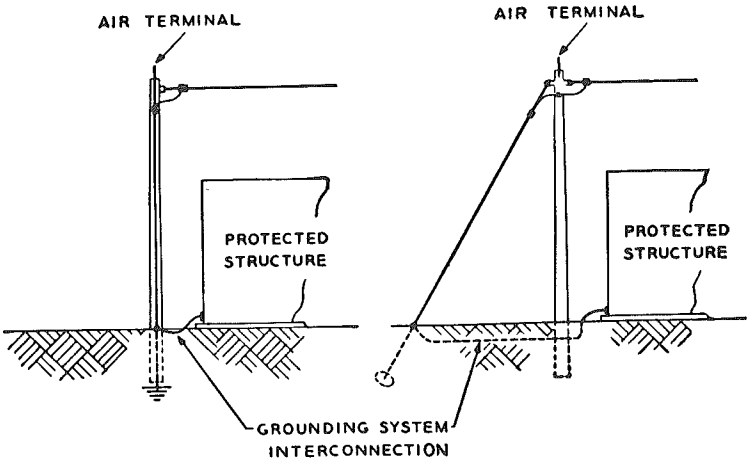


Figure D.

Alternate Grounding Method for Aerial Ground Wire Protection

lead between a point on the ground wire midway between the supporting masts and ground in excess of sixty feet, the clearance should be increased by one foot. These dimensions apply when the ground-wire system is interconnected with the grounding of the protective system in accordance with E-171.03 (2). Where no interconnection is made the recommendations of E-171.03 (2) apply. Variations in the ground-wire system design are shown in the plan view of Figure C.

(6) Masts used either separately or with ground wires may be of wood. An approved type of air terminal shall be securely mounted to the top of the pole (see Figure D) extending not less than two feet above the top of the pole and connected to ground electrodes. In case of an overhead ground-wire system, the pole guy wire may be used as the down conductor (see Figure D). For metallic masts, the air terminal and the down conductor are not required, but the masts shall be grounded as described.

E-171.04. Ground Resistance.

(1) The resistance of ground rods driven in the earth and separated by distances of 10 feet or more will be reduced in approximate proportion to the number of rods in parallel.

(2) The resistance of a conductor buried in the ground decreases almost directly in proportion to the increase in length of the buried conductor. Such conductors are usually buried from 1 to 3 feet beneath the ground surface and running parallel with the ground surface.

E-171.05. Electrostatic Shielding.

The electrostatically induced voltage on isolated objects in the field of a storm cloud may cause sparks to ground when a lightning discharge occurs to some adjacent object. Isolated objects within a structure that is adequately shielded will themselves be electrostatically shielded. If the structure is not shielded or is only partially shielded, then the isolated objects should be grounded to prevent electrostatic sparks. For further discussion of the grounding of isolated internal objects see E-161.07.

E-171.06. Flame Protection of Vapor Openings.

(1) Flame protectors of any type should be such as have been proved by adequate investigation and tests to be effective for the conditions under which they are installed and used.

(2) For pipe sizes larger than 4 inches, the effectiveness of flame protection employing screens on the Davy principle is questionable. Pressure relief valves that remain closed at pressure differentials of less than 1-inch head of water, and arresters in the forms of tubes, plates, and their equivalent, have been found to be reasonably effective flame protection devices.

(3) Flame protectors should be substantially encased and capable of withstanding the effect of cleaning and of flame and pressures without material distortion or injury.

(4) Where screens are used, they should be made of corrosion-resistant wire with a mesh of about 40 per inch. They should be protected so far as possible from mechanical injury.

CHAPTER E-172

PROTECTION OF SPECIFIC CLASSES OF STRUCTURES

E-172.01. Aboveground Steel Tanks Containing Flammable Liquids at Atmospheric Pressures.

The contents of steel tanks with steel roofs of riveted, bolted, or welded construction, with or without supporting members, used for the storage of flammable liquids, are considered to be reasonably well protected against lightning if the tanks conform to the following specifications:

(1) All joints between steel plates to be riveted, bolted, or welded.

(2) All pipes entering the tank to be metallically connected to the tank at the point of entrance.

(3) All vapor or gas openings to be closed or flameproofed, as described in

E-171.06 when the stored stock is a Class I or Class II flammable liquid.

(4) The metal tank and roof to have adequate thickness so that holes will not be burned through by lightning strokes (3/16 inch roof sheets on tanks when built have proved adequate).

(5) The roof to be continuously welded to the shell, or bolted, or riveted and caulked, to provide a gastight seam and electrical continuity.

E-172.02. Additional Protection.

In cases where additional protection is deemed to be justified, the following procedures are recommended:

(1) The internal structural supporting members shall be bolted, riveted, welded or otherwise metallically bonded to the tank roof at not more than ten-foot intervals. (Figure E.)

