NFPA 79

Electrical Standard for Industrial Machinery

2002 Edition

NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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This edition of NFPA 79, *Electrical Standard for Industrial Machinery*, was prepared by the Technical Committee on Electrical Equipment of Industrial Machinery and acted on by NFPA at its May Association Technical Meeting held May 19–23, 2002, in Minneapolis, MN. It was issued by the Standards Council on July 19, 2002, with an effective date of August 8, 2002, and supersedes all previous editions.

This edition of NFPA 79 was approved as an American National Standard on July 19, 2002.

Origin and Development of NFPA 79

This standard was first submitted at the 1961 NFPA Annual Meeting under the title *Electrical Standard for Machine Tools* and was tentatively adopted subject to comments. It was extensively revised and resubmitted at the 1962 Annual Meeting, where it was officially adopted. In 1965 a revised edition was adopted, reconfirmed in 1969, and in 1970, 1971, 1973, 1974, 1977, 1980, 1985, 1987, 1991, 1994, 1997, and 2002 revised editions were adopted.

In September 1941, the metalworking machine tool industry wrote its first electrical standard to make machine tools safer to operate, more productive, less costly to maintain, and to improve the quality and performance of their electrical components. That particular standard served as an American "War Standard."

To study the special electrical problems involved with machine tools, in 1941 the Electrical Section of the National Fire Protection Association sanctioned a Special Subcommittee on Wiring, Overcurrent Protection, and Control of Motor-Operated Machine Tools. This Subcommittee, cooperating with machine tool builders, manufacturers of control equipment, and Underwriters Laboratories Inc., conducted tests and investigated the peculiar conditions involved with machine tools that might warrant exception to certain specific *National Electrical Code®* requirements. This investigation resulted, on August 4, 1942, in a Tentative Interim Amendment and first appeared in a 1943 supplement to the 1940 edition of the *National Electrical Code* as Article 670, "Machine Tools." It remained essentially unchanged through the 1959 edition.

Meanwhile, manufacturers of other types of industrial equipment erroneously began to follow the specialized practices permitted by Article 670. Late in 1952, a Technical Subcommittee on Fundamentals of Electrically Operated Production Machinery and Material Handling and Processing Equipment for Fixed Locations was organized to attempt to group the special requirements of this broad field into one article. The extremely broad scope introduced so many problems that, in December 1956, this Technical Subcommittee was reorganized into an NFPA Committee whose scope was limited to machine tools and whose objective was the preparation of this NFPA standard with corresponding revisions in Article 670 in the *National Electrical Code*.

Modern machine tool electrical equipment may vary from that of single-motor machines, such as drill presses, that perform simple, repetitive operations, to that of very large, multimotored automatic machines that involve highly complex electrical control systems, including electronic and solid-state devices and equipment. Generally these machines are specially designed, factory wired, and tested by the builder and then erected in the plant in which they will be used. Because of their importance to plant production and their usually high cost, they are customarily provided with many safeguards and other devices not often incorporated in the usual motor and control application as contemplated by the *National Electrical Code*.

Although these machines may be completely automatic, they are constantly attended, when operating, by highly skilled operators. The machine usually incorporates many special devices to protect the operator, protect the machine and building against fires of electrical origin, protect the machine and work in process against damage due to electrical failures, and protect against loss of production due to failure of a machine component. To provide these safeguards, it may be preferable to deliberately sacrifice a motor or some other component, rather than to chance injury to the operator, the work, or the machine. It is because of such considerations that this standard varies from the basic concepts of motor protection as contained in the *National Electrical Code*.

As NFPA 79 evolved, it became apparent that certain classes of light industrial machinery (e.g., small drill presses, bench grinders, sanders, etc.) were not appropriately covered. The 1977 edition of the standard recognized this problem and purposely excluded tools powered by two horsepower or less.

Subsequent to publication of the 1977 standard, a light industrial machinery standard development activity was initiated by the Power Tool Institute. The 1985 edition of NFPA 79 reflects this activity, and appropriate requirements are now included in the standard.

In 1975, the Society of the Plastics Industry requested that this standard be enlarged in scope to include plastics machinery. A formal request was received by NFPA in September 1978, and, through the combined efforts of the NFPA 79 committee and representatives of the Society of the Plastics Industry, the scope was broadened to include such machinery in the 1980 edition.

In June 1981, the Joint Industrial Council (JIC) Board of Directors acknowledged the dated state of the electrical and electronic standards and requested that NFPA 79 incorporate into its standard the material and topics covered by the JIC electrical (EMP-1-67, EGP-1-67) and electronic (EL-1-71) standards with the intention that the JIC standards eventually would be declared superseded. The NFPA Standards Council approved the request with the stipulation that the material and topics incorporated from the JIC standards be limited to areas related to electrical shock and fire hazards. The 1985 edition reflected the incorporation of the appropriate material from the JIC electrical (EMP-1-67, EGP-1-67) standards not previously covered. The 1991, 1994, and 1997 editions include additional references to international standards and reflect the committee's efforts in harmonization.

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The 2002 edition is a major rewrite and represents a significant and historic effort in harmonizing an existing NFPA standard with an existing IEC standard. Major changes for this edition include renumbering section and chapter numbers to align with IEC 60204–1. A new chapter has been added to address testing. An informative Annex A has been added to assist the user in understanding the mandatory text portion of the standard. And, a new Annex H has been added to assist the user with cross references to previous edition section numbers.

To better coordinate its work, this Committee reports to the Association through the Correlating Committee of the National Electrical Code Committee. The primary reason is to correlate this standard and the *National Electrical Code®*, especially with respect to Article 670 thereof.

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Committee Scope: This Committee shall have primary responsibility for documents intended to minimize the potential hazard of electric shock and electrical fire hazards of industrial metalworking machine tools, woodworking machinery, plastics machinery and mass production equipment, not portable by hand. Reports to the Association through the Technical Correlating Committee of the National Electrical Code Committee.

This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

Vertical rules are not used to indicate new or changed material.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, Annex J lists the complete title and edition of the source documents for both mandatory and nonmandatory extracts. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the appropriate technical committee.

Information on referenced publications can be found in Chapter 2 and Annex J.

Chapter 1 Administration

1.1* Scope.

1.1.1 The provisions of this standard shall apply to the electrical/electronic equipment, apparatus, or systems of industrial machines operating from a nominal voltage of 600 volts or less, and commencing at the point of connection of the supply to the electrical equipment of the machine.

1.1.2 This standard shall not include the additional requirements for machines intended for use in hazardous (classified) locations.

1.2 Purpose. This standard shall provide detailed information for the application of electrical/electronic equipment, apparatus, or systems supplied as part of industrial machines that will promote safety to life and property.

1.3 Application.

1.3.1 This standard is not intended to be applied retroactively.

1.3.1.1 When changes other than repairs are made to machines that do not comply with the provisions of this standard, the changes shall conform with the provisions of this standard.

1.3.2 This standard shall not apply to the following:

(1) Fixed or portable tools judged under the requirements of a testing laboratory acceptable to the authority having jurisdiction
(2) Machines used in dwelling units

1.4 Specific Provisions Other Than NFPA 79.

1.4.1 The size and overcurrent protection of the supply conductors to a machine shall be covered by NFPA 70, *National Electrical Code®*, Article 670. The wiring between component machines of an industrial manufacturing system shall be covered by NFPA 70, *National Electrical Code.*

1.4.2 *Exception: Wiring of component machines of an industrial manufacturing system that is supplied by the manufacturer and is an integral part of the system, is adequately protected and supported, and meets the requirements of this standard.*

1.5* Specific Provisions Not Made in Relation to NFPA 70. On any point for which specific provisions are not made in this standard the provisions of NFPA 70, *National Electrical Code*, shall be observed.

1.6 State of the Art. This standard shall not limit or inhibit the advancement of the state of the art. Each type of machine has unique requirements that shall be accommodated to provide adequate safety.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 70, *National Electrical Code®,* 2002 edition.

2.3 Other Publications.

2.3.1 ANSI Publication. American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036.

ANSI Z535.4, *Product Safety Signs and Labels*, 1998.

2.3.2 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM B 8, *Standard Specification for Concentric – Lay – Stranded Copper Conductors Hard, Medium-Hard, or Soft,* 1999.

ASTM B 174, *Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors,* 1995.

ASTM B 286, *Standard Specification for Copper Conductors for Use in Hookup Wire for Electronic Equipment*, 1995.

2.3.3 IEC Publications. International Electrotechnical Commission, 3 rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

IEC 60072-1, *Dimensions and output series for rotating electrical machines Part 1*, 1991.

IEC 60072-2, *Dimensions and output series for rotating electrical machines Part 2*, 1990.

2.3.4 IEEE Publication. Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

IEEE 315, *Graphical Symbols for Electrical and Electronics Diagrams,* 1994.

2.3.5 NEMA Publications. National Electrical Manufacturers Association, 1300 N. 17th Street, Suite 1847, Rosslyn, VA 22209.

NEMA ICS 2, *Industrial Control and Systems, Controllers, Contactors, and Overload Relays Rated Not More Than 2000 Volts AC or 750 Volts DC,* 1993.

NEMA MG-1, *Motors and Generators,* 1998.

NEMA 250, *Enclosures for Electrical Equipment (1000 Volts Maximum),* 1997.

2.3.6 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 50, *Standard for Safety Enclosures for Electrical Equipment,* 1995.

UL 508, *Standard for Safety Industrial Control Equipment,* 1999.

UL 508A, *Standard for Safety Industrial Control Panels,* 2001.

UL 870, *Standard for Safety Wireways, Auxiliary Gutters and Associated Fittings,* 1995.

UL 1063, *Standard for Safety Machine – Tool Wires and Cables,* 1998.

Chapter 3 Definitions

3.1* General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not included, common usage of the terms shall apply.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.3 General Definitions.

3.3.1 Accessible (as applied to equipment). Admitting close approach; not guarded by locked doors, elevation, or other effective means. [**70**:100]

3.3.2 Accessible, Readily (Readily Accessible). Capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, etc. [**70**:100]

3.3.3* Actuator. The part of the actuating system to which an external actuating force is applied.

3.3.3.1 ***Actuator, Machine.*** A power mechanism used to effect motion of the machine.

3.3.4* Adjustable Speed Drives. An electrical device or group of electrical devices that alters the drive motor output speed over a range in a controlled manner.

3.3.5* Ambient Temperature. The temperature of the air or other medium where the equipment is to be used.

3.3.6 Ampacity. The current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. [**70**:100]

3.3.7* Attachment Plug (Plug Cap) (Plug). A device that, by insertion in a receptacle, establishes a connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle. [**70**:100]

3.3.8 Barrier. A physical obstruction that is intended to prevent contact with equipment or live parts or to prevent unauthorized access to a work area. [**70E**:I-2.1]

3.3.9* Bonding (Bonded). The permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct any current likely to be imposed. [**70**:100]

3.3.10 Branch Circuit. The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s). [**70**:100]

3.3.11 Cableless Control. Control devices employing cableless (e.g., radio, infrared) techniques for transmitting commands and signals between a machine control system and operator control station(s).

3.3.12 Cable Tray System. A unit or assembly of units or sections and associated fittings forming a structural system used to securely fasten or support cables and raceways. [**70**:392.2]

3.3.13* Cable Trunking System. A system of enclosures comprised of a base and a removable cover intended for the complete surrounding of insulated conductors, cables, and cords.

3.3.14* Circuit Breaker. A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating. [**70**:100]

3.3.15* Color Graphic Interface Device. An interface between the operator and the machine, where a color video display and either a touch screen or touch pad or keyboard or mouse are used to initiate machine action by the selection of on-screen icons.

3.3.16 Concurrent. Acting in conjunction; used to describe a situation wherein two or more control devices exist in an actuated condition at the same time (but not necessarily simultaneously).

3.3.17 Conduit.

3.3.17.1 ***Flexible Metal Conduit (FMC).*** A raceway of circular cross section made of helically wound, formed, interlocked metal strip. [**70:**348.2]

3.3.17.2 Intermediate Metal Conduit (IMC). A steel threadable raceway of circular cross section designed for the physical protection and routing of conductors and cables when installed with its integral or associated coupling and appropriate fittings.

3.3.17.3 Liquidtight Flexible Metal Conduit (LFMC). A raceway of circular cross section having an outer liquidtight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core with associated couplings, connectors, and fittings for the installation of electric conductors. [**70:**350.2]

3.3.17.4 Liquidtight Flexible Nonmetallic Conduit (LFNC). A nonmetallic raceway of circular cross section of oil-, water-, and flame-resistant construction and fittings for the installation of electrical conductors.

3.3.17.5 Rigid Metal Conduit (RMC). A threadable raceway of circular cross section designed for the physical protection and routing of conductors and cables when installed with its integral or associated coupling and appropriate fittings. RMC is generally made of steel (ferrous) with protective coatings or aluminum (nonferrous). Special use types are silicon bronze and stainless steel.

3.3.17.6 Rigid Nonmetallic Conduit (RNC). A nonmetallic raceway of circular cross section, with integral or associated couplings, connectors, and fittings for the installation of electrical conductors. [**70:**352.2]

3.3.18 Contact.

3.3.18.1 Direct Contact. Contact of persons with live parts.

3.3.18.2 Indirect Contact. Contact of persons with exposed conductive parts that have become live under fault conditions.

3.3.19* Control Circuit (of a machine). The circuit of a control apparatus or system that carries the electric signals directing the performance of the controller but does not carry the main power current.

3.3.20 Control Circuit Transformer. A voltage transformer utilized to supply a voltage suitable for the operation of control devices.

3.3.21 Control Circuit Voltage. The voltage utilized for the operation of control devices.

3.3.22 Control Device. A device connected into the control circuit and used for controlling the operation of the machine (e.g., position sensor, manual control switch, relay, magnetically operated valve).

3.3.23 Control Equipment. Operating elements, such as relays, contactors, circuit breakers, switches, solenoids, brakes, and similar types of components, intended to govern or perform a given function in the operation, including measuring, sensing, monitoring, protecting, and regulating of machinery.

3.3.24 Controller. A device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected. [**70**:100]

3.3.25 Cord. One or a group of flexible insulated conductors, enclosed in a flexible insulating covering.

3.3.26 Device. A unit of an electrical system that is intended to carry but not utilize electric energy. [**70**:100]

3.3.27 Digital. Operated by the use of discrete signals to represent data in the form of numbers or other characters.

3.3.28 Disconnecting Means. A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply. [**70**:100]

3.3.29* Duct. An enclosed channel designed expressly for holding and protecting electrical conductors, cables, and busbars.

3.3.30 Dwelling Unit. One or more rooms for the use of one or more persons as a housekeeping unit with space for eating, living, and sleeping, and permanent provisions for cooking and sanitation. [**70**:100]

3.3.31 Earth. See 3.3.46, Ground.

3.3.32 (Electrically) Instructed Person. A person adequately advised or supervised by an electrically skilled person to enable him or her to perceive risks and to avoid hazards that electricity can create.

3.3.33 (Electrically) Skilled Person. A person with relevant education and experience to enable him or her to perceive risks and to avoid hazards that electricity can create.

3.3.34 Electromechanical. Any device in which electrical energy is used to magnetically cause mechanical movement.

3.3.35 Electronic Equipment. That part of electrical equipment containing circuitry mainly based on electronic devices and components.

3.3.36 Emergency Switching Off. An emergency operation intended to switch off the supply of the electrical energy to all or part of an installation.

3.3.37 Enabling Device. Manually operated control device used in conjunction with a start control, when continuously actuated, will allow a machine to function.

3.3.38 Enclosure. The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts or to protect the equipment from physical damage. [**70:**100]

3.3.39 Energized. Electrically connected to a source of voltage. [**70**:100]

3.3.40 Equipment. A general term including material, fittings, devices, appliances, luminaires (fixtures), apparatus, and the like used as a part of, or in connection with, an electrical installation. [**70**:100]

3.3.41 Exposed (as applied to live parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts not suitably guarded, isolated, or insulated. [**70**:100]

3.3.42* Failure (of equipment). The termination of the ability of an item to perform a required function.

3.3.43* Fault. The state of an item characterized by inability to perform a required function, excluding the inability, during preventive maintenance or other planned actions, or due to lack of external resources.

3.3.44 Feeder. All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device. [**70**:100]

3.3.45 Flame Retardant. So constructed or treated that it will not support flame.

3.3.46 Ground. A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth. [**70**:100]

3.3.47 Grounded. Connected to earth or to some conducting body that serves in place of the earth. [**70**:100]

3.3.48 Grounded Conductor. A system or circuit conductor that is intentionally grounded. [**70**:100]

3.3.49 Grounding Conductor. A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes. [**70**:100]

3.3.50 Grounding Conductor, Equipment. The conductor used to connect the noncurrent-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor, the grounding electrode conductor, or both, at the service equipment or at the source of a separately derived system. [**70**:100]

3.3.51* Guard. Part of a machine specifically used to provide protection by means of a physical barrier.

3.3.52 Hazard. A source of possible injury or damage to health.

3.3.53 Hazardous Condition. A circumstance in which a person is exposed to a hazard(s) that has the potential to result in harm immediately or over a long period of time.

3.3.54* Identified (as applied to equipment). Recognizable as suitable for the specific purpose, function, use, environment, application, and so forth, where described in a particular code or standard requirement. [**70**:100]

3.3.55 Industrial Machinery (Machine). A power-driven machine (or a group of machines working together in a coordinated manner), not portable by hand while working, that is used to process material by cutting; forming; pressure; electrical, thermal, or optical techniques; lamination; or a combination of these processes. Machine can include associated equipment used to transfer material or tooling, including fixtures, to assemble/disassemble, to inspect or test, or to package. [The associated electrical equipment, including the logic controller(s) and associated software or logic together with the machine actuators and sensors, are considered as part of the industrial machine.] [**70**:670.2]

3.3.56 Industrial Manufacturing System. A systematic array of one or more industrial machines that is not portable by hand and includes any associated material handling, manipulating, gauging, measuring, or inspection equipment. [**70**:670.2]

3.3.57 Input. The terminals where current, voltage, power, or driving force may be applied to a circuit or device; the state or sequence of states occurring on a specific input channel; or the device or collective set of devices used for bringing data into another device.

3.3.58 Inrush Current (Solenoid). The inrush current of a solenoid is the steady-state current taken from the line at rated voltage and frequency with the plunger blocked in the rated maximum open position.

3.3.59 Inrush Locked Rotor Current (Motor). See 3.3.66, Locked Rotor Current.

3.3.60 In Sight From (Within Sight From, Within Sight). Where this standard specifies that one equipment shall be "in sight from," "within sight from," or "within sight," and so forth, of another equipment, the specified equipment is to be visible and not more than 15 m (50 ft) distant from the other. [**70**:100]

3.3.61 Interlock (for safeguarding). An arrangement that interconnects guard(s) or device(s) with the control system or all or part of the electrical energy distributed to the machine.

3.3.62* Interrupting Rating. The highest current at rated voltage that a device is intended to interrupt under standard test conditions. [**70**:100]

3.3.63 Jogging (Inching). The quickly repeated closure of the circuit to start a motor from rest for the purpose of accomplishing small movements of the driven machine.

3.3.64 Live Parts. Energized conductive components. [**70**:100]

3.3.65 Location.

3.3.65.1 Dry Location. A location not normally subject to dampness or wetness. A location classified as dry may be temporarily subject to dampness or wetness, as in the case of a building under construction. [**70**:100]

3.3.65.2 Wet Location. Installations underground or in concrete slabs or masonry in direct contact with the earth; and in locations subject to saturation with water or other liquids, such as vehicle washing areas; and in unprotected locations exposed to weather. [**70**:100]

3.3.66 Locked Rotor Current. The steady-state current taken from the line with the rotor locked and with rated voltage (and rated frequency in the case of alternating-current motors) applied to the motor.

3.3.67 Marking. Signs or inscriptions attached by the manufacturer, for the identification of the type of a component or device.

3.3.68 Obstacle. A part preventing unintentional direct contact, but not preventing direct contact by deliberate action.

3.3.69 Output. The terminals where current, voltage, power, or driving force may be delivered by a circuit or device; the state or sequence of states occurring on a specific output channel; or the device or collective set of devices used for taking data out of another device.

3.3.70* Overcurrent. Any current in excess of the rated current of equipment or the ampacity of the conductor. It may result from overload, short circuit, or electrical fault. [**70**:100]

3.3.71* Overload. Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or a ground fault, is not an overload. [**70**:100]

3.3.72 Point of Operation. The location in the (machine) where the material or workpiece is positioned and work is performed.

3.3.73 Positive Opening Operation (of a contact element). The achievement of contact separation as the direct result of a specified movement of the switch actuator through nonresilient members (e.g., not dependent upon springs).

3.3.74 Power Circuit. A circuit used for supplying power from the supply network to units of equipment used for productive operation and to transformers supplying control circuits.

3.3.75* Programmable Electronic System (PES). A system based on one or more central processing units (CPUs), connected to sensors or actuators, or both, for the purpose of control or monitoring.

3.3.76* Protective Bonding Circuit. The whole of the protective conductors and conductive parts used for protection against electric shock in the event of an insulation failure.

3.3.77 Protective Conductor. A conductor required by some measures for protection against electric shock for electrically connecting exposed conductive parts, extraneous conductive parts, or main earthing terminal.

3.3.78 Qualified Person. One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved. [**70:**100]

3.3.79 Raceway. An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars, with additional functions as permitted in this standard. Raceways include, but are not limited to, rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquidtight flexible conduit, flexible metallic tubing, flexible metal conduit, electrical nonmetallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways. [**70**:100]

3.3.80* Receptacle. A contact device installed at the outlet for the connection of an attachment plug. A single receptacle is a single contact device with no other contact device on the same yoke. A multiple receptacle is two or more contact devices on the same yoke. [**70**:100]

3.3.81 Redundancy. The application of more than one device or system, or part of a device or system, with the objective of ensuring that in the event of one failing to perform its function another is available to perform that function.

3.3.82 Reference Designation. A distinctive code that serves to identify an item in a diagram, list, chart, and on the equipment.

3.3.83 Relative Humidity. The ratio between the amount of water vapor in the gas at the time of measurement and the amount of water vapor that could be in the gas when condensation begins, at a given temperature.

3.3.84* Risk. A combination of the probability and the degree of possible injury or damage to health in a hazardous situation.

3.3.85 Safeguard. A guard or protective device used as a safety measure to protect persons from a present or impending hazard.

3.3.86 Safeguarding. Those safety measures consisting of the use of specific means called safeguards to protect persons from hazards that cannot reasonably be removed or are not sufficiently limited by design.

3.3.87 Safety Control Circuit. The part of the control circuit that incorporates safety related components.

3.3.88 Safety Distance. The distance between the pinch point or point-of-operation and the presence-sensing safety device (PSSD) sensing field that ensures that the operator cannot reach the danger point before the machine comes to a full stop.

3.3.89 Safety Function (Safety Measure). A means that eliminates or reduces a hazard.

3.3.90 Safe Working Procedure. A method of working that reduces risk.

3.3.91 Servicing Level. Location on which persons normally stand when operating or maintaining the electrical equipment.

3.3.92 Short-Circuit Current. An overcurrent resulting from a short circuit due to a fault or an incorrect connection in an electric circuit.

3.3.93 Socket. See 3.3.80, Receptacle.

3.3.94 Special Permission. The written consent of the authority having jurisdiction. [**70:**100]

3.3.95 Stop.

3.3.95.1 Controlled Stop. The stopping of machine motion, while retaining power to the machine actuators during the stopping process.

3.3.95.2 Uncontrolled Stop. The stopping of machine motion by removing power to the machine actuators, all brakes and/or other mechanical stopping devices being activated.

3.3.96 Subassembly. An assembly of electrical devices connected together that forms a simple functional unit.

3.3.97 Subplate. An internal metal surface separate from the walls of an enclosure or controller on which various component parts of the controller are mounted and wired.

3.3.98* Supplementary Overcurrent Protective Device. A device that provides overcurrent protection that is limited in application, due to the wide range of permissible ratings and performance, and is only used where specifically permitted in this standard.

3.3.99* Supplier. An entity (e.g., manufacturer, contractor, installer, integrator) that provides equipment or services associated with the machine.

3.3.100 Switching Device. A device designed to make or break the current in one or more electric circuits.

3.3.101 Tap Conductors. As used in this standard, a tap conductor is defined as a conductor, other than a service conductor, that has overcurrent protection ahead of its point of supply that exceeds the value permitted for similar conductors that are protected as described elsewhere in this standard. [**70:**240.2]

3.3.102 Terminal. A conductive part of a device provided for electrical connection to circuits external to the device.

3.3.103 Tight (suffix). So constructed that the specified material is excluded under specified conditions.

3.3.104* Undervoltage Protection. The effect of a device that operates on the reduction or failure of voltage to cause and maintain the interruption of power.

3.3.105 User. An entity that utilizes the machine and its associated electrical equipment.

3.3.106 Ventilated. Provided with a means to permit circulation of air sufficient to remove excess heat, fumes, or vapors. [**70**:100]

3.3.107 Voltage, Nominal. A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (e.g., 120/240 volts, 480Y/277 volts, 600 volts). The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment. [**70**:100]

3.3.108 Wireway. A sheet-metal or flame-retardant nonmetallic trough with hinged or removable covers for housing and protecting electric wires and cable and in which conductors are laid in place after the wireway has been installed as a complete system.

Chapter 4 General Operating Conditions

4.1* General Considerations. This chapter describes the general requirements and conditions for the operation of the electrical equipment of the machine. The risks associated with the hazards relevant to the electrical equipment shall be assessed as part of the overall requirements for risk assessment of the machine.

4.2 Electrical Components and Devices. Electrical components and devices shall be installed and used assuming the operating conditions of ambient temperature, altitude, humidity, and supply voltage outlined in this chapter, and within their design ratings, taking into account any derating stipulated by the component or device manufacturer.

4.3 Electrical Supply.

4.3.1* General. The electrical equipment shall be designed to operate correctly with the conditions of the supply as specified according to one of the following:

(1) The requirements in 4.3.2, 4.3.3, and 4.3.4
(2) The requirements specified by the user
(3) The requirements specified by the supplier

4.3.2* Alternating Current (ac) Supplies.

4.3.2.1 Voltage. The electrical equipment shall be designed to operate correctly where the steady state supply voltage is from 90 percent to 110 percent of the nominal voltage.

4.3.2.2 Frequency. The electrical equipment shall be designed to operate correctly where the supply frequency is from 99 percent to 101 percent of the nominal frequency continuously. For short periods of time, the supply frequency shall be permitted to be from 98 percent to 102 percent of the nominal frequency.

4.3.2.3 Harmonics. The electrical equipment shall be designed to operate correctly where the harmonic distortion from the electric supply does not exceed 10 percent of the total voltage (rms value) between ungrounded conductors for the sum of the second through fifth harmonic. An additional 2 percent of the total voltage (rms value) between ungrounded conductors for the sum of the sixth through thirtieth harmonic shall be permitted.

4.3.2.4 Voltage Unbalance (in 3-Phase Supplies). The electrical equipment shall be designed to operate correctly where neither the voltage of the negative sequence component nor the voltage of the zero sequence component in 3-phase supplies exceeds 2 percent of the voltage of the positive sequence component.

4.3.2.5 Voltage Impulses. The electrical equipment shall be designed to operate correctly where the supply voltage impulses do not to exceed 1.5 milliseconds in duration with a rise/fall time between 500 nanoseconds and 500 microseconds. A peak supply voltage impulse shall not exceed more than 200 percent of the rated supply voltage (rms value).

4.3.2.6 Voltage Interruption. The electrical equipment shall be designed to operate correctly where the supply voltage is interrupted at zero voltage for not more than 3 milliseconds at any random time in the supply cycle. The time interval between successive voltage interruptions shall be more than 1 second.

4.3.2.7 Voltage Dips. The electrical equipment shall be designed to operate correctly where the supply voltage dips do not exceed 20 percent of the peak voltage of the supply for more than one cycle. The time interval between successive dips shall be more than 1 second.

4.3.3 Direct Current (dc) Supplies from Batteries.

4.3.3.1 Voltage. The electrical equipment shall be designed to operate correctly where the dc supply voltage of batteries is from 85 percent to 115 percent of the nominal voltage. A supply voltage from 70 percent to 120 percent of the nominal voltage shall be permitted for dc supplies to battery-operated vehicles.

4.3.3.2 Voltage Interruption. The electrical equipment shall be designed to operate correctly where the dc supply voltage of batteries is interrupted for a time interval not exceeding 5 milliseconds.

4.3.4 Direct Current (dc) Supplies from Converting Equipment.

4.3.4.1 Voltage. The electrical equipment shall be designed to operate correctly where the dc supply voltage of converting equipment is from 90 percent to 110 percent of the nominal voltage.

4.3.4.2 Voltage Interruption. The electrical equipment shall be designed to operate correctly where the dc supply voltage of converting equipment is interrupted for a time interval not exceeding 20 milliseconds. The time interval between successive voltage interruptions shall be more than 1 second.

4.3.4.3 Ripple (Peak-to-Peak). The electrical equipment shall be designed to operate correctly where the dc supply voltage ripple (peak-to-peak value) of converting equipment does not exceed 0.05 of the nominal voltage.

4.4* Physical Environment and Operating Conditions.

4.4.1* General. The electrical equipment shall be suitable for use in the physical environment and operating conditions specified in 4.4.3 to 4.4.6 and 4.4.8. When the physical environment or the operating conditions are outside those specified, an agreement between the supplier and the user shall be considered.

4.4.2* Electromagnetic Compatibility (EMC).

4.4.3* Ambient Operating Temperature. Electrical equipment shall be capable of operating correctly in the intended ambient air temperature. The ambient operating temperatures for correct operation of the electrical equipment shall be between air temperatures of 5°C and 40°C (41°F to 104°F).

4.4.4* Relative Humidity. The electrical equipment shall be capable of operating correctly within a relative humidity range of 20 to 95 percent (noncondensing). Harmful effects of relative humidity outside the permitted range shall be avoided by proper design of the equipment or, where necessary, by proper additional measures (e.g., built-in heaters, air conditioners, humidifiers).

4.4.5* Altitude. Electrical equipment shall be capable of operating correctly at altitudes up to 1000 m (3300 ft) above mean sea level.

4.4.6* Contaminants. Electrical equipment shall be adequately protected against the ingress of solid bodies and liquids *(see Section 12.3)*. Equipment shall be suitable for the environment where contaminants (e.g., dust, acids, corrosive gases, salt) are present.

4.4.7* Nonionizing Radiation.

4.4.8 Vibration, Shock, and Bump. Undesirable effects of vibration, shock, and bump, including those generated by the machine and its associated equipment and those created by the physical environment shall be avoided by the selection of suitable equipment, by mounting it away from the machine, or by the use of antivibration mountings.

4.5 Transportation and Storage. The electrical equipment shall be designed to withstand storage and transportation temperatures within the range of –25°C to 55°C (–13°F to +131°F) and up to 70°C (158°F) for short periods not exceeding 24 hours. Suitable means shall be provided to prevent damage from excessive moisture, vibration, stress, and mechanical shock during shipment.

4.6 Provisions for Handling. Heavy and bulky electrical equipment that has to be removed from the machine for transport or that is independent of the machine shall be provided with suitable means for handling by cranes or similar equipment.

4.7 Installation and Operating Conditions. The electrical equipment shall be installed and operated in accordance with the manufacturer's instructions. Any conditions that are outside the operating conditions specified in Chapter 4 shall be permitted where acceptable to both the manufacturer and user.

Chapter 5 Incoming Supply Circuit Conductor Terminations and Devices for Disconnecting and Removing Power

5.1 Incoming Supply Circuit Conductor Terminations.

5.1.1* Where practicable, the electrical equipment of a machine shall be connected to a single power supply circuit. Where it is necessary to use another supply circuit for certain parts of the equipment (e.g., electronic circuits, electromagnetic clutches), that supply circuit shall, as far as is practicable, be derived from devices (e.g., transformers, converters) forming part of the electrical equipment of the machine.

5.1.2 Connections to guarded terminal blocks or other devices ahead of the disconnecting means shall be permitted for excepted circuits according to 5.3.5. Terminals for more than one conductor shall be so identified.

5.1.3* Where a grounded conductor is used it shall be clearly indicated in the technical documentation of the machine, such as in the installation diagram and in the circuit diagram. A separate insulated terminal shall be provided for the grounded conductor.

5.1.4 All terminals for the incoming supply circuit connection shall be legibly marked.

5.2* Grounding Terminal. A grounding terminal shall be provided for each incoming supply circuit.

5.3 Supply Circuit Disconnecting (Isolating) Means.

5.3.1 General. The following general requirements apply to 5.3.2 through 5.3.5.

5.3.1.1 A supply circuit disconnecting means shall be provided for the following:

(1) Each incoming supply circuit to a machine
(2) The supply circuit to a feeder system using collector wires, collector bars, slip-ring assemblies, or flexible cable systems (reeled, festooned) to a machine or a number of machines
(3) Each on-board power source (e.g., generator)

5.3.1.1.1 Each disconnecting means required by 5.3.1.1 shall be legibly marked to indicate its purpose.

5.3.1.1.2 Where a machine is supplied by more than one supply circuit, a marking shall be installed at each supply circuit disconnect location denoting the location of all other supply circuit disconnects.

5.3.1.2 The supply circuit disconnecting means shall disconnect (isolate) the electrical equipment of the machine, including all control circuits, from the supply circuit when required (e.g., for work on the machine, including the electrical equipment). Circuits that are not required to be disconnected by the supply circuit disconnecting means shall comply with 5.3.5.

5.3.1.3 The supply circuit disconnecting means other than attachment plugs and receptacles shall be mounted within the control enclosure or immediately adjacent thereto.

Exception: Externally mounted supply circuit disconnecting means, whether interlocked or not interlocked with the control enclosure, supplying machines totaling 2 hp or less shall be permitted to be mounted up to 6 m (20 ft) away from the enclosure providing that the disconnecting means is in sight from and readily accessible to the operator.

5.3.1.4 Supply circuit disconnecting means mounted within or adjacent to the control enclosure shall be interlocked with the control enclosure in accordance with 6.2.3. Where the supply circuit disconnecting means is not adjacent to the control enclosure, or where the supply disconnecting means is an attachment plug and receptacle, a tool shall be required to open the control enclosure door and a label shall be attached to that door warning of dangerous voltage inside and advising disconnection of the power before opening.

5.3.1.5 Wire bending space shall be provided for the supply circuit disconnecting means in accordance with 430.10(B) of NFPA 70, *National Electrical Code*. Space shall be determined by maximum wire size of incoming lines. Accidental contact with the line side live parts shall be inhibited. The supply circuit conductors to the disconnecting means shall be separated from other internal conductors by either of the following:

(1) Mounting the disconnect as near as practicable to the top of the enclosure while dedicating sufficient space between the top of the enclosure and the disconnect for the supply circuit conductors
(2) Mounting the disconnect other than at the top of the enclosure and guarding its line side live parts against accidental contact, and by separating the supply circuit conductors from other internal conductors by the use of a barrier

5.3.1.6 There shall be no exposed live parts with the disconnecting means in the open (off) position.

5.3.1.7 Where two or more disconnecting means are provided within the control enclosure for multiple supply circuits,

they shall be grouped in one location where practicable. Protective interlocks for their correct operation shall be provided where a hazardous condition or damage to the machine or to the work in progress can occur.

5.3.2 Type. The supply circuit disconnecting device shall be one of the following types:

(1) A listed motor circuit switch (switch disconnector) rated in horsepower
(2) A listed, branch circuit rated, molded case circuit breaker
(3) A listed molded case switch
(4) An instantaneous trip circuit breaker that is part of a listed combination motor controller
(5) A listed self-protected combination controller limited to single motor applications
(6) An attachment plug and receptacle (plug/socket combination) for cord connection to motor loads totaling 2 hp or less

5.3.3 Requirements.

5.3.3.1 Where the supply circuit disconnecting device is one of the types in 5.3.2(1) through 5.3.2(5), the device shall fulfill all of the following requirements:

(1) Isolate the electrical equipment from the supply circuit and have one off (open) and one on (closed) position only. Circuit breakers are permitted to have a reset (tripped) position between off (open) and on (closed).
(2) Have an external operating means (e.g., handle).

Exception: Power-operated switchgear need not be operable from outside the enclosure where there are other means to open it.

(3) Be provided with a permanent means permitting it to be locked in the off (open) position only (e.g., by padlocks) independent of the door position. When so locked, remote as well as local closing shall be prevented.
(4) Simultaneously disconnect all ungrounded conductors of the power supply circuit.
(5) Be operable, by qualified persons, independent of the door position without the use of accessory tools or devices.
(6) Be rated for the application as follows:
    (a) The ampere rating shall be at least 115 percent of the sum of the full-load currents required for all equipment that may be in operation at the same time under normal conditions of use.
    (b) Where rated in horsepower, the horsepower rating shall be at least equal that which is defined by Table 430.151(B) of NFPA 70, *National Electrical Code,* for a locked rotor equivalent equal to the largest sum resulting from the locked rotor currents of any combination of motors that can be started simultaneously and the full-load currents of the remaining motor and nonmotor loads that can be operated at that time.
    (c) The voltage rating shall be at least equal to the nominal supply circuit voltage.

5.3.3.2 Where the supply circuit disconnecting device is one of the types in 5.3.2(1) through 5.3.2(5), the available fault current at the point of the supply to the machine shall not be greater than the short-circuit current rating of the disconnecting device.

5.3.3.3 When the supply circuit disconnecting device is an attachment plug and receptacle (plug/socket combination), it shall fulfill all of the following requirements:

(1) Have a load-break rating or be interlocked with a switching device that is load-break rated, capable of interrupting the locked rotor current of the largest motor plus the sum of the remaining load that is operating at that time
(2) Be of such a type and be so installed as to prevent unintended contact with live parts at any time even during insertion or removal of the connectors
(3) Have a first make, last break grounding (earthing) contact
(4) Have a retaining means to prevent unintended or accidental disconnection where rated at more than 20 amperes
(5) Be located within sight from the operator station and be readily accessible

5.3.3.3.1 In addition, a switching device on the machine shall be provided for switching the machine on and off.

5.3.4 Operating Handle.

5.3.4.1 The center of the grip of the operating handle of the disconnecting means, when in its highest position, shall be not more than 2.0 m (6 ft 7 in.) above the floor. A permanent operating platform, readily accessible by means of a permanent stair or ladder, shall be considered as the floor for the purpose of this requirement.