(a) Any bonding conductor between the expandable roof and the rigid supporting structure should be made as short as possible for electrical reasons, but should be sufficiently long to prevent snapping off due to mechanical motion of the roof. The conductor should be flexible and of a size not less than No. 1 AWG. The metal of the conductor should be corrosive resistant for the liquids and vapors existing in the tank.

(2) Provide an overhead ground-wire system or mast protection to prevent contact of direct strokes with the roof (see E-171.03).

E-172.03. Floating Roof Tanks.

(1) General. Floating roof tanks with hanger mechanisms, located within a vapor space have occasionally ignited at the seal during lightning storms even though there was no evidence of being struck. This may result from sparks that could occur in the pinned joints of the hanger mechanisms when bound charges on the roof are suddenly released by a nearby lightning stroke and return to earth through the hanger mechanism and tank shell.

(2) Protection.

(a) Experience indicates that floating roof tanks without vapor spaces

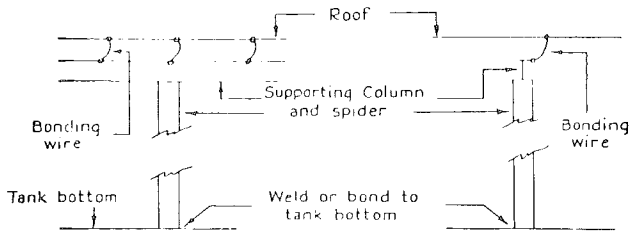

Roof
Supporting Column
and spider
Bonding
wire
Bonding
wire
Tank bottom
Weld or bond to
tank bottom

Figure E.

have not been subject to ignition, and protective measures need not be considered.

(b) In areas where lightning protection is deemed to be justified, floating roof tanks with hangers located within a vapor space may be protected as follows:

1. Bond the roof to the shoes of the seal at intervals not greater than 10 feet on the circumference of the tank, and

2. Break up the conductive paths through the hanger linkage by means of insulated joints or install short jumper bonds around each pinned joint of the hanger mechanism.

E-172.04. Steel Tanks With Non-metallic Roofs.

(1) Steel tanks with wooden or other non-metallic roofs are not considered to be self-protecting, even if the roof is essentially gastight and sheathed with thin metal and with all gas openings closed or flameproofed.

(2) Such tanks should be provided with air terminals of sufficient height and number to receive all strokes and keep them away from the roof. The air terminals should be thoroughly bonded to each other, to the metallic sheathing, if any, and to the tank. Isolated metal parts should be avoided or else bonded to the tank. In lieu of air terminals, any of the following may be used, conducting masts, suitably spaced around the tank; or overhead ground wires; or a combination of masts and overhead ground wires.

E-172.05. Grounding Tanks.

(1) Tanks should be well grounded to conduct away the current of direct strokes and avoid building up potential that may cause sparks to ground.

(2) Steel tanks that are in intimate contact with the ground, or aboveground steel tanks connected to extensive metallic piping, are sufficiently well grounded inherently.

E-172.06. Pressure Storage of Flammable Liquids or Gases.

Aboveground storage tanks containing flammable liquids or liquefied petroleum

gas under pressure do not require lightning protection.

E-172.07. Earthen Containers.

Earthen containers, lined or unlined, with or without roofs, may be protected by air terminals, separate masts, overhead ground wires, or a combination of these.

PART 5

ELECTRICAL AND COMMUNICATION EQUIPMENT AND WIRING INCLUDING GROUNDING

CHAPTER E-190.

SCOPE AND APPLICATION OF RULES

E-190.01. Scope of Rules.

In Part 5, the National Electrical Code has generally been followed. (The chapter numbers in the State Code correspond to the article numbers in the National Electrical Code). In some cases the rules differ from those in the National Electrical Code.

E-190.02. Application of Rules.

(1). General.

(a) Except as otherwise specified hereafter, these rules, which have for their purpose the practical safeguarding of persons and buildings and their contents from electrical hazards arising from the use of electricity, apply to the electric and communication conductors and equipment installed in places of employment, within or on public and private buildings and other premises, including yards, carnival and parking lots, mines, trenches and tunnels, and industrial substations; also the conductors that connect the installations to a supply of electricity, and other outside conductors adjacent to the premises.

(b) These rules do not apply to installations employed by a railway, electric or communication utility in the exercise of its function as a utility where the installations are located outdoors or in quarters used exclusively for that purpose, but they do apply to wires used in such quarters to distribute a power supply for lighting, service outlets, and other utilization equipment.

(c) These rules do not apply to installations in ships, aircraft, railway cars or automotive equipment.

(d) Chapter E-800 governs the installation of communication systems. No other chapters of Part 5 apply to such installations, except as they may be specifically referred to in Chapter E-800.