5.3.4.2 An operating handle of the disconnecting means shall meet the following criteria:

(1) Be readily accessible with doors in the open or closed position
(2) Maintain the environmental rating of the enclosure to the degree necessary for the application
(3) Not be restricted by the enclosure door when the door is in the open position

5.3.5 Excepted Circuits.

5.3.5.1 The following circuits shall not be required to be disconnected by the main supply circuit disconnecting means:

(1) Lighting circuits for lighting needed during maintenance or repair
(2) Attachment plugs and receptacles (plug and socket outlets) for the exclusive connection of repair or maintenance tools and equipment (e.g., hand drills, test equipment)
(3) Undervoltage protection circuits that are only used for automatic tripping in the event of supply circuit failure
(4) Circuits supplying equipment that are required to remain energized for satisfactory operation [e.g., temperature-controlled measuring devices, product (work in progress) heaters, program storage devices]

5.3.5.2 Supply circuits for excepted circuits shall comply with all of the following conditions:

(1) Be a separate primary disconnecting means, isolating transformer, and secondary overcurrent protection furnished in an enclosure and mounted either adjacent to the main control enclosure or within the control enclosure, adjacent to the main disconnecting means.
(2) Have line side (of the supply circuit disconnect) supply circuit connections internal to the control enclosure that are separate from and do not share a raceway with other conductors, and that are encased in rigid or flexible conduit if longer than 460 mm (18 in.)

5.3.5.3 The control interlocking circuits shall be capable of being disconnected at the control panel from which they are sourced.

5.3.5.4 Where circuits are not disconnected by the supply circuit disconnecting means, all of the following requirements shall be met:

(1) Permanent warning label(s) shall be placed adjacent to the supply circuit disconnecting means indicating that it does not de-energize all exposed live parts when it is in the open (off) (isolated) position.
(2) A corresponding statement shall be included in the machine documentation.
(3) A permanent warning label shall be placed in proximity to each excepted circuit, or shall be identified by color as defined in 14.2.4.

5.4 Means for Removal of Power for Prevention of Unexpected Start-Up.

5.4.1 Means for removal of power shall be provided when prevention of unexpected start-up is required (e.g., during maintenance where the unexpected start-up of a machine can create a hazard). Such means shall include all of the following:

(1) Appropriate for the intended use
(2) Conveniently located
(3) Readily identifiable
(4) Provided with permanent means for locking in the off position only

5.4.2 Removal of power can be accomplished by the use of the supply circuit disconnecting means, additional devices conforming to 5.3.2, or other means (e.g., a contactor switched off by a control circuit).

5.4.3 Where other means of removal of power are used, a single failure of any of its components shall not result in an inadvertent or unexpected start-up.

5.4.4 Other means of removal of power shall be employed only for situations that include the following:

(1) Routine exchange of work pieces, fixtures, and tools requiring no significant dismantling of the machine
(2) Work on the electrical equipment where all of the following conditions exist:
    (a) There is no hazard arising from electric shock and burn.
    (b) The switching off means cannot be negated by the work.
    (c) The work is of a minor nature (e.g., replacement of plug-in devices without disturbing existing wiring).
    (d) There is no hazard arising from the unexpected energizing or de-energizing of circuits.

5.5 Devices for Disconnecting (Isolating) Electrical Equipment.

5.5.1 Devices shall be provided for disconnecting (isolating) electrical equipment to enable work to be performed without a risk from electric shock or burn.

5.5.2 The supply circuit disconnecting device (*see Section 5.3*) shall be permitted to fulfill this requirement where there is no need for disconnecting individual portions of the electrical circuit.

5.5.3 Where it is expected that it will be necessary to work on separately operable parts of a machine, a disconnecting means shall be permitted for the electrical equipment of each such part of the machine requiring separate disconnection.

5.5.4 The following devices shall be permitted to fulfill the isolating function of 5.5.3:

(1) Devices described in 5.3.2
(2) A manual motor controller suitable for motor disconnecting and compliant with UL 508 where located on the load side of the last short-circuit protective device (in the branch)
(3) Redundantly monitored, remotely operated contactor isolating system that incorporates control lockout provisions and is listed for disconnection purposes.

5.5.5 The devices in 5.5.4 shall include all of the following:

(1) Readily accessible
(2) Within sight of the part of the machine requiring disconnection
(3) Readily identifiable
(4) For other than attachment plugs, provided with permanent means for locking in the off position only

Chapter 6 Protection from Electric Shock

6.1 General. Electrical equipment shall provide protection of persons from electrical hazards during both normal operation and during fault conditions.

6.2 Protection from Electric Shock During Normal Operation. Live parts operating at 50 volts rms ac or 60 volts dc or more shall be guarded against accidental contact.

6.2.1 Protection by Insulation of Live Parts. Live parts protected by insulation shall be completely covered with insulation that can only be removed by destruction. Such insulation shall be capable of withstanding the mechanical, chemical, electrical, and thermal stresses to which it can be subjected under normal operating conditions. Paints, varnishes, lacquers, and similar products shall not be considered adequate protection against electric shock under normal operating conditions.

6.2.2 Protection by Enclosures.

6.2.2.1 Direct Contact from Outside an Enclosure. In the absence of a rated enclosure, the determination of the suitability of an enclosure as protection from electrical shock shall be determined by using a test finger as described in Figure 6.2.2.1. The test finger shall be applied, without appreciable force, in every opening in the enclosure after removal of all parts of the enclosure that can be removed without the use of a tool.

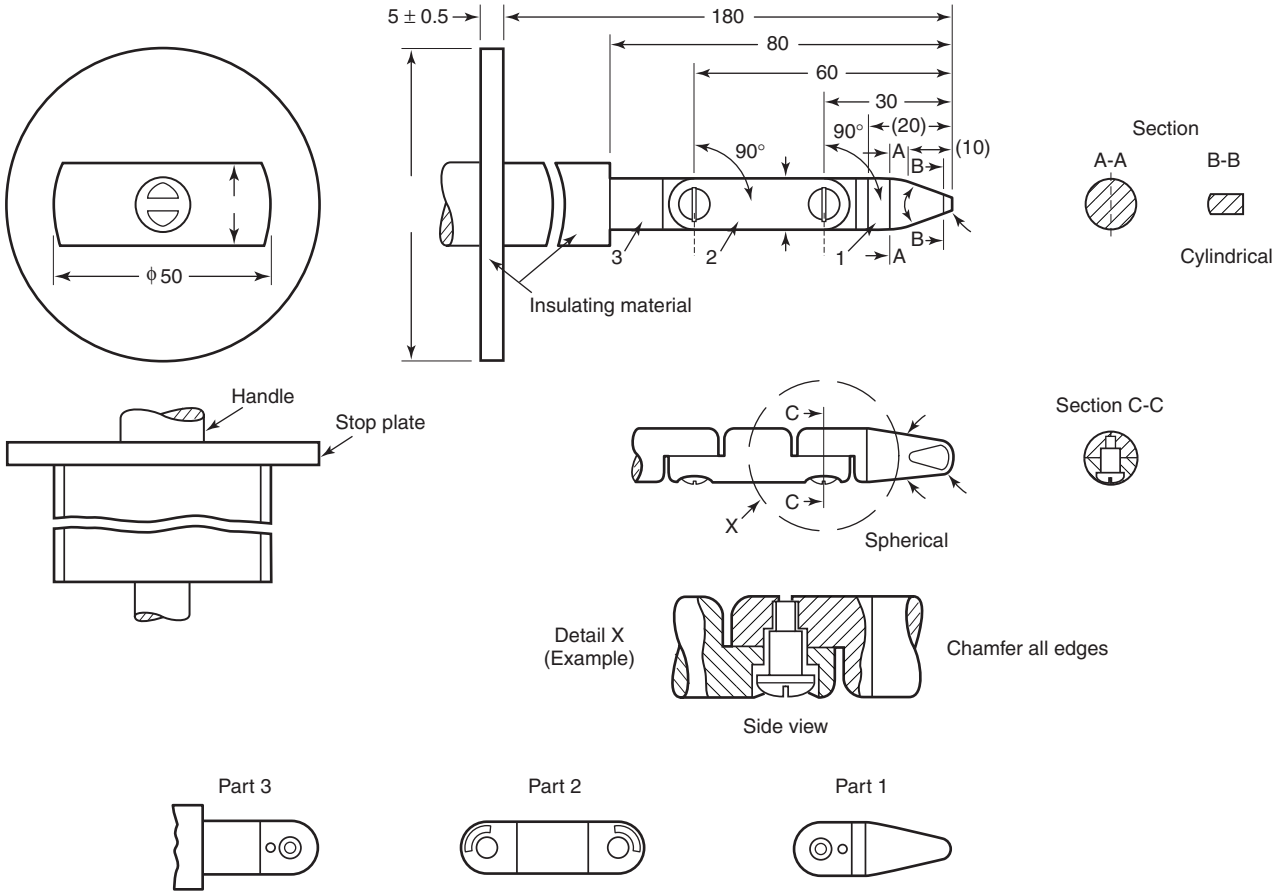
6.2.3 Enclosure Interlocking. Enclosure interlocking as described in 6.2.3.1 through 6.2.3.3 shall be provided.

6.2.3.1 Each disconnecting means mounted within or adjacent to a control enclosure that contains live parts operating at 50 volts ac (rms value) or 60 volts dc or more shall be mechanically or electrically interlocked, or both, with the control enclosure doors so that none of the doors can be opened unless the power is disconnected. Interlocking shall be reactivated automatically when all the doors are closed.

Exception No. 1: A disconnecting means used only for maintenance lighting circuits within control enclosures shall not be required to be interlocked with the control enclosure. A safety sign shall be provided that meets the requirements of 17.2.5.

Exception No. 2: A disconnecting means used for power supply circuits within control enclosures to memory elements and their support logic requiring power at all times to maintain information storage shall not be required to be interlocked with the control enclosure doors. A safety sign shall be provided that meets the requirements of 17.2.5.

6.2.3.1.1* Means shall be permitted to be provided for qualified persons, using appropriate work practices, to gain access without removing power.



Dimensions in millimeters

Tolerances on dimensions without specific tolerance:

On angles: $^{0}_{-10'}$

On linear dimensions:

up to 25 mm: $^{0}_{-0.05}$ mm

over 25 mm: ± 0.2 mm

Material of finger: heat-treated steel, etc.

Both joints of this finger may be bent through an angle of $(90^{+10}_{0})^{\circ}$ but in one and the same direction only.

Using the pin and groove solution is only one of the possible approaches in order to limit the bending angle to 90°. For this reason dimensions and tolerances of these details are not given in the drawing. The actual design must ensure a $(90^{+10}_{0})^{\circ}$ bending angle.

FIGURE 6.2.2.1 Jointed Test Finger.

6.2.3.1.2 The interlocking means shall meet the following requirements:

(1) Utilize a device or tool as specified by the manufacturer of the interlock to allow qualified persons to defeat the interlock
(2) Be reactivated automatically when the door(s) is closed
(3) Prevent closing of the disconnecting means while the enclosure door is open, unless an interlock is operated by deliberate action

6.2.3.2 Where a qualified (skilled) person, using appropriate work practices, needs to enter an enclosure that does not have a disconnect, one of the following conditions shall be met:

(1) The use of a key or tool shall be required for opening the enclosure.
(2) An enclosure door shall be permitted to be opened without the use of a key or a tool and without disconnection of live parts only when all live parts inside are separately enclosed or guarded such that there cannot be any direct contact with live parts.

6.2.3.3 Where the equipment has two or more sources of power or two or more independent disconnecting means, power wiring from each disconnecting means shall be run in separate raceway and shall not terminate in or pass through common junction boxes.

6.3 Protection by the Use of Protective Extra Low Voltage (PELV).

6.3.1 General Requirements. The use of PELV, as described in Section 6.3, is to protect persons against electric shock from indirect contact and limited area direct contact.

6.3.1.1 PELV circuits shall satisfy all of the following conditions:

(1)*The nominal voltage shall not exceed the following:
   (a) 30 volts ac (rms value) or 60 volts dc (ripple-free) when the equipment is used in normally dry locations and when large area contact of live parts with the human body is not expected
   (b) 6 volts ac (rms value) or 15 volts dc ripple-free in all other cases

(2) One side of the circuit or one point of the source of the supply of that circuit shall be connected to the equipment grounding (protective bonding) circuit.

(3)*Live parts of PELV circuits shall be electrically separated from other live circuits. Electrical separation shall be not less than that required between the primary and secondary circuits of a safety isolating transformer.

(4) Conductors of each PELV circuit shall be physically separated from those of any other circuit. When this requirement is impracticable, the insulation provisions of 14.1.3 shall apply.

(5) Attachment plugs and receptacles (plugs and socket combinations) for a PELV circuit shall conform to the following:
   (a) Attachment plugs (plugs) shall not be able to enter receptacles (socket-outlets) of other voltage systems.
   (b) Receptacles (socket-outlets) shall not admit plugs of other voltage systems.

6.3.2 Sources for PELV. The source for PELV shall be one of the following:

(1) A safety isolating transformer
(2) A source of current providing a degree of safety equivalent to that of the safety isolating transformer (e.g., a motor generator with winding providing equivalent isolation)
(3) An electrochemical source (e.g., a battery) or another source independent of a higher voltage circuit (e.g., a diesel-driven generator)
(4) An identified electronic power supply conforming to appropriate standards specifying measures to be taken to ensure that, even in the case of an internal fault, the voltage at the outgoing terminals cannot exceed the values specified in 6.3.1.1(1)

6.4 Protection Against Residual Voltages.

6.4.1 Live parts having a residual voltage greater than 60 volts after the supply has been disconnected shall be reduced to 60 volts or less within 5 seconds after disconnection of the supply voltage.

Exception No. 1: Exempted from this requirement are components having a stored charge of 60 microcoulombs or less.

Exception No. 2: Where such a provision would interfere with the proper functioning of the equipment, a durable warning notice drawing attention to the hazard and stating the delay required before entry to the enclosure is allowed shall be displayed at an easily visible location on or immediately adjacent to the enclosure containing the capacitance.

6.4.2 The withdrawal of plugs or similar devices, which results in the exposure of conductors (e.g., pins), shall have a discharge time that does not exceed 1 second.

Exception No. 1: Exempted from this requirement are components having a stored charge of 60 microcoulombs or less.

Exception No. 2: Exempted from this requirement are conductors that are protected against direct contact.

Chapter 7 Protection of Equipment

7.1 General. Chapter 7 shall detail the measures to be taken to protect equipment against the effects of the following:

(1) Overcurrent arising from a short circuit
(2) Overload currents
(3) Ground faults
(4) Overvoltages due to lightning and switching surges
(5) Abnormal temperatures
(6) Loss of or reduction in the supply voltage
(7) Overspeed of machines/machine elements
(8) Incorrect phase sequence

7.2 Overcurrent Protection.

7.2.1* General.

7.2.1.1 Overcurrent protection shall be provided where the current in a machine circuit can exceed either the rating of any component in the circuit or the current carrying capacity of the conductors in the circuit, whichever is the lesser value.

7.2.1.2 All protective devices shall be selected and applied with proper consideration being given to, but not limited to, the following:

(1) System maximum available fault current at the point of application
(2) Interrupting rating of the protective device
(3) Voltage rating of the system
(4) Load and circuit characteristics
   (a) Normal operating current
   (b) Inrush characteristics
   (c) Thermal withstand capability (I^2t)
   (d) Magnetic withstand capability (I_p)
(5) Current-limiting ability of the protective device
(6) Coordination of the protective devices to each other.

7.2.1.3 Supplementary overcurrent protective devices shall not be used as a substitute for branch-circuit overcurrent protective devices.

7.2.2* Supply Conductors. Unless otherwise specified by the user, the supplier of the electrical equipment shall not be responsible for providing the overcurrent protective device for the supply conductors to the electrical equipment. The supplier of the electrical equipment shall state on the installation diagram the data necessary for selecting this overcurrent protective device.

7.2.3 Power Circuits. Feeder and branch-circuit conductors shall be protected against overcurrent in accordance with their ampacities as specified in Section 13.5. In power circuits for motors, devices for detection and interruption of overcurrent, selected in accordance with 7.2.10, shall be applied to each ungrounded phase conductor.

7.2.4 Control Circuits.

7.2.4.1 General. A control circuit tapped from the load side of the branch-circuit short-circuit and ground-fault protective device(s) and functioning to control the load(s) connected to

that branch circuit shall be protected against overcurrent in accordance with 7.2.4.2. Such a tapped control circuit shall not be considered to be a branch circuit and shall be permitted to be protected by either a supplementary or branch-circuit overcurrent protective device(s).

7.2.4.2 Conductor Protection.

7.2.4.2.1 Conductors, other than flexible cords and fixture wires, shall be protected against overcurrent in accordance with their ampacities as specified in Section 13.5, unless otherwise permitted in 7.2.4.2.2 through 7.2.4.2.6.

7.2.4.2.2 Conductors sizes of 18, 16, and 14 AWG shall be considered as protected by an overcurrent device(s) of not more than a 20-ampere rating.

7.2.4.2.3 Conductors that do not extend beyond the control cabinet enclosure shall be considered protected by the load branch-circuit short-circuit and ground-fault protective device(s) where the rating of the protective device(s) is not more than 400 percent of the ampacity of the control circuit conductor for conductors 14 AWG and larger, or not more than 25 amperes for 18 AWG and 40 amperes for 16 AWG.

7.2.4.2.4 Conductors of 14 AWG and larger that extend beyond the enclosure shall be considered protected by the load branch-circuit short-circuit and ground-fault protective device(s) where the rating of the protective device(s) is not more than 300 percent of the ampacity of the control circuit conductors.

7.2.4.2.5 Conductors supplied by the secondary side of a single-phase transformer having a 2-wire (single-voltage) secondary shall be considered protected by overcurrent protection provided on the primary (supply) side of the transformer, if this protection is in accordance with 7.2.7 and does not exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary voltage ratio. Transformer secondary conductors (other than 2-wire) are not considered to be protected by the primary overcurrent protective device.

7.2.4.2.6 Conductors of control circuits shall be considered protected by the motor branch-circuit short-circuit and ground-fault protective device(s) where the opening of the control circuit would create a hazard (e.g., the control circuit of a magnetic chuck).

7.2.5 Receptacle (Socket) Outlets and Their Associated Conductors.

7.2.5.1 Overcurrent protection shall be provided for the circuits feeding general purpose receptacle (socket) outlets intended primarily for supplying power to maintenance equipment.

7.2.5.2 Overcurrent protective devices shall be provided in the ungrounded phase conductors of each circuit feeding receptacle (socket) outlets. Overcurrent protection for these receptacle (socket) outlets shall not exceed 15 amperes.

7.2.6 Lighting Circuits. Overcurrent protection for lighting branch circuits shall not exceed 15 amperes.

7.2.7 Transformers.

7.2.7.1 Transformers for motor control circuits shall be protected in accordance with Article 430, Part VI, of NFPA 70, *National Electrical Code*. Transformers for other than motor control circuits shall be protected in accordance with Article 450, Part I, of NFPA 70, *National Electrical Code*.

7.2.8 Location of Overcurrent Protective Devices. An overcurrent protective device shall be located at the point where the conductor to be protected is connected to the supply except as follows:

(1) Overcurrent protection at the supply shall not be required if all of the following conditions are met:
   (a) The current carrying capacity of the conductors is at least equal to that required for the load.
   (b) Each connecting conductor to the overcurrent protective devices is no longer than 3 m (10 ft).
   (c) The conductor is suitably protected from physical damage.
   (d) The conductor does not extend beyond the control panel enclosure.
   (e) The conductor terminates in a branch circuit rated circuit breaker, or a branch circuit rated set of fuses or a listed self-protected combination controller.
(2) Overcurrent protection at the supply shall not be required if all of the following conditions are met:
   (a) The conductor has an ampacity of at least one-third that of the conductor from which it is supplied.
   (b) The conductor is suitably protected from physical damage.
   (c) The conductor is not over 7.5 m (25 ft) long and the conductor terminates in a single circuit breaker or set of fuses.

7.2.9* Short-Circuit Interrupting Rating. The short-circuit interrupting rating shall be at least equal to the available fault current at the point of application. Where the short-circuit current to an overcurrent protective device can include additional currents other than from the supply (e.g., from motors, from power factor correction capacitors), these shall be taken into consideration.

7.2.10 Rating and Setting of Overcurrent Protective Devices.

7.2.10.1* Each motor controller and its associated wiring shall be protected as an individual branch circuit by a short-circuit protective device (SCPD) as specified by the controller manufacturer. The maximum rating of the designated SCPD shall be as shown in Table 7.2.10.1.

Exception: Table 7.2.10.1 shall not apply to Design B energy efficient motor circuits. The provisions of NFPA 70, National Electrical Code, shall be observed for Design B energy efficient motor circuits.

7.2.10.2 Several motors each not exceeding 1 hp in rating shall be permitted on a nominal 120-volt branch circuit protected at not over 20 amperes or a 600-volt nominal or less branch circuit, protected at not over 15 amperes, where all of the following conditions are met:

(1) The full-load rating of each motor does not exceed 6 amperes.
(2) The rating of the branch-circuit short-circuit and ground-fault protective device marked on any of the controllers is not exceeded.
(3) Individual overload protection conforms to Section 7.3.

7.2.10.3 Where the branch-circuit short-circuit and ground-fault protective device is selected not to exceed that allowed by 7.2.10.1 for the smallest rated motor, two or more motors or one or more motors and other load(s), with each motor having individual overload protection, shall be permitted to be connected to a branch circuit where it can be determined that the branch-circuit short-circuit and ground-fault protective device will not open under the most severe normal conditions of service that might be encountered.

Table 7.2.10.1 Maximum Rating[1] or Setting of Fuse and Circuit Breakers: Motor, Motor Branch Circuit, and Motor Controller

	Full-Load Current (%)		
Fuse Class with Non-Time Delay	**AC-2**	**AC-3**	**AC-4**
R	300	300	300
J	300	300	300
CC	300	300	300
T	300	300	300
	Type[3] of Application		
Fuse Class with Time Delay[2]	**AC-2**	**AC-3**	**AC-4**
RK-5[4]	150	175	175
RK-1	150	175	175
J	150	175	225
CC	150	300	300
Instantaneous trip circuit breaker[5]	800	800	800
Inverse trip circuit breaker[6]	150	250	250

Notes:

[1]Where the values determined by Table 7.2.10.1 do not correspond to the standard sizes or ratings, the next higher standard size, rating, or possible setting shall be permitted.

[2] Where the rating of a time-delay fuse (other than CC type) specified by the table is not sufficient for the starting of the motor, it shall be permitted to be increased but shall in no case be permitted to exceed 225 percent. The rating of a time-delay Class CC fuse and non-time-delay Class CC, J, or T fuse shall be permitted to be increased but shall in no case exceed 400 percent of the full-load current.

[3] Types of starting duty:

(1) AC-2: All light-starting duty motors, including slip-ring motors; starting, switching off.
(2) AC-3: All medium starting duty motors including squirrel-cage motors; starting, switching off while running, occasional inching, jogging, or plugging but not to exceed 5 operations per minute or 10 operations per 10 minutes and all wye-delta and two-step autotransformer starting motors.
(3) AC-4: All heavy starting duty motors including squirrel-cage motors; starting, plugging, inching, jogging.

[4]Unless a motor controller is listed for use with RK-5 fuses, Class RK-5 fuses shall be used only with NEMA-rated motor controllers.

[5]Instantaneous trip circuit breakers shall be permitted to be used only if they comply with all of the following:

(1) If they are adjustable.
(2) If part of a combination controller has motor-running protection and also short-circuit and ground-fault protection in each conductor.
(3) If the combination is especially identified for use.
(4) It is installed per any instructions included in its listing or labeling.
(5) If they are limited to single motor applications, circuit breakers with adjustable trip settings shall be set at the controller manufacturer's recommendation, but not greater than 1300 percent of the motor full-load current.

[6]Where the rating of an inverse time circuit breaker specified in Table 7.2.10.1 is not sufficient for the starting current of the motor, it shall be permitted to be increased but in no case exceed 400 percent for full-load currents of 100 amperes or less or 300 percent for full-load currents greater than 100 amperes.

7.2.10.4 Two or more motors and their control equipment shall be permitted to be connected to a single branch circuit where short-circuit and ground-fault protection is provided by a single inverse time circuit breaker or a single set of fuses, provided both of the following conditions are met:

(1)*Each motor controller and overload device is listed for group installation with specified short-circuit current ratings.

(2) The rating or setting of the overcurrent device does not exceed the values in Table 7.2.10.4 for the smallest conductor in the circuit.

7.2.11 Resistance Heating Branch-Circuit Overcurrent Protection.

7.2.11.1 If the branch circuit supplies a single nonmotor-operated load rated at 16.7 amperes or more, the overcurrent device rating shall not exceed 150 percent of the load rating.

Table 7.2.10.4 Relationship Between Conductor Size and Maximum Rating or Setting of Short-Circuit Protective Device for Power Circuits

	Maximum Rating	
Conductor Size (AWG)	Non-Time-Delay Fuse or Inverse Time Circuit Breaker (amperes)	Time Delay or Dual Element Fuse (amperes)
14	60	30
12	80	40
10	100	50
8	150	80
6	200	100
4	250	125
3	300	150
2	350	175
1	400	200
0	500	250
2/0	600	300
3/0	700	350
4/0	800	400

7.2.11.2 Equipment employing resistance-type heating elements rated at more than 48 amperes shall have the heating elements subdivided. Each subdivided load shall not exceed 48 amperes and shall be protected at not more than 60 amperes.

Exception: A single sheath-type heating element requiring more than 48 amperes shall be protected at not more than 125 percent of the load where the element is integral with and enclosed within the machine housing.

7.2.11.3 The additional overcurrent protective devices shall include all of the following:

(1) Installed within or on the machinery or provided as a separate assembly
(2) Accessible but need not be readily accessible
(3) Suitable for branch-circuit protection

The main conductors supplying these overcurrent protective devices shall be considered branch-circuit conductors.

7.2.12 Programmable Electronic System Power Supply Input Overcurrent Protection. Programmable electronic system power supply inputs shall be protected by overcurrent protective devices either externally or internally. The overcurrent protection size or rating shall be in accordance with the manufacturer's instructions.

7.2.13 Control Devices. Pushbuttons, selector switches, sensors, and limit switches shall in no case be connected to a circuit rated larger than 10 amperes.

7.2.14 Common Overcurrent Device. The use of the same overcurrent device to provide the protection called for in 7.2.4, 7.2.6, and 7.2.7 shall be permitted.

7.3 Overload Protection of Motors.

7.3.1 General. Overload devices shall be provided to protect each motor, motor controller, and branch-circuit conductor against excessive heating due to motor overloads or failure to start.

7.3.1.1 Motors. Motor overload protection shall be provided in accordance with Article 430, Part III, of NFPA 70, *National Electrical Code*.

7.3.1.2* Adjustable Speed Drives (Electronic Drives). Where load conditions or reduced speeds can cause motor overheating, embedded motor thermal protection (effective over the motor speed range) shall be provided and interlocked with the adjustable speed drive system.

Exception: In accordance with Section 430.2 of NFPA 70, National Electrical Code, where adjustable speed drives are marked to indicate that overload protection is included, additional overload protection shall not be required.

7.3.2 Resetting. Resetting of the overload device shall not restart the motor.

Exception: Where the machine has only a single motor of 2 hp or less, an overload reset operator mounted on the motor shall be permitted to restart the motor provided that the distance between the overload reset operator and the machine start pushbutton operator is 300 mm (12 in.) or less, and a suitable warning label is attached on or adjacent to the overload reset operator.

7.3.3 Number of Overloads. The minimum number and location of running overload units shall be determined from Table 7.3.3.

7.3.3.1 An overload unit in each phase shall not be required where overload protection is provided by other approved means.

7.3.3.2 Short-time–rated motors or high-reversing duty motors that cannot be adequately protected by external overload devices shall be protected by a thermal device mounted in the motor and sensitive to the temperature of the motor, or to both motor temperature and current.

7.3.3.3 Motors that are an integral part of a refrigeration compressor of the hermetic or semihermetic type shall be protected per the compressor manufacturer's recommendations.

Table 7.3.3 Running Overload Units

Kind of Motor	Supply System	Number and Location of Overload Units (Such as Trip Coils, Relays, or Thermal Cutouts)
1-phase, ac or dc	2-wire, 1-phase ac or dc ungrounded	1 in either conductor
1-phase, ac or dc	2-wire, 1-phase ac or dc, one conductor grounded	1 in ungrounded conductor
1-phase, ac or dc	3-wire, 1-phase ac or dc, one conductor grounded	1 in either ungrounded conductor
3-phase, ac	Any 3-phase	3, one in each phase

Note: For 2-phase power supply systems, see NFPA 70, *National Electrical Code,* Section 430.37.

7.4* Abnormal Temperature Protection. Resistance heating or other circuits that are capable of attaining or causing abnormal temperatures and, therefore, can cause a hazardous condition shall be provided with suitable detection to initiate an appropriate control response.

7.5 Protection Against Supply Interruption or Voltage Reduction and Subsequent Restoration.

7.5.1 General. Where a supply interruption or a voltage reduction can cause a hazardous condition or damage to the machine or to the work in progress, undervoltage protection shall be provided (e.g., to switch off the machine) at a predetermined voltage level. Where only a part of the machine or of the group of machines working together in a coordinated manner is affected by the voltage reduction or supply interruption, the undervoltage protection shall initiate appropriate control responses to ensure coordination.

7.5.2 Undervoltage Protection. Where the operation of the machine can allow for an interruption or a reduction of the voltage for a short time period, delayed undervoltage protection shall be permitted to be provided. The operation of the undervoltage device shall not impair the operation of any stopping control of the machine.

7.5.3 Restarting. Upon restoration of the voltage or upon switching on the incoming supply, automatic or unintentional restarting of the machine shall be prevented when such a restart can cause a hazardous condition.

7.6 Overspeed Protection.

7.6.1* Motor Overspeed Protection. Unless the inherent characteristics of the motor or the controller, or both, are such as to limit the speed adequately, drive systems motors shall include protection against motor overspeed where overspeed results in a hazardous condition.

7.6.2 Equipment Overspeed Protection. Where the safe operating speed of the equipment is less than that of the drive motor, means shall be provided to limit the speed of the equipment.

7.7 (Reserved)

7.8* Phase Sequence Protection. Where a phase loss or an incorrect phase sequence of the supply voltage can cause a hazardous condition or damage to the machine, protection shall be provided.

7.9 Protection Against Overvoltages Due to Lightning and Switching Surges.

7.9.1 Protective devices shall be permitted to be provided to protect against the effects of overvoltages due to lightning or switching surges.

7.9.2 Where provided, devices for the suppression for overvoltages shall be connected in accordance with product markings and installation instructions.

7.9.3 Where provided, devices for the suppression of overvoltages due to switching surges shall be connected across the terminals of all equipment requiring such protection.

7.10 Power Factor Correction Capacitors.

7.10.1* Overcurrent Protection. Where capacitors are installed for motor power factor correction on circuits of 600 volts, nominal, and under, overcurrent protection for the conductors shall be provided. Each capacitor cell or capacitor bank shall be protected against rupture of the individual cells. Protection included as a part of the capacitor assembly shall be permitted.

7.10.2 Discharge of Stored Energy. Capacitors shall be provided with a means of discharging stored energy. [**70**:460.6]

7.10.2.1 Time of Discharge. The residual voltage of a capacitor shall be reduced to 50 volts, nominal, or less, within 1 minute after the capacitor is disconnected from the source of supply. [**70**:460.6]

7.10.2.2 Means of Discharge. The discharge circuit shall be either permanently connected to the terminals of the capacitor or capacitor bank, or provided with automatic means of connecting it to the terminals of the capacitor bank upon removal of voltage from the line. Manual means of switching or connecting the discharge circuit shall not be used. [**70**:460.6]

Chapter 8 Grounding

8.1* General.

8.1.1 Applicability. This chapter shall provide for grounding, bonding, and grounded conductor requirements.

8.1.2 Connections. Grounded conductors shall not be connected to the equipment grounding (protective bonding) circuit, except for separately derived systems. Transformer mounting hardware shall not be used for either grounding or bonding terminations.

8.2 Equipment Grounding (Protective Bonding) Circuit.

8.2.1 Grounding System. The equipment grounding (protective bonding) circuit shall consist of the following:

(1) Equipment grounding (protective) conductor terminal(s)
(2) Conductive structural parts of the electrical equipment and the machine
(3) Equipment grounding (protective) conductors and equipment bonding jumpers

All parts of the equipment grounding (protective bonding) circuit shall be capable of withstanding the highest thermal and mechanical stress that can be caused by fault currents flowing in that part of the circuit. All exposed conductive parts of the electrical equipment and the machine(s) shall be connected to the equipment grounding (protective bonding) circuit.

Exception: Small parts such as screws, rivets, and nameplates that are not likely to become energized shall not be required to be grounded.

8.2.1.1 Equipment Grounding. The machine and all exposed, noncurrent-carrying conductive parts, material, and equipment likely to be energized shall be effectively grounded. Where electrical devices are mounted on metal mounting panels that are located within nonmetallic enclosures, the metal mounting panels shall be effectively grounded.

8.2.1.2* Equipment Grounding (Protective) Conductor Terminal.

8.2.1.2.1 For each incoming supply circuit, an equipment grounding (protective) conductor terminal shall be provided in the vicinity of the associated phase conductor terminals.

8.2.1.2.2 All of the items in 8.2.1.1 shall be interconnected to the equipment grounding (protective) conductor terminal.

8.2.1.2.3 The equipment grounding (protective) conductor terminal shall accommodate an equipment grounding conductor sized in accordance with Table 8.2.2.3.

8.2.1.2.4* The equipment grounding (protective) conductor terminal shall be identified with the word "GROUND," the letters "GND" or "GRD," the letter "G," the color GREEN, or the symbol in Figure 8.2.1.2.4. In addition to the required marking, the letters PE shall also be permitted to identify this terminal.

FIGURE 8.2.1.2.4 Grounding Symbol.

8.2.1.2.5 Where a supplementary electrode is specified, the terminal shall accommodate this additional grounding conductor.

8.2.2 Equipment Grounding (Protective) Conductors and Bonding Jumpers. Equipment grounding (protective) conductors and bonding jumpers shall be identified in accordance with 14.2.2.

8.2.2.1 Conductors used for grounding and bonding purposes shall be copper. Stipulations on stranding and flexing as outlined in Chapter 13 shall apply.

8.2.2.2 Equipment grounding conductors and bonding jumpers shall be insulated, covered, or bare and shall be protected against physical damage.

8.2.2.3 Equipment grounding conductors and bonding jumpers of the wire type shall not be smaller than shown in Table 8.2.2.3, but shall not be required to be larger than the circuit conductors supplying the equipment.

8.2.2.3.1 Machine members or structural parts of the electrical equipment shall be permitted to be used in the equipment grounding circuit provided that the cross-sectional area of these parts is at least electrically equivalent to the minimum cross-sectional area of the copper conductor required.

8.2.3 Continuity of the Equipment Grounding (Protective Bonding) Circuit.

8.2.3.1 The continuity of the equipment grounding (protective bonding) circuit shall be ensured by effective connections through conductors or structural members.

8.2.3.2 Removing a device shall not interrupt the continuity of the equipment grounding (protective) circuit.

8.2.3.3 Bonding of equipment with bolts or other identified means shall be permitted where paint and dirt are removed from the joint surfaces or where the bonded members are effectively penetrated.

8.2.3.4 Moving machine parts, other than accessories or attachments, having metal-to-metal bearing surfaces shall be considered as bonded. Sliding parts separated by a nonconductive fluid under pressure shall not be considered as bonded.

8.2.3.5 Raceways, wireways, and cable trays shall not be used as equipment grounding or bonding conductors.

Table 8.2.2.3 Minimum Size of Equipment Grounding Conductors and Bonding Jumpers

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of the Equipment (Not Exceeding Amperes)	Copper Conductor Size (AWG or kcmil)
10	16
15	14
20	12
30	10
40	10
60	10
100	8
200	6
300	4
400	3
500	2
600	1
800	1/0
1000	2/0
1200	3/0
1600	4/0
2000	250
2500	350
3000	400
4000	500
5000	700
6000	800

8.2.3.6 Doors or Covers.

8.2.3.6.1 Where electrical devices are mounted on conductive doors or covers, an equipment (protective) bonding jumper shall be installed.

8.2.3.6.2 Where required, an equipment (protective) bonding jumper shall connect the conductive door or cover to the equipment enclosure or to an equipment grounding (protective bonding) terminal within the enclosure.

8.2.3.7 Portable, pendant, and resilient-mounted equipment shall be bonded by separate conductors. Where multiconductor cable is used, the bonding conductor shall be included as one conductor of the cable.

8.2.3.8 Where equipment grounding conductors are subject to physical damage they shall be protected.

8.2.4* Exclusion of Switching Devices. The equipment grounding (protective bonding) circuit shall not contain any switches or overcurrent protective devices. Separable connections such as those provided in drawout equipment or attachment plugs and mating connectors and receptacles shall provide for first-make, last-break of the equipment grounding conductor. First-make, last-break shall not be required where interlocked equipment, plugs, receptacles, and connectors preclude energization without grounding continuity.

8.2.5 Equipment Grounding (Protective) Conductor Connecting Points.

8.2.5.1 All equipment grounding (protective) conductors shall be terminated in accordance with 14.1.1. The equipment grounding (protective) conductor connecting points shall have no other function.

8.2.5.2* The equipment grounding conductor connecting points, other than the equipment grounding terminal, shall be identified by the color GREEN, by the bicolor combination of GREEN-AND-YELLOW, or by use of the symbol in Figure 8.2.1.2.4.

8.3 Control Circuits. Control circuits shall be permitted to be grounded or ungrounded. Where grounding is provided, that side of the circuit common to the coils shall be grounded at the control transformer if alternating current or at the power supply terminal if direct current.

Exception No. 1: Exposed control circuits as permitted by Section 6.3 shall be grounded.

Exception No. 2: Overload relay contacts shall be permitted to be connected between the coil and the grounded conductor where the conductors between such contacts and coils of magnetic devices do not extend beyond the control enclosure.

8.3.1 Ungrounded control circuits shall be provided with an insulation monitoring device that either indicates a ground (earth) fault or interrupts the circuit automatically after a ground (earth) fault.

Exception: Class 2 low-voltage circuits in Article 725 of NFPA 70, National Electrical Code, shall not require insulation monitoring.

8.4 Lighting Circuits.

8.4.1 One conductor of all machine lighting and maintenance lighting circuits shall be grounded. The grounded conductor(s) shall be identified in accordance with Section 14.2.