Note 1. The provisions of this Code constitute a minimum standard. Compliance therewith and proper maintenance will result in an installation reasonably free from hazard but not necessarily efficient or convenient. This Code is to be regarded neither as a design specification nor an instruction manual for untrained persons. Good service and satisfactory results will often require larger sizes of wire, more branch circuits, and better types of equipment than the minimum which is here specified.

Note 2. It is recommended that architects, when drawing plans and specifications, make provision for ample raceways for wiring, spaces for equipment, and allowances for future increases in the use of electricity. In laying out an installation for constant-potential systems, provision should be made for distribution centers located in easily accessible places for convenience and safety of operation.

Note 3. It is elsewhere provided in this Code that the number of wires and circuits confined in a single enclosure be varyingly restricted. It is strongly recommended that architects and others provide similar restrictions wherever practicable, to the end that the effects of breakdowns from short-circuits or grounds, even though resulting fire and similar damage is confined to wires, their insulation and enclosures, may not involve entire services to premises nor interruptions of essential and independent services.

(2). Equipment of More than 600 Volts.

(a) All electrical equipment and conductors of more than 600 volts shall comply with the rules applying to electrical supply stations, Part 1. (See E-110.01.)

(b) If such equipment and conductors are installed in supply stations or other quarters accessible only to qualified persons, they need not comply with the rules of Part 5, but only with the rules of Part 1.

(c) If such equipment and conductors are not installed in supply stations or other quarters accessible only to qualified persons, they shall comply with the rules of Part 5 for equipment of over 600 volts (See Chapter E-710) and also with the rules of Part 1. In addition, all current-carrying parts shall be either incased in effectively grounded metal cases or conduit, or otherwise suitably guarded to prevent access (or too close approach) to such current-carrying parts by any but qualified persons.

(3). Equipment Accessible to Qualified Persons Only.

Electrical equipment and conductors, if installed in supply stations or other quarters accessible only to qualified persons, may be installed in conformity with the orders applying to electrical supply stations (Part 1), in which case only wiring used to distribute a power supply for lighting, service outlets and other utilization equipment need comply with the orders of Part 5. (See E-110.01).

CHAPTER E-195. GENERAL

E-195.01. Scope.

This Chapter includes provisions applicable generally in installations of electric wiring and equipment.

E-195.02. Approval.

The conductors and equipment required or permitted by this Code shall be acceptable only when approved. See definition of "Approved" in Chapter E-100.

E-195.03. Mandatory and Advisory Rules.

Mandatory rules of this Code are characterized by the use of the word "shall". Advisory rules are characterized by the use of the word "should", or are stated as recommendations of that which is advised but not required.

E-195.04. Examination of Equipment.

Materials, devices, fittings, apparatus and appliances designed for use under this Code shall be judged chiefly with reference to the following considerations which also determine the classification by types, size, voltages, current capacities, and specific use.

(1) Suitability for installation and use in conformity with the provisions of this Code.

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

(3) Electrical insulation.

(4) Heating effects under normal conditions of use and also under abnormal conditions likely to arise in service.

(5) Arcing effects.

E-195.05. Voltages.

Throughout this Code the voltage considered shall be that at which the circuit operates.

E-195.06. Conductor Gauges.

Conductor sizes are given in American Wire Gauge (AWG).

E-195.07. Conductors.

Conductors normally used to carry current shall be of copper unless otherwise provided in this Code. Where conductor sizes are given in this Code, they shall apply to copper conductors. Where other materials are used, the size shall be changed accordingly.

E195.08. Wiring Methods.

(1) Only wiring methods recognized as suitable are included in this Code. The recognized methods of wiring may be installed in any type of building or occupancy except as otherwise provided in this Code.

(2) All conductors shall be guarded in an approved manner when brought closer to floor or platform than 8 feet, or when exposed to mechanical injury above that level.

(a) Exception: Trolley conductors, grounding conductors size No. 4 or larger, lightning arrester ground conductors, pendants, and portable cords are exempt from this rule.

(3) Bus-bars and other open bare ungrounded conductors which are elevated less than 8 feet above floor or platform, shall be enclosed by suitable guards.

E195.09. Interrupting Capacity.

Devices intended to break current shall have an interrupting capacity sufficient for the voltage employed and for the current which must be interrupted.

E-195.10. Deteriorating Agencies.

Unless approved for the purpose, no conductors or equipment shall be located in a damp or wet location; where exposed to gases, fumes, vapors, liquids or other agents having a deteriorating effect on the conductors or equipment; nor where exposed to excessive temperatures.

E-195.11. Mechanical Execution of Work.

Electrical equipment shall be installed in a neat and workmanlike manner.

E-195.12. Mounting of Equipment.