8.4.2 Where the lighting circuit is supplied by a separate isolation transformer, one terminal of the secondary of the transformer shall be directly connected to the equipment grounding (protective bonding) circuit.

8.4.3 The grounded conductor, where run to a screw-shell lampholder, shall be connected to the screw-shell.

Chapter 9 Control Circuits and Control Functions

9.1 Control Circuits.

9.1.1 Control Circuit Supply.

9.1.1.1 Control transformers shall be used for supplying the control circuits. Control circuits shall not be derived from autotransformers. Control circuits supplied from windings of multiwinding power transformers shall be permitted if the output voltage of the winding supplying the control circuit does not exceed 120 volts ac and the available short-circuit current does not exceed 1000 amperes rms.

9.1.1.2 Where dc control circuits are connected to the equipment grounding (protective bonding) circuit, they shall be supplied from a separate winding of the ac control circuit transformer or by another control circuit transformer or a listed dc power supply.

9.1.1.3 Transformers shall not be required if the supply voltage does not exceed 120 volts ac and the available short-circuit current does not exceed 1000 amperes rms.

9.1.1.4 The source of supply for all control circuits shall be taken from the load side of the supply disconnecting means.

Exception: The power supply circuit to memory elements and their support logic requiring power at all times to maintain the storage of information shall be permitted to be taken from the line side of the supply disconnecting means or other power source.

9.1.1.5 The marking requirements of 17.2.4 shall apply.

9.1.2 Control Circuit Voltages.

9.1.2.1 AC Control Circuit Voltages. The ac voltage for control circuits shall not exceed 120 volts, ac single phase.

Exception No. 1: Other voltages shall be permitted, where necessary, for the operation of electronic, precision, static, or similar devices used in the control circuit.

Exception No. 2: Any electromechanical magnetic device having an inrush current exceeding 20 amperes at 120 volts shall be permitted to be energized at line voltage through contactor or relay contacts. The contactor or relay contacts shall break both sides of the line voltage circuit to the magnetic device. The relay coil shall be connected to the control circuit.

9.1.2.2 DC Control Circuit Voltages. DC control voltage shall be 250 volts or less.

9.1.3 Protection. Control circuits shall be provided with overcurrent protection in accordance with Chapter 7.

9.1.4 Connection of Control Circuit Devices.

9.1.4.1 All operating coils of electromechanical magnetic devices and indicator lamps (or transformer primary windings for indicator lamps) shall be directly connected to the same side of the control circuit. All control circuit contacts shall be connected between the coil and the other side of the control circuit.

Exception No. 1: Overload relay contacts where the wiring to these contacts does not extend beyond the control enclosure.

Exception No. 2: Contacts of multipole control circuit switching devices that simultaneously open both sides of the control circuit.

Exception No. 3: Ground test switching device contacts in ungrounded control circuits.

Exception No. 4: Solenoid test switching device contacts in ungrounded circuits.

Exception No. 5: Coils or contacts used in electronic control circuits where the wiring to these coils or contacts does not extend beyond the control enclosure.

Exception No. 6: "Run" pushbuttons for two-hand operation, such as for presses having ground detection circuits and overcurrent protection in each conductor.

9.1.4.2 Contacts shall not be connected in parallel where the purpose is to increase ampacity.

9.2 Control Functions.

9.2.1 Start Functions. Start functions shall operate by energizing the relevant circuit.

9.2.2* Stop Functions. The three categories of stop functions shall be as follows:

(1) Category 0 is an uncontrolled stop by immediately removing power to the machine actuators.
(2) Category 1 is a controlled stop with power to the machine actuators available to achieve the stop then remove power when the stop is achieved.
(3) Category 2 is a controlled stop with power left available to the machine actuators.

9.2.3 Operating Modes.

9.2.3.1 Each machine shall be permitted to have one or more operating modes (e.g., automatic, manual, normal, and bypass) determined by the type of machine and its application.

9.2.3.2 Where a hazardous condition results from mode selection, inadvertent selection shall be prevented from occurring (e.g., key-operated switch, access code). Mode selection by itself shall not initiate machine operation. A separate action by the operator shall be required.

9.2.3.3* Safeguarding means shall remain effective for all operating modes.

9.2.3.4 Indication of the selected operating mode shall be provided (e.g., position of mode selector, provision of indicating light, visual display indication).

9.2.4 Overriding Safeguards. Where it is necessary to temporarily override one or more safeguards, a mode selection device or means capable of being secured (e.g., locked) in the desired mode shall be provided to prevent automatic operation. The control circuit for the suspension of a safeguard shall have the same safety requirements as the suspended safeguard itself. In addition, one or more of the following measures shall be provided:

(1) Initiation of motion by a hold-to-run or other control device.
(2) A portable control station (e.g., pendant) with an emergency stop device, and where appropriate, an enabling device. Where a portable station is used, motion shall only be initiated from that station.
(3) Limiting the speed or the power of motion.
(4) Limiting the range of motion.

9.2.5 Operation.

9.2.5.1 General.

9.2.5.1.1 The necessary interlocks shall be provided for safe operation.

9.2.5.1.2 Measures shall be taken to prevent movement of the machine in an unintended manner after any stopping of the machine (e.g., locked-off condition, power supply fault, battery replacement, lost signal condition with cableless control).

9.2.5.2 Start.

9.2.5.2.1 The start of an operation shall be possible only where all of the safeguards are in place and functional except for conditions as described in 9.2.4.

9.2.5.2.2 On those machines where safeguards cannot be applied for certain operations, manual control of such operations shall be by hold-to-run controls together with enabling devices.

9.2.5.2.3 Interlocks shall be provided to ensure correct sequential starting.

9.2.5.2.4 On machines requiring the use of more than one control station to initiate a start, the following criteria shall be met:

(1) Each control station shall have a separate manually actuated start control device.
(2) All required conditions for machine operation shall be met.
(3) All start control devices shall be in the released (off) position before a start operation is permitted.
(4) All start control devices shall be actuated concurrently.

9.2.5.3 Stop.

9.2.5.3.1 Each machine shall be equipped with a Category 0 stop.

9.2.5.3.2 Category 0, Category 1, and/or Category 2 stops shall be provided where indicated by an analysis of the risk assessment and the functional requirements of the machine. Category 0 and Category 1 stops shall be operational regardless of operating modes, and Category 0 shall take priority. Stop function shall operate by de-energizing that relevant circuit and shall override related start functions.

9.2.5.3.3 Where required, provisions to connect protective devices and interlocks shall be provided. Where applicable, the stop function shall signal the logic of the control system that such a condition exists. The reset of the stop function shall not initiate any hazardous conditions.

9.2.5.4* Emergency Operations (Emergency Stop, Emergency Switching Off).

9.2.5.4.1 Emergency Stop. Emergency stop functions provided in accordance with 9.2.5.3 shall be designed to be initiated by a single human action.

9.2.5.4.1.1 In addition to the requirements for stop, the emergency stop shall have the following requirements:

(1) It shall override all other functions and operations in all modes.
(2) Power to the machine actuators, which causes a hazardous condition(s), shall be removed as quickly as possible without creating other hazards (e.g., by the provision of mechanical means of stopping requiring no external power, by reverse current braking for a Category 1 stop).
(3) Reset of an emergency stop circuit shall not initiate a restart.

9.2.5.4.1.2 Where required, provisions to connect additional emergency stop devices shall be provided in accordance with Section 10.7.

9.2.5.4.1.3 The emergency stop shall function as either a Category 0 or a Category 1 stop (*see 9.2.2*). The choice of the category of the emergency stop shall be determined by the risk assessment of the machine.

9.2.5.4.1.4 Where a Category 0 stop is used for the emergency stop function, it shall have only hardwired electromechanical components.

Exception: An electronic logic (hardware or software) system as well as the communication network or link that complies with both 9.4.3 and 11.3.4 and is listed for Category 0 emergency stop function shall be permitted. The final removal of power shall be accomplished by means of electromechanical components.

9.2.5.4.1.5 Where a Category 0 or a Category 1 stop is used for the emergency stop function, final removal of power to the machine actuators shall be ensured and shall be by means of electromechanical components. Where relays are used to accomplish a Category 0 emergency stop function, they shall be nonretentive relays.

9.2.5.4.2 Emergency Switching Off. Where the emergency switching off function is used, it shall be initiated by a single human action.

9.2.5.4.2.1 Emergency switching off shall be permitted as follows:

(1) Where protection against direct contact (e.g., with collector wires, collector bars, slip-ring assemblies, control gear in electrical operating areas) is achieved only by placing out of reach or by obstacles.
(2) Where other hazards or damage caused by electricity are possible.

9.2.5.4.2.2 Emergency switching off shall be accomplished by disconnecting the incoming supply circuit of the machine effecting a Category 0 stop. Where the machine cannot tolerate the Category 0 stop, it shall be necessary to provide other protection (e.g., against direct contact), so that emergency switching off is not necessary.

9.2.5.5 Hold-to-Run Controls.

9.2.5.5.1 Hold-to-run controls (e.g., jog, inch functions) shall require continuous actuation of the control device(s) to achieve operation.

9.2.5.5.2 Jog or inch functions shall operate only in the manual mode. Manual reverse shall be considered a jog function. The prevention of run or automatic operation during jog or inch shall be accomplished by an operator interface and a separate jog or inch selection method.

9.2.5.6* Two-Hand Control. All two-hand controls shall have the following features:

(1) The provision of two control devices shall require the concurrent actuation by both hands.
(2) It shall be necessary to actuate the control devices within a certain time limit of each other, not exceeding 0.5 seconds.
(3) Where this time limit is exceeded, both control devices shall be released before operation is initiated.
(4) The control devices shall require continuous actuation during the hazardous conditions.
(5) Machine operation shall cease upon the release of either control device when hazardous conditions are still present and
(6) Require the release of both control devices, before the machine operation is reinitiated.

9.2.5.7 Enabling Device.

9.2.5.7.1 When an enabling device is provided as a part of a system, it shall be designed to allow motion when actuated in one position only. In any other position, motion shall be stopped.

9.2.5.7.2 Enabling devices shall have the following features:

(1) Connect to a Category 0 or a Category 1 stop *(see 9.2.2)*
(2) Design follows ergonomic principles
(3) For two-position types, the positions are as follows:
    (a) Position 1 is the off function of the switch (actuator is not operated).
    (b) Position 2 is the enabling function (actuator is operated).
(4) For three-position types, the positions are as follows:
    (a) Position 1 is the off function of the switch (actuator is not operated).
    (b) Position 2 is the enabling function (actuator is operated in its mid position).
    (c) Position 3 is the off function of the switch (actuator is operated past its mid position).

A three-position enabling device shall require manual operation to reach Position 3. When returning from Position 3 to Position 2, the function shall not be enabled.

9.2.5.7.3 An enabling device shall automatically return to its off function when its actuator is not manually held in the enabling position.

9.2.6 Combined Start and Stop Controls. A single pushbutton and other devices that alternately start and stop motion shall only be used for secondary functions where no hazardous condition arises when they are operated.

9.2.7 Cableless Control Functions.

9.2.7.1 General.

9.2.7.1.1 Means shall be provided to remove or disconnect the power supply of the operator control station.

9.2.7.1.2 Means (e.g., key-operated switch, access code) shall be provided, as necessary, to prevent unauthorized use of the operator control station.

9.2.7.1.3 Each operator control station shall carry an unambiguous indication of which machine(s) is intended to be controlled by that operator control station.

9.2.7.2 Control Limitation.

9.2.7.2.1 Measures shall be taken to ensure that control commands affect only the following:

(1) The intended machine
(2) The intended functions

9.2.7.2.2 Measures shall be taken to prevent the machine from responding to signals other than those from the intended operator control station(s).

9.2.7.2.3 Means shall be provided so that the machine shall only be controlled from operator control stations in one or more predetermined zones or locations.

9.2.7.3 Stop Function.

9.2.7.3.1 Operator control stations shall include a separate and clearly identifiable means to initiate the stop function of the machine or of all the motions that causes a hazardous condition. The actuating means to initiate this stop function shall not be marked or labeled as an emergency stop device, even though the stop function initiated on the machine results in an emergency stop function.

9.2.7.3.2 A machine that has safety critical functions that are equipped with cableless control shall have a means of automatically initiating the stopping of the machine and preventing the initiation of potentially hazardous motions in the following situations:

(1) When a stop signal is received
(2) When a fault is detected in the system
(3)*When a valid signal has not been detected within a specified period of time

9.2.7.4* Serial Data Communication. In a machine where the control of safety critical functions relies on serial data transfer, correct communications shall be ensured by using an error detection method that is able to cope with up to three error bits in any command sequence. The safety capability of the serial data communication system shall be listed to have the same degree of safety capability as hardware-based components installed in accordance with this standard.

9.2.7.5 Use of More Than One Operator Control Station. Where a machine has more than one operator control station, measures shall be taken to ensure that only one control station shall be enabled at a given time. Indication of which operator control station is in control of the machine shall be provided at locations where necessary for the safety requirements of the machine.

Exception: A stop command from any one of the control stations shall be effective where necessary for the safety requirements of the machine.

9.2.7.6 Battery-Powered Operator Control Stations. A variation in the battery voltage shall not cause a hazardous condition. If one or more potentially hazardous motions are controlled using a battery-powered operator control station, a clear indication shall be given to warn the operator when a variation in battery voltage exceeds specified limits. Under those circumstances, the operator control station shall remain functional long enough to put the machine into a nonhazardous condition.

9.3 Protective Interlocks.

9.3.1 Reclosing or Resetting of an Interlocking Safeguard. The reclosing or resetting of an interlocking safeguard shall not initiate machine motion or operation that results in a hazardous condition.

9.3.2 Overtravel Limits. Where a machine overtravel causes a hazardous condition, a position sensor or limit switch shall be provided to initiate control action.

9.3.3 Operation of Auxiliary Functions.

9.3.3.1 Appropriate devices (e.g., pressure sensors) shall check the correct operation of the auxiliary functions.

9.3.3.2 Where the nonoperation of a motor or device for an auxiliary function (e.g., lubrication, coolant, swarf removal) causes a hazardous condition or causes damage to the machine or to the work in progress, interlocking shall be provided.

9.3.4 Interlocks Between Different Operations and for Contrary Motions.

9.3.4.1 All contactors, relays, and other control devices that control elements of the machine that cause a hazardous condition when actuated at the same time (e.g., those that initiate contrary motion) shall be interlocked against incorrect operation.

9.3.4.2 Motor contactors and starters that initiate opposing motion shall be both mechanically and electrically interlocked to prevent simultaneous operation. Relays and solenoids that are mechanically interlocked shall be electrically interlocked.

9.3.4.3 Where certain functions on the machine are required to be interrelated for safety or for continuous operation, coordination shall be ensured by interlocks. For a group of machines working together in a coordinated manner and having more than one controller, provision shall be made to coordinate the operations of the controllers as necessary.

9.3.4.4 Where a failure of a mechanical brake actuator results in the brake being applied when the associated machine actuator is energized and a hazardous situation results, interlocks shall be provided to switch off the machine actuator.

9.3.5 Reverse Current Braking.

9.3.5.1 Where reverse current braking is used on a motor, effective measures shall be taken to prevent the motor starting in the opposite direction at the end of braking where this reversal will cause a hazardous condition or damage to the machine or to the work in progress. For this purpose, the use of a device operating exclusively as a function of time shall not be allowed.

9.3.5.2 Control circuits shall be arranged so that rotation of a motor shaft, manually or otherwise, shall not result in a hazardous condition.

9.3.6 Protective Interlock. Where doors or guards have interlocked switches used in circuits with safety related functions, the interlocking devices shall be listed safety switches, have either positive (direct) opening operation, or provide similar reliability and prevent the operation of the equipment when the doors or guards are open (difficult to defeat or bypass).

9.4 Control Functions in the Event of Failure.

9.4.1* General Requirements. Where failures or disturbances in the electrical equipment can cause a hazardous condition or damage to the machine or the work in progress, measures shall be taken to minimize the probability of the occurrence of such failures or disturbances.

9.4.2 Protection Against Unintended Operation Due to Ground (Earth) Faults and Voltage Interruptions.

9.4.2.1 Ground (Earth) Faults. Ground (earth) faults on any control circuit shall not cause unintentional starting or potentially hazardous motions, or prevent stopping of the machine. Grounded control circuits shall be in accordance with Section 8.2 and Section 8.3. Ungrounded control circuits shall be provided with an insulation monitoring device that either indicates a ground (earth) fault or interrupts the circuit automatically after a ground (earth) fault. A restart of the machine with a detected ground (earth) fault shall be prevented.

9.4.2.2 Voltage Interruptions.

9.4.2.2.1 The requirements detailed in Section 7.5 shall apply.

9.4.2.2.2 Where a memory is used, its functioning in the event of power failure shall be ensured (e.g., by using a nonvolatile memory) where such loss of memory can result in a hazardous condition.

9.4.3* Control Systems Incorporating Software and Firmware Based Controllers. Control systems incorporating software and firmware based controllers performing safety-related functions shall conform to all of the following:

(1) In the event of any single failure perform as follows:
   (a) Lead to the shutdown of the system in a safe state
   (b) Prevent subsequent operation until the component failure has been corrected
   (c) Prevent unintended startup of equipment upon correction of the failure
(2) Provide protection equivalent to that of control systems incorporating hardwired/hardware components
(3) Be designed in conformance with an approved standard that provides requirements for such systems

Chapter 10 Operator Interface and Control Devices

10.1 General.

10.1.1* Applicability. This chapter shall contain the requirements for devices mounted outside or partially outside control enclosures.

10.1.2 Location and Mounting.

10.1.2.1 Control Devices. As far as is practicable, control devices shall be as follows:

(1) Readily accessible for service and maintenance
(2) Mounted in such a manner as to minimize the possibility of damage from activities such as material handling

10.1.2.2 Hand-Operated Control Devices. The actuators of hand-operated control devices shall be selected and installed as follows:

(1) They are not less than 0.6 m (2 ft) above the servicing level and are within easy reach of the normal working position of the operator.
(2) The operator is not placed in a hazardous situation when operating them.
(3) The possibility of inadvertent operation is minimized.

10.1.3* Protection. Operator interface, control devices, and enclosures shall be suitable for the environment and shall withstand the stresses of expected use.

10.1.4 Position Sensors.

10.1.4.1 Position sensors (e.g., limit switches, position switches, proximity switches) shall be arranged so that they will not be damaged in the event of overtravel.

10.1.4.2* Position sensors used in circuits with safety-related functions either shall have positive (direct) opening operation or shall provide similar reliability.

10.1.5 Portable and Pendant Control Stations.

10.1.5.1 Portable and pendant operator control stations and their control devices shall be selected and arranged to minimize the possibility of inadvertent machine operations.

10.1.5.2 Pendant control stations that are vertically suspended from overhead shall comply with 14.4.2.4 or 14.5.10.

10.1.6 Operator Interface Devices.

10.1.6.1 Location of Operator Interface Devices.

10.1.6.1.1 Operator interface devices shall be mounted in locations that will minimize exposure to oil, coolant, and other contaminants.

10.1.6.1.2 Operator interface devices shall be within normal reach of the machine operator and shall be placed so that the operator is not exposed to hazards.

10.1.6.1.3 Operator interface devices shall be located so that unintentional operation by normal movement of the machine, operator, or work will be unlikely.

10.1.6.2 Arrangement of Operator Interface Devices. All start pushbuttons shall be mounted above or to the left of their associated stop pushbuttons.

Exception No. 1: Start pushbuttons in series, such as operating pushbuttons on punch presses.

Exception No. 2: Wobble-stick or rod-operated emergency stop pushbuttons mounted in the bottom of pendant stations.

10.1.7 Foot-Operated Switches. Foot-operated switches used for applications where accidental actuation could create a hazardous situation shall be protected to prevent accidental actuation by falling or moving objects and from unintended operation by accidental stepping onto the switch.

Exception: Foot-operated switches used for emergency stop in accordance with 10.7.2.1 shall not be of the covered or hooded type.

10.2 Pushbutton Actuators and Color Graphic Interface Devices.

10.2.1 Pushbutton Actuators. Pushbutton actuators used to initiate a stop function shall be of the extended operator or mushroom-head type.

10.2.2 Colors. Pushbutton actuators and action initiating icons of color graphic interface devices shall be color-coded in accordance with 10.2.2.1 through 10.2.2.6.

10.2.2.1 Start or On. The preferred color of start or on shall be GREEN, except that BLACK, WHITE, or GRAY shall be permitted. RED shall not be used for start or on.

10.2.2.2 Stop or Off. The preferred color of stop or off shall be RED, except that BLACK, WHITE, or GRAY shall be permitted. GREEN shall not be used for stop or off.

Exception: Stop function operators of the wobble-stick or rod-operated types in the bottom of a pendant station need not be colored RED.

10.2.2.3 Emergency Stop. RED shall be used for emergency stop actuators in accordance with 10.7.4.

10.2.2.4 Alternate Action. Pushbuttons that, when pressed, act alternately as start and stop or on and off shall be BLACK, WHITE, or GRAY. RED, YELLOW, or GREEN shall not be used.

10.2.2.5 Abnormal Conditions. The color YELLOW shall be used for actuators used to respond to abnormal conditions.

10.2.2.6 Hold to Operate. Pushbuttons that cause movement when pressed and stop movement when they are released (e.g., jogging) shall be BLACK, WHITE, GRAY, or BLUE with a preference for BLACK.

10.2.2.7 Reset. Reset pushbuttons shall be BLUE, BLACK, WHITE, or GRAY except when they also act as a stop or off button, in which case they shall be RED.

10.2.3 Legends.

10.2.3.1 A legend shall be provided for each operator interface device to identify its function and shall be located so that it can be easily read by the machine operator from the normal operator position. The legends shall be durable and suitable for the operating environment.

Exception: Emergency stop devices require no legend if they meet the requirements of 10.7.4.

10.2.3.2 For illuminated pushbuttons, the function(s) of the light is separated from the function(s) of the button by a virgule (/).

10.3 Indicator Lights and Icons of Color Graphic Interface Devices.

10.3.1 Modes of Use. Indicator lights and icons of color graphic interface devices shall provide the following information:

(1) Indication to attract the operator's attention or to indicate that a certain task should be performed. The colors RED, YELLOW (AMBER), GREEN, and BLUE are normally used in this mode.
(2) Confirmation of a command or a condition, or the termination of a change or transition period. The colors BLUE and WHITE are normally used in this mode. GREEN shall be permitted to be used in some cases.

10.3.2 Colors. Indicator lights and icons of color graphic interface devices shall be color-coded with respect to the condition (status) of the machine in accordance with Table 10.3.2. Alternate purposes shall be permitted to indicate machine or process status.

Table 10.3.2 Machine Indicator Lights and Icons

	Purposes		
Color	Safety of Persons or Environment	Condition of Process	State of Equipment
RED	Danger	Emergency	Faulty
YELLOW (AMBER)	Warning/ Caution	Abnormal	Abnormal
GREEN	Safe	Normal	Normal
BLUE	Mandatory action		
CLEAR WHITE GRAY BLACK	No specific meaning assigned		

10.3.3 Flashing Lights. Flashing lights shall be permitted to be used for any of the following purposes:

(1) Attract attention
(2) Request immediate action
(3) Indicate a discrepancy between the command and actual states
(4) Indicate a change in process (flashing during transition)

10.4 Illuminated Pushbuttons. Illuminated pushbutton actuators shall be color-coded in accordance with Table 10.3.2. The color RED for the emergency stop actuator shall not depend on the illumination source.

10.5 Rotary Control Devices. Devices having a rotational member, such as potentiometers and selector switches, shall be mounted in such a way as to prevent rotation of the stationary member. Friction alone shall not be relied upon to prevent rotation.

10.6 Start Devices. Actuators used to initiate a start function or the movement of machine elements (e.g., slides, spindles, carriers) shall be constructed and mounted to minimize inadvertent operation. Mushroom-type actuators for two-hand control initiation shall conform to 9.2.5.6.

10.7 Devices for Stop and Emergency Stop.

10.7.1 Location and Operation.

10.7.1.1 Stop and emergency stop pushbuttons shall be continuously operable and readily accessible.

10.7.1.2 Stop or emergency stop pushbuttons shall be located at each operator control station and at other locations where emergency stop is required.

10.7.2 Types.

10.7.2.1 The types of devices for emergency stop shall include, but are not limited to, the following:

(1) Pushbutton-operated switches in accordance with 10.7.4
(2) Pull-cord-operated switches
(3) Foot-operated switches without a mechanical guard
(4) Push-bar-operated switches
(5) Rod-operated switches

10.7.2.2* Pushbutton-type devices for emergency stop shall be of the self-latching type and shall have positive (direct) opening operation.

10.7.2.3 Emergency stop switches shall not be flat switches or graphic representations based on software applications.

10.7.3 Restoration of Normal Function After Emergency Stop. It shall not be possible to restore an emergency stop circuit until the emergency stop device has been manually reset. Where several emergency stop devices are provided in a circuit, it shall not be possible to restore that circuit until all emergency stop devices that have been operated have been reset.

10.7.4 Emergency Stop Actuators. Actuators of emergency stop devices shall be colored RED. The background immediately around pushbuttons and disconnect switch actuators used as emergency stop devices shall be colored YELLOW. The actuator of a pushbutton-operated device shall be of the palm or mushroom-head type. The RED/YELLOW color combination shall be reserved exclusively for emergency stop applications.

Exception: The RED/YELLOW color combination shall be permitted for emergency stop actuators in accordance with 10.8.4.

10.7.5 Local Operation of the Supply Disconnecting Means to Effect Emergency Stop.

10.7.5.1 The supply disconnecting means shall be permitted to be locally operated to serve the function of emergency stop as follows:

(1) Where it is readily accessible to the operator
(2) Where it is of the type described in 5.3.2(1), 5.3.2(2), or 5.3.2(3)

10.7.5.2 Where used as an emergency stop, the supply disconnecting means shall meet the color requirements of 10.7.4.

10.8 Devices for Emergency Switching Off.

10.8.1 Location. Emergency switching off devices as described in 9.2.5.4.2 shall be located as necessary for the given application.

10.8.2 Types.

10.8.2.1 The types of devices that initiate an emergency switching off operation shall be permitted to include, but are not limited to, the following:

(1) Pushbutton-operated switches
(2) Pull-cord-operated switches

10.8.2.2 The pushbutton operated switch shall be permitted in a break-glass enclosure.

10.8.2.3 Emergency switching off devices shall not be flat switches or graphic representations based on software applications.

10.8.3 Restoration of Normal Function After Emergency Switching Off. It shall not be possible to restore an emergency switching off circuit until the emergency switching off circuit has been manually reset.

10.8.4 Actuators.

10.8.4.1 Actuators of emergency switching off devices shall be colored RED. The background immediately around the device actuator shall be permitted to be colored YELLOW.

10.8.4.2 Where the emergency switching off initiating device is separate from the emergency stop device, the emergency switching off initiating device shall be functionally identified.

10.8.5 Local Operation of the Supply Disconnecting Means to Effect Emergency Switching Off. Where the supply disconnecting means is to be locally operated for emergency switching off, it shall be readily accessible and shall meet the color requirements of 10.8.4.1.

10.9* Displays. Displays (e.g., visual display units, alarm annunciators, indicator lights, and the action-initiating icons of graphic interface devices) shall be selected and installed in such a manner as to be visible from the normal position of the operator.

Chapter 11 Electronic Equipment

11.1 General.

11.1.1 This chapter shall apply to all types of electronic equipment including programmable electronic systems, subassemblies, printed circuit boards, electronic components, and other miscellaneous solid-state equipment.

11.1.2 Electronic equipment used as part of an industrial machine, including subassemblies, printed circuit boards, devices, internal wiring, and components, shall not be required to be inspected at the time of installation of the industrial machine, except to detect alterations or damage, if the equipment has been listed by a qualified electrical testing laboratory.

11.1.3 Listed or labeled electronic equipment shall be permitted to be used without modifications, on or with industrial machines, where approved for the location and use.

11.2 Basic Requirements.

11.2.1 Equipment Grounding (Equipotential Bonding).

11.2.1.1 All input/output racks (remote or local), processor racks, and conductive enclosures of power supplies shall be electrically bonded together in accordance with the supplier's specifications and connected to the equipment grounding (protective bonding) circuit.

11.2.1.2 Where specified by the manufacturer, components and subassemblies shall be effectively bonded to the equipment grounding (protective bonding) circuit in accordance with the manufacturer's recommendations.

11.2.2 Subassemblies. Subassemblies shall be readily removable for inspection or replacement.

11.2.3 Electrical Noise and Transient Suppression. Transient suppression, isolation, or other appropriate means shall be provided where the electronic equipment generates electrical noise or transients, which can affect the operation of equipment.

11.2.4 Output Protection. Outputs controlled by programmable electronic systems shall be protected from overload and short-circuit conditions.

11.3 Programmable Equipment.

11.3.1 Software Modification. Programmable electronic systems shall be designed and constructed so that the ability to modify the application program shall be limited to authorized personnel and shall require special equipment or other means to access the program (e.g., access code, key-operated switch).

Exception: For safety reasons, the manufacturer or supplier shall be permitted to retain the right not to allow the user to alter the program.

11.3.2 Memory Retention and Protection.

11.3.2.1 Means shall be provided to prevent memory alteration by unauthorized persons.

11.3.2.2 Loss of memory shall not result in a hazardous condition.

11.3.2.3 Power supplies for electronic units that require memory retention shall have battery backup of sufficient capacity to prevent memory loss for a period of at least 72 hours.

11.3.3 Software Verification. Equipment using reprogrammable logic shall have means for verifying that the software is in accordance with the relevant program documentation.

11.3.4* Use in Safety-Related Functions. Software and firmware based controllers to be used in safety-related functions shall be listed for such use.

Chapter 12 Control Equipment: Location, Mounting, and Enclosures

12.1 General Requirements.

12.1.1 All control equipment shall be located and mounted so as to facilitate the following:

(1) Accessibility and maintenance of the equipment
(2) Protection against the external influences or conditions under which the equipment is intended to operate
(3) Operation and maintenance of the machine and its associated equipment

12.1.2 Minimum construction requirements shall comply with UL 508, UL 508A, UL 50, or NEMA 250 for metallic and nonmetallic enclosures.

12.1.3 The depth of the enclosure or compartment including doors or covers shall not be less than the maximum depth of the enclosed equipment plus the required electrical clearances.

12.1.4 Any door(s) that permits access to live parts operating at 50 volts ac (rms value) or 60 volts dc or more shall comply with 6.2.3.

12.2 Location and Mounting.

12.2.1 Accessibility and Maintenance.

12.2.1.1 All items of control equipment shall be placed and oriented so that they can be identified without moving them or the wiring. Where practicable, items that require checking or adjustment for correct operation or that are liable to need replacement, those actions shall be possible without dismantling other equipment or parts of the machine (except opening doors or removing covers). Terminals not associated with control equipment shall also conform to these requirements.

12.2.1.2 Terminal blocks shall be mounted to provide unobstructed access to the terminals and their conductors.

12.2.1.3 Exposed, nonarcing, bare, live parts operating at 50 volts ac (rms value) or 60 volts dc or more within an enclosure or compartment shall have an air space of not less than 13 mm (½ in.) between them and the uninsulated walls of the enclosure or compartment, including conduit fittings. The air space for uninsulated doors of the enclosure shall be not less than 25 mm (1 in.). Where barriers between metal enclosures or compartments and arcing parts are required, they shall be of flame-retardant, noncarbonizing insulating materials.

12.2.1.4* All control equipment shall be mounted so as to facilitate its operation and maintenance. Where a special tool is necessary to remove a device, the tool shall be supplied.

12.2.1.5 Threaded fasteners with machine threads shall be used to attach components to a subplate and shall provide sufficient thread engagement to maintain secure mounting.

12.2.1.5.1 Steel subplate thickness shall provide engagement of at least 2 full threads.

12.2.1.5.2 Aluminum subplate thickness shall provide engagement of at least 3 full threads.

12.2.1.5.3 Thread cutting or thread forming screws shall be permitted if the thread engagement requirements of 12.2.1.5.1 and 12.2.1.5.2 are met.

12.2.1.5.4 Sheet metal screws, rivets, welds, solders, or bonding materials shall not be used to mount components to a subplate.

Exception: Rivets shall be permitted to be used for attaching mounting rails and wiring channels provided the exposed surface is smooth and free from any portion of a protruding stud.

12.2.1.6 Swing frames or swing out panels shall be permitted, provided the swing is more than 110 degrees. Wiring shall not inhibit swing. Panel-mounted components behind swing frames shall be accessible when open.

12.2.1.7* Where control devices are connected through plug-in arrangements, their association shall be made clear by type (shape), marking, or reference designation, singly or in combination.

12.2.1.8 Attachment plugs and receptacles (plug/socket combinations) that are handled during normal operation shall be located and mounted so as to provide unobstructed access.

12.2.1.9 Test points, where provided, shall be mounted to provide unobstructed access, plainly marked to correspond with markings on the drawings, adequately insulated, and sufficiently spaced for connection of test leads.

12.2.2 Physical Separation or Grouping.

12.2.2.1 Machine compartments containing control equipment shall be completely isolated from coolant and oil reservoirs. The compartment shall be readily accessible and completely enclosed. The compartment shall not be considered enclosed where it is open to the floor, the foundation upon which the machine rests, or other compartments of the machine that are not clean and dry.

12.2.2.2 Pipelines, tubing, or devices (e.g., solenoid valves) for handling air, gases, or liquids shall not be located in enclosures or compartments containing electrical control equipment.

Exception No. 1: Equipment for cooling electronic devices.

Exception No. 2: Pipelines, tubings, or devices that are an integral part of listed equipment and are separated by suitable barriers.

12.2.2.3 Control devices mounted within the control enclosure and connected to the supply voltage, or to both supply and control voltages, shall be grouped separately from those connected only to the control voltages.

12.2.2.4 Terminals shall be separated into groups for power circuits, associated control circuits, and other control circuits, fed from external sources (e.g., for interlocking).

12.2.2.5 Terminal groups for power circuits, associated control circuits, and other control circuits shall be permitted to be mounted adjacently, provided that each group can be readily identified (e.g., by markings, by use of different sizes, by use of barriers, by colors).

12.2.3 Heating Effects. Heat-generating components (e.g., heat sinks, power resistors) shall be located so that the temperature of each component in the vicinity remains within the component manufacturer's specified limits.

12.3 Degrees of Protection.

12.3.1* The protection of control equipment against ingress of solid foreign objects and of liquids shall be adequate taking into account the external influences under which the machine is intended to operate (i.e., the location and the physical environmental conditions including dust, coolants, and swarf).

12.3.2 Enclosures of control equipment shall provide a degree of protection of at least NEMA Type 1.

Exception: Where removable collectors on collector wire or collector bar systems are used and NEMA Type 1 enclosures are not practicable, suitable protection shall be provided (e.g., elevation, guarding).

12.4 Enclosures, Doors, and Openings.

12.4.1 Enclosures shall be constructed and finished using materials capable of withstanding the mechanical, electrical, and thermal stresses, as well as the effects of humidity and corrosion that are likely to be encountered in normal service.

12.4.2 Where corrosion protection beyond normal requirements is needed, nonmetallic enclosures identified for the purposes shall be permitted if they meet the requirements of UL 508.

12.4.3 Subplates having a surface area of more than 15,484 cm^2 (2400 $in.^2$) shall have supports provided in addition to the panel mounting means to aid in subplate installation.

12.4.4 Enclosures and subplates shall be free of burrs and sharp edges.

12.4.5 Inherently corrosion-resistant surfaces of the enclosure interior, exterior, and subplates shall not be painted unless the paint process is suitable for the adhesion of the paint to the surface material.

12.4.6* Fasteners used to secure doors shall be of the captive type.

12.4.7 Door fasteners on enclosures and compartments with door openings shall comply with either UL 50, UL 508, UL 508A, or NEMA 250.

12.4.8 A print pocket sized to accommodate electrical diagrams shall be attached to the inside of the door of the control enclosure or compartment. Single-door and multi-door enclosures shall have at least one print pocket.

12.4.9 The joints or gaskets of doors, lids, covers, externally mounted accessories, interconnect panels, and enclosures shall withstand the deleterious effects of liquids, vapors, or

gases used on the machine. The means used to maintain the enclosure's degree of protection on doors, lids, and covers that require opening or removal for operation or maintenance shall be securely attached to either the door/cover or the enclosure and not deteriorate due to removal or replacement of the door or the cover, which would impair the degree of protection.

12.4.10 All openings in the enclosure, including those toward the floor or foundation or to other parts of the machine, shall be closed by the supplier(s) in a manner ensuring the protection specified for the equipment. Openings for cable entries shall be easily reopened on site. A suitable opening shall be permitted in the base of enclosures within the machine so that moisture due to condensation is allowed to drain.

12.4.11 Openings shall not be permitted between enclosures containing electrical equipment and compartments containing coolant, lubricating fluids, or hydraulic fluids, or compartments into which oil, other liquids, or dust can penetrate. This requirement shall not apply to electrical devices specifically designed to operate in oil (e.g., electromagnetic clutches) or to electrical equipment in which coolants are used.

12.4.12 Where there are holes in an enclosure for mounting purposes, care shall be taken so that after mounting, the holes do not impair the required protection.

12.4.13 Equipment that, in normal or abnormal operation, can attain a surface temperature sufficient to cause a risk of fire or harmful effect to an enclosure material shall be one of the following:

(1) Located within an enclosure that will withstand, without risk of fire or harmful effect, such temperatures as can be generated
(2) Mounted and located at a sufficient distance from adjacent equipment so as to allow safe dissipation of heat *(see also 12.2.3)*
(3) Otherwise screened by material that can withstand, without risk of fire or harmful effect, the heat emitted by the equipment

12.5 Spaces Around Control Cabinets and Compartments. Access and working space for control cabinets and compartments operating at 600 volts, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized shall comply with the provisions of Chapter 12. Sufficient access and working space shall be provided and maintained around all control cabinets and compartments to permit ready and safe operation and maintenance of such control cabinets and compartments.

12.5.1 Working Space. The working space shall permit at least 90-degree opening of control cabinet and compartment doors or hinged panels.

12.5.1.1 The depth of the working space in the direction of access to live parts shall not be less than indicated in Table 12.5.1.1. Distances shall be measured from the control cabinet or compartment front or opening.

Exception No. 1: Working space shall not be required in back or sides of control cabinets or compartments, where there are no renewable or adjustable parts on the back or sides and where all connections are accessible from locations other than the back or sides. Where rear access is required to work on de-energized parts on the back of enclosed control cabinet and compartment, a minimum working space of 762 mm (2½ ft) horizontally shall be provided.