Electrical equipment shall be firmly secured to the surface on which it is mounted. Wooden plugs driven into holes in masonry, concrete, plaster or similar materials shall not be depended on for security.

E-195.13. Connections to Terminals.

Connection of conductors to terminal parts shall insure a thoroughly good connection without damaging the conductors and shall be made by means of pressure connectors (including set screw type), solder lugs or splices to flexible leads

except that No. 8 or smaller solid conductors and No. 10 or smaller stranded conductors may be connected by means of clamps or screws with terminal plates having upturned lugs. Terminals for more than one conductor shall be of a type approved for the purpose.

Note: Because of different characteristics of copper and aluminum the devices and fittings, such as pressure connectors, splices, solder lugs, solder, and fluxes employed where making connections, should be suitable for the material of the conductor.

E-195.14. Splices.

Conductors shall be spliced or joined with approved splicing devices 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 on the conductors.

E-195.15. Working Space about Electrical Equipment.

Suitable working space shall be provided and maintained about all electrical equipment.

(1) Horizontal Dimensions. Except as elsewhere required or permitted in this Code, the horizontal dimensions of the working space in front of live parts, operating at not more than 600 volts, which must be handled while alive, shall not be less than:

(a) For parts of more than 150 volts to ground on one side of the working space and no bare live or grounded parts on the other side of the working space, $2\frac{1}{2}$ feet.

(b) For parts of more than 150 volts to ground on one side of the working space and bare live or grounded parts on the other side of the working space, 4 feet.

(c) For parts of 150 volts or less to ground on one side of the working

space and no bare live or grounded parts on the other side of the working space, 1½ feet.

(d) For parts of 150 volts or less to ground on one side of the working space and bare live or grounded parts on the other side of the working space, 2 ½ feet.

Note: For voltages above 600, see Chapter E-710.

(2) Clear Spaces. Working spaces adjacent to exposed live parts shall not be used as passageways, or for storage.

(3) Elevation of Equipment. The elevation of the equipment at least 8 feet above ordinarily accessible working platforms, usually affords protection at least equivalent to that provided by the horizontal clearances of E-195.15(1). and may be used in lieu thereof.

E-195.16. Guarding of Live Parts.

Except as elsewhere required, or permitted by this Code, exposed live parts of electrical equipment operating at 50 volts or more shall be guarded against accidental contact by enclosure or by locating the equipment as follows:

(1) In a room or enclosure which is accessible only to qualified persons;

(2) On a suitable balcony, gallery, or platform, so elevated and arranged as to exclude unqualified persons;

(3) Elevated 8 feet or more above the floor;

(4) So that it will be protected by a guard rail if the equipment operates at 600 volts or less.

Note: For motors see E-430.132. For voltages above 600 volts see Chapter E-710.

E-195.17. Arcing Parts.

Parts of electrical equipment which in ordinary operation produce arcs, sparks, flames or molten metal, shall be enclosed unless separated and isolated from all combustible material. For hazardous locations see Chapters E-500-517, inclusive. For motors see E-430.011 and E-430.014.

E-195.18. Light and Power from Railway Conductors.

Circuits for lighting and power shall not be connected to any system containing trolley wires with a ground return, except in electric railway cars, car houses, power houses, or passenger and freight stations operated in connection with electric railways.

E-195.19. Insulation Resistance.

All wiring shall be so installed that when completed the system will be free from short-circuits and from grounds other than as provided in Chapter E-250. In order that a reasonable factor of safety may be provided, the following table of insulation resistances is suggested as a guide where the insulation is subjected to test:

(1) For circuits of No. 14 or No. 12 wire, 1,000,000 ohms. For circuits of No. 10 or larger conductor, a resistance based upon the allowable current-carrying capacity of conductors as fixed in Tables E-310.12 through E-310.15 as follows:

25 to 50 amperes, inclusive	250,000 ohms
51 to 100 amperes, inclusive	100,000 ohms
101 to 200 amperes, inclusive	50,000 ohms
201 to 400 amperes, inclusive	25,000 ohms
401 to 800 amperes, inclusive	12,000 ohms
Over 800 amperes	5,000 ohms

(2) The above values are to be determined with all switchboards, panelboards, fuseholders, switches, receptacles and overcurrent devices in place.

(3) If lampholders, . . fixtures, or appliances are also connected, the minimum resistances permitted for branch circuits supplying same shall be one-half the values specified in paragraph (1).

(4) Where climatic conditions are such that the wiring or equipment is exposed to excessive humidity, it may be necessary to modify the foregoing provisions.

E-195.20. Marking.

The maker's name, trademark, or other identification shall be placed on all electrical equipment. Other markings shall be provided giving voltage, current, wattage, or other ratings as are prescribed elsewhere in this Code.