Table 12.5.1.1 Working Space Depth

Nominal Voltage to Ground	Minimum Clear Distance		
	Condition 1	Condition 2	Condition 3
0–150	900 mm (3 ft)	900 mm (3 ft)	900 mm (3 ft)
151–600	900 mm (3 ft)	1 m (3½ ft)	1.2 m (4 ft)

Note: Where the conditions are as follows:
Condition 1 — Exposed live parts on one side and no live or grounded parts on the other side of the working space, or exposed live parts on both sides effectively guarded by insulating materials. Insulated wire or insulated busbars operating at not over 300 volts to ground shall not be considered live parts.
Condition 2 — Exposed live parts on one side and a grounded surface on the other side. Concrete, brick, or tile walls shall be considered as grounded.
Condition 3 — Exposed live parts on both sides of the working space (not guarded as provided in Condition 1) with the operator between.

Exception No. 2: By special permission, working space clearance depth of 762 mm (2½ ft) or less shall be permitted where all uninsulated parts are at a voltage no greater than 50 volts rms ac or 60 volts dc.

Exception No. 3: Condition 2 working clearance depth shall be permitted between control cabinets or compartments located across the aisle from each other or across from nonmachinery associated switchgear, panelboards, or motor control centers where conditions of maintenance and supervision ensure that written procedures have been adopted to prohibit the affected equipment doors on both sides of the aisle from being open at the same time and qualified persons who are authorized will service the installation.

Exception No. 4: Condition 1 working clearance depth shall be permitted between control cabinets or compartments located across the aisle from each other, or across from a grounded surface, and all associated control cabinet or compartment devices and equipment operating at greater than 50 volts rms ac or 60 volts dc are separately enclosed, guarded, or constructed so that openings to live parts of the devices and equipment will not permit the entry of a 12.5 mm (0.5 in.) diameter rod.

Exception No. 5: A working space clearance depth of 762 mm (2½ ft) shall be permitted where all of the following conditions are met:

(1) The control cabinet or compartment is operating at not over 150 volts line-to-line or line-to-ground.
(2) The conditions of maintenance and supervision ensure that only qualified persons will service the installation.
(3) The door(s) of the control cabinet or compartment open at least 90 degrees or are removable.

Exception No. 6: By special permission, working space clearance depth of less than 762 mm (2½ ft) shall be permitted where all of the following conditions are met:

(1) The control cabinet or compartment is operating at not over 150 volts line-to-line or line-to-ground.
(2) The conditions of maintenance and supervision ensure that only qualified persons will service the installation.
(3) The control cabinet and compartment requires a tool to open.
(4) Where only diagnostic troubleshooting and testing on live parts is involved.
(5) The door(s) of the control cabinet and compartment open at least 90 degrees or are removable.

12.5.1.2 The width of the working space in front of control cabinets and compartments shall be the width of the control cabinet or compartment, or 750 mm (2½ ft), whichever is greater.

12.5.1.3 The working space height shall be clear and extend from the grade, floor, or platform to a height of 2.0 m (6½ ft). Within the height requirements of Section 12.5, other equipment associated with the machine located above or below the control cabinet or compartment shall be permitted to extend not more than 150 mm (6 in.) beyond the front of the electrical control cabinet or compartment.

12.5.2 Access. At least one entrance of sufficient area shall be provided to give access to the working space around control cabinets or compartments.

12.5.2.1 Working space required by Section 12.5 shall not be used for storage.

12.5.2.2 When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, shall be suitably guarded.

12.5.3 Door in gangways and for access to electrical operating areas shall be at least 0.7 m (2 ft 4 in.) wide and 2.0 m (6½ ft) high, open outwards, and have a means (e.g., panic bolts or panic bars) to allow opening from the inside without the use of a key or tool.

12.6 Machine-Mounted Control Equipment.

12.6.1 Control equipment (e.g., limit switches, brakes, solenoids, position sensors) shall be mounted rigidly in a reasonably dry and clean location, unless designed for a specific environment, shall be protected from physical damage, and shall be free from the possibility of accidental operation by normal machine movements or by the operator.

Exception No. 1: A solenoid sealed in an individual oil-filled container shall be permitted.

Exception No. 2: Prewired devices (e.g., limit switches, proximity switches) provided with an identified cable need not be equipped with provisions for termination of conduit.

12.6.2 All limit switches or position sensors shall be installed so that accidental overtravel by the machine will not damage the limit switch or sensor.

12.6.3 Solenoids for operating devices shall be mounted so that liquids drain away from the electrical component enclosure.

Chapter 13 Conductors, Cables, and Flexible Cords

13.1 General Requirements.

13.1.1* General. Conductors, cables, and flexible cords shall be selected for the operating conditions and external influences that can exist. Conductors, cables, and flexible cords shall be identified for their intended use.

13.1.2 Wire Insulation. Conductors shall be insulated.

Exception No. 1: Busbars shall not be required to be insulated.

Exception No. 2: Bare conductors, such as capacitor or resistor leads and jumpers between terminals, shall be permitted where the method of securing provides electrical clearance.

Exception No. 3: Equipment grounding conductors and bonding jumpers shall be permitted to be covered or bare.

13.1.3 Type MI Cable. Mineral-insulated, metal-sheathed cable, Type MI, shall be permitted. Temperature range shall be 85°C (185°F) for dry and wet locations.

13.1.4 Conductors and Static Control. Conductors smaller than 18 AWG used to connect electronic programmable control, input/output, and static control shall be listed.

13.2 Conductors.

13.2.1 Conductor Material. Conductors shall be copper.

Exception No. 1: Aluminum alloy busbars, located internal to the enclosure, shall be permitted where suitable for the application.

Exception No. 2: The metal frame of the machine shall be permitted to be used as an equipment grounding (protective bonding) conductor.

13.2.2 Stranded Conductors. Conductors 22 through 4/0 AWG and 250 through 1000 kcmil shall be only of stranded soft-annealed copper. Requirements for conductor cross-sectional area, dc resistance, and stranding shall be in accordance with Table 13.2.2.

Exception No. 1: Conductors with stranding other than that specified in Table 13.2.2 shall be permitted on individual devices that are purchased completely wired (e.g., motor starters).

Exception No. 2: Conductors subject to temperatures, voltages, environmental conditions, or flexing exceeding the ratings listed in this chapter shall have suitable characteristics.

13.2.3 Constant Flexing. Where constant flexing service is required, conductor stranding shall conform to Table 13.2.2.

13.2.4 Solid Conductors. Solid conductors 24 to 30 AWG of soft-annealed copper shall be permitted for use within control enclosures where not subject to flexing.

13.2.5 Printed Wire Assemblies. Printed wire assemblies of flame-retardant material shall be permitted in place of conductor assemblies provided they are within control enclosures and are mounted in such a way as to minimize flexing or stress.

13.2.6 Shielded Conductors. Where shielding is used around conductors in single or multiconductor cables, a foil shield shall be permitted for nonflexing applications. A continuous drain wire shall be provided for foil shield types. A braided shield shall be used where subject to longitudinal flexing. Torsional flexing applications (e.g., a robot arm) shall require shields designed specifically for their use. The shields and drain wire shall be covered with an outer jacket that is suitable for the environment. In all cases the shield shall provide a continuous conduction surface in the presence of bending and flexing.

13.2.7 Special Cables and Conductors.

13.2.7.1 Other listed conductors and listed cables shall be permitted.

13.2.7.2 Special conductors such as RG -/U transmission cable shall be permitted where necessary for the proper functioning of the equipment.

13.3 Insulation.

13.3.1 The insulation and the finished wires and cables shall have flame-retardant properties and temperature limits and characteristics as follows:

(1) MTW — Moisture-, Heat-, and Oil-Resistant Thermoplastic
60°C (140°F) Wet Locations
90°C (194°F) Dry Locations

Table 13.2.2 Single Conductor Characteristics

Wire Size (AWG or kcmil)	Cross-Sectional Area, Nominal (cm/mm^2)	DC Resistance at 25°C (ohms/1000 ft)	Minimum Number of Strands		
			Nonflexing (ASTM Class)	Flexing (ASTM Class)	Constant Flex (ASTM Class/AWG Size)
22 AWG	640/0.324	17.2	7(‘)	7(‘)	19(M/34)
20	1020/0.519	10.7	10(K)	10(K)	26(M/34)
18	1620/0.823	6.77	16(K)	16(K)	41(M/34)
16	2580/1.31	4.26	19(C)	26(K)	65(M/34)
14	4110/2.08	2.68	19(C)	41(K)	41(K/30)
12	6530/3.31	1.68	19(C)	65(K)	65(K/30)
10	10380/5.261	1.060	19(C)	104(K)	104(K/30)
8	16510/8.367	0.6663	19(C)	(\)	(–)
6	26240/13.30	0.4192	19(C)	(\)	(–)
4	41740/21.15	0.2636	19(C)	(\)	(–)
3	52620/26.67	0.2091	19(C)	(\)	(–)
2	66360/33.62	0.1659	19(C)	(\)	(–)
1	83690/42.41	0.1315	19(B)	(\)	(–)
1/0	105600/53.49	0.1042	19(B)	(\)	(–)
2/0	133100/67.43	0.08267	19(B)	(\)	(–)
3/0	167800/85.01	0.06658	19(B)	(\)	(–)
4/0	211600/107.2	0.05200	19(B)	(\)	(–)
250 kcmil	- /127	0.04401	37(B)	(\)	(–)
300	- /152	0.03667	37(B)	(\)	(–)
350	- /177	0.03144	37(B)	(\)	(–)
400	- /203	0.02751	37(B)	(\)	(–)
450	- /228	0.02445	37(B)	(\)	(–)
500	- /253	0.02200	37(B)	(\)	(–)
550	- /279	0.02000	61(B)	(\)	(–)
600	- /304	0.01834	61(B)	(\)	(–)
650	- /329	0.01692	61(B)	(\)	(–)
700	- /355	0.01572	61(B)	(\)	(–)
750	- /380	0.01467	61(B)	(\)	(–)
800	- /405	0.01375	61(B)	(\)	(–)
900	- /456	0.01222	61(B)	(\)	(–)
1000	- /507	0.01101	61(B)	(\)	(–)

Notes:
(B), (C), (K): ASTM Class designation B and C per ASTM B 8-1999; Class designation K per ASTM B 174-1995.
(‘): A class designation has not been assigned to this conductor but it is designated as 22-7 AWG in ASTM B 286-1995 and is composed of strands 10 mils in diameter (30 AWG).
(\): Nonflexing construction shall be permitted for flexing service per ASTM Class designation B 174-1995, Table 3.
(–): Constant flexing cables are not constructed in these sizes.

(2) THHN — Heat-Resistant Thermoplastic
90°C (194°F) Dry Locations
(3) THW — Moisture- and Heat-Resistant Thermoplastic
75°C (167°F) Dry and Wet Locations
(4) THWN — Moisture- and Heat-Resistant Thermoplastic
75°C (167°F) Dry and Wet Locations
(5) RHH — Thermoset
90°C (194°F) Dry Locations
(6) RHW — Moisture-Resistant Thermoset
75°C (167°F) Dry and Wet Locations
(7) RHW-2 — Moisture-Resistant Thermoset
90°C (194°F) Dry and Wet Locations
(8) XHHW — Moisture-Resistant Thermoset
75°C (167°F) Wet Locations
90°C (194°F) Dry Locations
(9) XHHW-2 — Moisture-Resistant Thermoset
90°C (194°F) Dry and Wet Locations

13.3.2 The average and the minimum thickness of the insulation in constructions A and B shall be in accordance with Table 13.3.2.

13.3.3 Construction B shall have a nylon jacket applied directly over the insulation. The jacket shall be snug on the insulation and shall be at least as thick as indicated in Table 13.3.2.

13.4 Wire Markings.

13.4.1 A durable legend printed on the outer surface of the insulation of construction A, on the outer surface of the nylon jacket of construction B, on the outer surface of the insulation under the jacket of construction B (only if clearly legible

Table 13.3.2 Thickness of Single Conductor Insulation (Mils)

Wire Size (AWG or kcmil)	A	B
	Average/Minimum	Average/Minimum (Jacket)
22 AWG	30/27	15/13(4)
20	30/27	15/13(4)
18	30/27	15/13(4)
16	30/27	15/13(4)
14	30/27	15/13(4)
12	30/27	15/13(4)
10	30/27	20/18(4)
8	45/40	30/27(5)
6	60/54	30/27(5)
4–2	60/54	40/36(6)
1–4/0	80/72	50/45(7)
250–500 kcmil	95/86	60/54(8)
550–1000	110/99	70/63(9)

Notes:
A — No outer covering.
B — Nylon covering.
Source: UL 1063, Table 1.1, *NEC* Construction.

through the nylon), or on the outer surface of the jacket of a multiconductor cable shall be repeated at intervals of no more than 610 mm (24 in.) throughout the length of the single-conductor or the multiconductor cable.

Exception: Sizes smaller than 16 AWG shall be permitted to be marked on the reel or on the smallest unit of the shipping carton.

13.4.2 The legend shall include the manufacturer's name or trademark, the wire type, voltage rating, and gauge or size.

13.4.3 Where the conductor is 16 through 10 AWG and the stranding is intended for flexing service, the legend shall include "flexing" or "Class K."

13.4.4 Wire insulation shall be identified and adequate for the voltage on that conductor.

13.5 Conductor Ampacity.

13.5.1 The continuous current carried by conductors shall not exceed the values given in Table 13.5.1.

13.5.2 Ampacity adjustment for 90°C insulated conductors ampacities shall be based on the ampacities in the 75°C column of Table 13.5.1.

13.5.3 Motor circuit conductors supplying a single motor shall have an ampacity not less than 125 percent of the motor full-load current rating.

13.5.4 Combined load conductors shall have an ampacity not less than 125 percent of the full-load current rating of all resistance heating loads plus 125 percent of the full-load current rating of the highest rated motor plus the sum of the full-load current ratings of all other connected motors and apparatus based on their duty cycle in operation at the same time.

13.5.5 Where ampacity derating is required for ambient temperature correction for other than 30°C or adjusted for more than three current-carrying conductors in a raceway or cable, the factor(s) shall be taken from Table 13.5.5(a) and Table 13.5.5(b).

Table 13.5.1 Conductor Ampacity Based on Copper Conductors with 60°C and 75°C Insulation in an Ambient Temperature of 30°C

Conductor Size (AWG)	Ampacity	
	60°C	75°C
30	–	0.5
28	–	0.8
26	–	1
24	2	2
22	3	3
20	5	5
18	7	7
16	10	10
14	15	15
12	20	20
10	30	30
8	40	50
6	55	65
4	70	85
3	85	100
2	95	115
1	110	130
1/0	125	150
2/0	145	175
3/0	165	200
4/0	195	230
250	215	255
300	240	285
350	260	310
400	280	335
500	320	380
600	355	420
700	385	460
750	400	475
800	410	490
900	435	520
1000	455	545

Notes:
1. Wire types listed in 13.3.1 shall be permitted to be used at the ampacities listed in this table
2. The sources for the ampacities in this table are Table 310-16 of NFPA 70, *National Electrical Code*.

Sizing of conductors within control enclosures in wiring harnesses or wiring channels shall be based on the ampacity in cable or raceway. These factors shall apply to NFPA 70, Article 725, Class 1, control conductors, only if their continuous load exceeds 10 percent of the conductor ampacity.

13.5.6 The maximum size of a conductor selected from Table 13.5.1 and connected to a motor controller shall not exceed the values given in Table 13.5.6.

Exception: Where other motor controllers are used, the maximum conductor size shall not exceed that specified by the manufacturer.

13.5.7 Conductor/Terminal Compatibility. The conductor(s) shall be compatible with the device terminal(s), and the conductor size(s) shall not exceed the range recommended by the device manufacturer.

Table 13.5.5(a) Correction Factors

Ambient Temperature (°C)	Factor 75°C	Ambient Temperature (°F)
21 – 25	1.05	70 – 77
26 – 30	1.00	78 – 86
31 – 35	.94	87 – 95
36 – 40	.88	96 – 104
41 – 45	.82	105 – 113
46 – 50	.75	114 – 122
51 – 55	.67	123 – 131
56 – 60	.58	132 – 140
61 – 70	.33	141 – 158

Table 13.5.5(b) Adjustment Factors for More Than Three Current-Carrying Conductors in a Raceway or Cable

Number of Current-Carrying Conductors	Percent of Values in Table 13.5.5(a) as Adjusted for Ambient Temperature if Necessary
4 – 6	80
7 – 9	70
10 – 20	50
21 – 30	45
31 – 40	40
41 and above	35

Table 13.5.6 Maximum Conductor Size for Given Motor Controller Size*

Motor Controller Size	Maximum Conductor Size (AWG or kcmil)
00	14 AWG
0	10
1	8
2	4
3	1/0
4	3/0
5	500 kcmil

*See ANSI/NEMA ICS 2 [1993] Table 2, 110-1.

13.6 Conductor Sizing.

13.6.1 Conductors shall not be smaller than 14 AWG for power circuits unless otherwise permitted in 13.6.1.1 or 13.6.1.2.

13.6.1.1 16 AWG shall be permitted if part of a jacketed multiconductor cable assembly or flexible cord, or individual conductors used in a cabinet or enclosure, under the following conditions:

(1) Non-motor power circuits of 8 amperes or less provided all the following conditions are met:
   (a) Circuit is protected in accordance with Chapter 7.
   (b) Overcurrent protection does not exceed 10 amperes.
   (c) Overcurrent protection is provided by one of the following:
      i. A branch circuit rated circuit breaker listed and marked for use with 16 AWG wire
      ii. Branch circuit rated fuses listed and marked for use with 16 AWG wire
      iii. Class CC, Class J, or Class T fuses

(2) Motor power circuits with a full-load ampacity of 8 amperes or less provided all the following conditions are met:
   (a) Circuit is protected in accordance with Chapter 7.
   (b) Circuit is provided with Class 10 overload protection.
   (c) Overcurrent protection is provided by one of the following:
      i. A branch circuit rated circuit breaker listed and marked for use with 16 AWG wire
      ii. Branch circuit rated fuses listed and marked for use with 16 AWG wire
      iii. Class CC, Class J, or Class T fuses

(3) Motor power circuits with a full-load ampacity of 5.5 amperes or less provided all the following are met:
   (a) Circuit is protected in accordance with Chapter 7.
   (b) Circuit is provided with Class 20 overload protection.
   (c) Overcurrent protection is provided by one of the following:
      i. A branch circuit rated circuit breaker listed and marked for use with 16 AWG wire
      ii. Branch circuit rated fuses listed and marked for use with 16 AWG wire
      iii. Class CC, Class J, or Class T fuses

13.6.1.2 18 AWG shall be permitted if part of a jacketed multiconductor cable assembly or flexible cord, or individual conductors used in a cabinet or enclosure, under the following conditions:

(1) Non-motor power circuits of 5.6 amperes or less provided all the following conditions are met:
   (a) Circuit is protected in accordance with Chapter 7.
   (b) Overcurrent protection does not exceed 7 amperes.
   (c) Overcurrent protection is provided by one of the following:
      i. A branch circuit rated circuit breaker listed and marked for use with 18 AWG wire
      ii. Branch circuit rated fuses listed and marked for use with 18 AWG wire
      iii. Class CC, Class J, or Class T fuses

(2) Motor power circuits with a full-load ampacity of 8 amperes or less provided all the following conditions are met:
   (a) Circuit is protected in accordance with Chapter 7.
   (b) Circuit is provided with Class 10 overload protection.
   (c) Overcurrent protection is provided by one of the following:
      i. A branch circuit rated circuit breaker listed and marked for use with 18 AWG wire
      ii. Branch circuit rated fuses listed and marked for use with 18 AWG wire
      iii. Class CC, Class J, or Class T fuses

(3) Motor power circuits with a full-load ampacity of 5.5 amperes or less provided all the following are met:
   (a) Circuit is protected in accordance with Chapter 7.
   (b) Circuit is provided with Class 20 overload protection.

(c) Overcurrent protection is provided by one of the following:
   i. A branch circuit rated circuit breaker listed and marked for use with 18 AWG wire
   ii. Branch circuit rated fuses listed and marked for use with 18 AWG wire
   iii. Class CC, Class J, or Class T fuses

13.6.2 Conductors shall not be smaller than 16 AWG for lighting and control circuits conductors on the machine and in raceways or 18 AWG where part of a jacketed, multiconductor cable assembly.

13.6.3 Conductors shall not be smaller than 18 AWG for control circuits within control enclosures or operator stations.

13.6.4* Conductors for electronic programmable control input/output and static control shall not be smaller than permitted in (1) or (2):

(1) Conductors installed in raceways shall not be smaller than 24 AWG.

Exception: 30 AWG or larger shall be permitted if part of a jacketed, multiconductor cable assembly or cord.

(2) Conductors installed within control enclosures shall not be smaller than 26 AWG.

Exception: Conductors 30 AWG or larger shall be permitted for jumpers and special wiring applications.

13.6.5 Shielded Conductors. Shielded conductors shall consist of stranded, annealed copper of 25 AWG or larger for single conductors used in subassemblies and 22 AWG or larger for all other uses.

13.7 Conductors and Cables Used for Flexing Applications.

13.7.1 General.

13.7.1.1 Conductors and cables used for flexing applications shall be selected from Table 13.2.2.

13.7.1.2* Cables that are subjected to severe duties shall be of adequate construction to protect against the following:

(1) Abrasion due to mechanical handling and dragging across rough surfaces
(2) Kinking due to operation without guides
(3) Stress resulting from guide rollers and forced guiding and being wound and rewound on cable drums

13.7.2 Mechanical Rating. The cable handling system of the machine shall be so designed to keep the tensile stress of the conductors as low as practicable during machine operations. The tensile stress shall not exceed manufacturer's specifications.

13.7.3* Current-Carrying Capacity of Cables Wound on Drums. Cables to be wound on drums *(see Table 13.7.3)* shall be selected with conductors of a cross-sectional area such that, when fully wound on and carrying the normal service load, the maximum allowable operating temperature is not exceeded.

13.8 Flexible Cords.

13.8.1 Multiconductor flexible cords shall be suitable for the intended use and be of the type listed in Table 13.8.2.

13.8.2 Ampacity of Flexible Cords. The continuous current by flexible cords shall not exceed the values given in Table 13.8.2.

13.8.3 Where ampacity derating is required for more than three current-carrying conductors, the factor(s) shall be taken from Table 13.5.5(b).

Table 13.7.3 Derating Factors for Cables Wound on Drums

	Number of Layers of Cable				
Drum Type	**Any Number**	**1**	**2**	**3**	**4**
Cylindrical ventilated	—	0.85	0.65	0.45	0.35
Radial ventilated	0.85	—	—	—	—
Radial nonventilated	0.75	—	—	—	—

Notes:
1. A radial-type drum is one where spiral layers of cable are accommodated between closely spaced flanges; if fitted with solid flanges, the drum is described as nonventilated and if the flanges have suitable apertures, as ventilated.
2. A ventilated cylinder drum is one where the layers of cable are accommodated between widely spaced flanges and the drum and end flanges have suitable ventilating apertures.
3. It is recommended that the use of derating factors be discussed with the cable and the cable drum manufacturers. This can result in other factors being used.

Table 13.8.2 Allowable Ampacity for Flexible Cords and Cables [Based on Ambient Temperature of 30°C (86°F)]

Size (AWG)	Thermoset Type TS	Thermoset Types C, E, EO, PD, S, SJ, SJO, SJOW, SJOO, SJOOW, SO, SOW, SOO, SOOW, SP-1, SP-2, SP-3, SRD, SV, SVO, SVOO		Types HPD, HPN, HS, HSJ, HSO, HSJO, HSOO, HSJOO
	Thermoplastic Types TPT, TST	Thermoplastic Types ET, ETLB, ETP, ETT, SE, SEW, SEO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW, SPE-1, SPE-2, SPE-3, SPT-1, SPT-1W, SPT-2, SPT-2W, SPT-3, ST, SRDE, SRDT, STO, STOW, STOO, STOOW, SVE, SVEO, SVT, SVTO, SVTOO		
		A[a]	B[b]	
27[c]	0.5	—	—	—
20	—	5[d]	[e]	—
18	—	7	10	10
17	—	—	12	—
16	—	10	13	15
15	—	—	—	17
14	—	15	18	20
12	—	20	25	30
10	—	25	30	35
8	—	35	40	—
6	—	45	55	—
4	—	60	70	—
2	—	80	95	—

Notes:

[a] The allowable currents apply to three-conductor cords and other multiconductor cords connected to utilization equipment so that only three conductors are current carrying.

[b] The allowable currents apply to two-conductor cords and other multiconductor cords connected to utilization equipment so that only two conductors are current carrying.

[c] Tinsel cord.

[d] Elevator cables only.

[e] 7 amperes for elevator cables only; 2 amperes for other types.

Chapter 14 Wiring Practices

14.1 Connections and Routing.

14.1.1 General Requirements.

14.1.1.1 All connections shall be secured against accidental loosening and shall ensure a thoroughly good connection. Thread locking sealants, epoxies, glues, or other similar compounds shall not be used.

14.1.1.2 The means of connection shall be identified for the cross-sectional areas and the type of conductors being terminated.

14.1.1.3 Terminals for more than one conductor shall be so identified.

14.1.1.4 A power distribution block designed for multiple tap conductors (e.g., single or multiple conductors "in" and multiple conductors "out") shall be permitted for additional tap connections and circuit branching.

14.1.1.5 Soldered connections shall only be permitted where terminals are provided that are identified for soldering.

14.1.1.6 Terminals on terminal blocks shall be plainly identified to correspond with markings on the diagrams.

14.1.1.7 The installation of flexible conduits and cables shall be such that liquids drain away from the fittings. Where practicable, raceway connections shall enter the sides or bottom of an enclosure or box.

14.1.1.8 Means of retaining conductor strands shall be provided when terminating conductors at devices or terminals that are not equipped with this facility. Solder shall not be used for that purpose.

14.1.1.9 Shielded conductors shall be terminated so as to prevent fraying of strands and to permit easy disconnection.

14.1.1.10* Identification tags shall be readable, permanent, and identified for use in the physical environment.

14.1.1.11* Terminal blocks shall be mounted and wired so that the internal and external wiring does not cross over the terminals.

14.1.2 Conductor and Cable Runs.

14.1.2.1 Conductors and cables shall be run from terminal to terminal without splices or joints.

Exception No. 1: Splices shall be permitted to leads attached to electrical equipment, such as motors and solenoids. Such splices shall be insulated with oil-resistant electrical tape or insulation equivalent to that of the conductors and installed in a suitable enclosure.

Exception No. 2: Where it is impracticable to provide terminals in a junction box (e.g., on mobile machines, on machines having long flexible cables), the use of splices or joints shall be permitted.

14.1.2.2 Factory-applied connectors molded onto cables shall be permitted. Such connectors shall not be considered as splices or joints.

14.1.2.3 Where it is necessary to connect and disconnect cables and cable assemblies, an additional length shall be provided for that purpose.

14.1.2.4 The terminations of cables shall be supported to prevent mechanical stresses at the termination of the conductors.

14.1.3 Conductors of Different Circuits. Conductors of different circuits shall be permitted to be laid side by side and occupy the same raceway (duct) (e.g., wireway or cable trunking), or be in the same multiconductor cable assembly, provided that the arrangement does not impair the functioning of the respective circuit. Functionally associated circuit conductors including power, control, remote input/output, signaling, and communication cables shall be permitted in the same raceway or cable assembly regardless of voltage, provided all are insulated for the maximum voltage of any circuit within the raceway or cable assembly. Where those circuits operate at different voltages, the conductors shall be separated by barriers or shall be insulated for the highest voltage to which any conductor within the same raceway (duct) or cable assembly is subjected.

Exception: Different voltage insulation levels or conductor properties shall be permitted in the same cable assembly, provided the cable assembly has been designed and tested to the identified application.

14.1.4 Cables.

14.1.4.1 Exposed cables installed along the structure of the equipment or system or in the chases of the machinery shall be permitted. Exposed cables shall be installed to closely follow the surface and structural members of the machinery.

14.1.4.2 Cables shall be supported by the equipment or system structure as follows:

(1) In such a manner that the cable will not be damaged by normal equipment use
(2) Every 305 mm (12 in.) in a nonvertical run

Exception: The supporting distance shall be permitted to be increased up to 914 mm (36 in.) where the structure of the machine or system makes support impractical every 305 mm (12 in.).

(3) Every 914 mm (36 in.) in a vertical run

Exception: Supporting distance shall be permitted to be increased to 2.44 m (96 in.), where the structure of the machine or system makes support impractical every 914 mm (36 in.).

(4) When suspended in air spanning a distance up to 457 mm (18 in.)

Exception: Span distance shall be permitted to be increased up to 914 mm (36 in.), where the structure of the machine or system makes support impractical every 457 mm (18 in.).

14.1.4.3 Cables shall not be supported by machinery guards that are likely to be removed for maintenance access.

Exception: Wiring for components that are an integral part of the guard and designed to remain on the guard when the guard is removed for maintenance access shall be permitted to be supported by the guard.

14.1.4.4 Multiple cables shall be permitted to be supported and fastened together in a bundle, provided the method of support and fastening is sufficient to support the mechanical weight and strain of the bundle.

14.1.4.5 Cables shall be fastened where supported.

Exception No. 1: Where horizontal runs are inherently supported by the machine or system structure or by a floor or deck, fastening is not required.

Exception No. 2: Where run at not more than a 45-degree angle from horizontal, fastening is not required.

14.1.4.6 Cables shall be fastened with cable mounting clamps or with cable ties supported by any of the following methods:

(1) Screw-on cable tie mounts
(2) Hammer-on cable tie mounting clips
(3) Around the machine or system structural members
(4) Through holes in the machine or system structural members
(5) Other methods identified as acceptable for the purpose

14.1.4.7 The free ends of cable ties shall be cut flush after final adjustment and fastening. Cable ties of the reusable or releasable type shall not be permitted for use as a permanent fastening method.

14.1.4.8 Cables subjected to physical damage shall be protected as follows:

(1) By alternative routing
(2) With additional guarding or railings
(3) When supported by flooring or decking, with walk over or drive over cable protective devices
(4) By installation in a wire way
(5) By installation in a floor or deck covering trapezoidal walk over raceway specifically designed for cable protection

14.1.4.9 Bends in cables shall be made so as not to cause undue stress. The radius of the curve (measured from the inside edge of the bend) shall not be less than five times the diameter of the cable.

14.1.4.10 Where a cable is used in a length longer than optimally required, the excess cable shall be coiled in loops. The coil shall be fastened to itself and to the machinery structure.

Exception: When an excess cable is associated with a horizontal cable run that is inherently and fully supported, the coil is not required to be fastened to the equipment or system structure.

14.1.5 Cord.

14.1.5.1* Manufactured assemblies with factory-applied molded connectors applied to cord shall be permitted.

14.1.5.2 The use of cord shall be limited to individual exposed lengths of 15 m (50 ft) or less.

14.1.5.3 Cord shall be installed in accordance with the provision of 14.1.4.

14.1.5.4 Cord shall be permitted for use with flexible connections to pendant pushbutton stations. Chains or wire rope external to the cord shall support the weight of pendant stations.

Exception: Cords listed for the purpose shall be permitted to be used without an external chain or wire rope.

14.1.5.5 Cord shall be permitted for use with connections involving small or infrequent movements. Cord shall also be permitted to complete the connection to normally stationary motors, limit switches, and other externally mounted devices.

14.1.5.6 Connections to frequently moving parts shall be made with conductors for flexing service in accordance with Section 13.7. Cord with conductors for flexing service shall have vertical connections and shall be installed to avoid excessive flexing and straining.

Exception: Horizontal connections shall be permitted where the cord is adequately supported.

14.2 Identification of Conductors.

14.2.1 General Requirements.

14.2.1.1 Conductors shall be identified at each termination by number, letter, color (either solid or with one or more stripes), or a combination thereof and shall correspond with the technical documentation. Internal wiring on individual devices purchased completely wired shall not require additional identification.

14.2.1.2 Where numbers are used to identify conductors, they shall be Arabic; letters shall be Roman (either upper or lower case).

14.2.2 Identification of the Equipment Grounding (Protective) Conductor.

14.2.2.1* The color GREEN with or without one or more YELLOW stripes shall be used to identify the equipment grounding conductor where insulated or covered. This color identification shall be strictly reserved for the equipment grounding (protective bonding) conductor.

Exception No. 1: In multiconductor cable-connected assemblies where equipment grounding is not required, the solid color GREEN shall be permitted for other than equipment grounding.

Exception No. 2: It shall be permitted to use conductors of other colors provided the insulation or cover is appropriately identified at all points of access.

Exception No. 3: For grounded control circuits, use of a GREEN insulated conductor with or without one or more YELLOW stripes or a bare conductor from the transformer terminal to a grounding terminal on the control panel shall be permitted.

14.2.2.2 Where the equipment grounding (protective) conductor is identified by its shape, position, or construction (e.g., a braided conductor) or where the insulated conductor is not readily accessible, color coding throughout its length shall not be required. The ends or accessible portion shall be clearly identified by the symbol in Figure 8.2.1.2.4, the color GREEN with or without one or more YELLOW stripes, or the bicolor combination GREEN-AND-YELLOW.

14.2.3 Identification of the Grounded Circuit Conductor.

14.2.3.1* Where an ac circuit includes a grounded conductor, this conductor shall be WHITE, GRAY, or three continuous WHITE stripes on other than GREEN, BLUE, ORANGE, or YELLOW insulation along its entire length.

14.2.3.2 The use of other colors for the following applications shall be as follows:

(1) WHITE with BLUE stripe for grounded (current-carrying) dc circuit conductor.
(2) WHITE with ORANGE stripe or WHITE with YELLOW stripe for grounded (current-carrying) ac circuit conductor, which remains energized when the main disconnecting means is in the off position.
(3) Whichever color stripe is selected, that color stripe shall be consistent with the ungrounded conductor of the excepted circuit described in 5.3.5.

14.2.3.3 Where identification by color is used, busbars used as grounded conductors shall be either colored by a stripe, 15 mm to 100 mm (0.6 in. to 3.9 in.) wide in each compartment or unit or at each accessible position, or colored throughout their length.

14.2.4 Identification by Color for Other Conductors.

14.2.4.1* Ungrounded circuit conductors that remain energized when the supply disconnecting means is in the off position shall be consistently applied as either ORANGE or YELLOW. These color identifications shall be strictly reserved for this application only.

Exception No. 1: Internal wiring on individual devices purchased completely wired.

Exception No. 2: Where the insulation used is not available in the colors required (e.g., high temperature insulation, chemically resistant insulation).

14.2.4.2 Where color is used for identification, the color shall be used throughout the length of the conductor either by the color of the insulation or by color markers.

Exception: Multiconductor cables shall be permitted to be permanently reidentified at the time of installation.

14.2.4.3 The use of other colors for the purpose of identification shall be as follows:

(1) BLACK for ungrounded line, load, and control conductors at line voltage
(2) RED for ungrounded ac control conductors at less than line voltage
(3) BLUE for ungrounded dc control conductors

Exception No. 1: Internal wiring on individual devices purchased completely wired.

Exception No. 2: Where the insulation used is not available in the colors required (e.g., high temperature insulation, chemically resistant insulation).

Exception No. 3: Where multiconductor cable is used and other means of permanent identification is provided.

Exception No. 4: Where the identification of machine power and control wiring is such that compliance with the mandatory color codes is too restrictive for specific applications, it shall be permitted to use additional identification at selected locations as an alternative. This means of identification shall be permitted to be by separate color coding, marking tape, tagging, or other approved means and shall be permanently posted on the inside of the main electrical control panel enclosure in a visible location.

14.3 Wiring Inside Enclosures.

14.3.1* Nonmetallic ducts shall be permitted only when they are made with a flame-retardant insulating material.

14.3.2 Electrical equipment mounted inside enclosures shall be installed in such a way as to permit access to the wiring.

14.3.3 Conductors and cables used to connect devices mounted on doors or to other movable parts shall comply with flexing requirements of Section 13.7. Conductors and cables used for flexing applications shall be of sufficient length to permit full movement of the door or the moveable part. The conductors shall be anchored to the fixed part and to the movable part independently of the electrical connection.

14.3.4 Panel conductors shall be supported where necessary to keep them in place. Conductors that do not run in ducts shall be supported.

14.3.5 Multiple-device control panels shall be equipped with terminal blocks or with attachment plugs and receptacles for all outgoing control conductors. Wiring directly

to the terminal connection points on input or output modules of programmable electronic systems shall be permitted.

14.3.6 The direct connection of power cables and cables of measuring circuits to the terminals of the devices for which the connections were intended shall be permitted.

14.3.7 Flexible cords, ac receptacles, ac plugs, appliance couplers, and power cord sets shall be permitted inside enclosures for internal wiring and connections between assemblies with ac power where used in accordance with their listing.

14.4 Wiring Outside Enclosures.

14.4.1 General Requirements. The means of introduction of cables or ducts with their individual glands, bushings, and so forth into an enclosure shall ensure that the degree of protection is not reduced.

14.4.2 External Raceways (Ducts).

14.4.2.1 All conductors of the same ac circuit routed to the same location shall be contained in the same raceway (duct).

14.4.2.2 Conductors external to the electrical equipment enclosure(s) shall be enclosed in raceways (ducts) described in Section 14.5.

Exception: Cables and cable connectors need not be enclosed in a raceway where they are protected and supported in accordance with 14.1.4.

14.4.2.3 Fittings used with raceways (ducts) or multiconductor cable shall be identified for use in the physical environment.

14.4.2.4 Flexible conduit or multiconductor cable with flexible properties shall be used where it is necessary to employ flexible connections to pendant pushbutton stations. The weight of the pendant stations shall be supported by means other than the flexible conduit or the multiconductor cable with flexible properties, except where the conduit or cable is specifically designed for that purpose.

14.4.2.5 Flexible conduit or multiconductor cable with flexible properties shall be used for connections involving small or infrequent movements. They shall also be permitted to complete the connection to stationary motors, position switches, and other externally mounted devices. Where prewired devices (e.g., position switches, proximity switches) are supplied, the integral cable shall not be required to be enclosed in a raceway (duct).

14.4.3 Connection to Moving Elements of the Machine.

14.4.3.1 Connections to moving parts shall be made using conductors in accordance with Section 13.7. Flexible cable and conduit shall have vertical connections and shall be installed to avoid excessive flexing and straining. Horizontal connections shall be permitted where the flexible cable or conduit is adequately supported. Cable with flexible properties and flexible conduit shall be so installed as to prevent excessive flexing and straining, particularly at the fittings.

14.4.3.2 Cables with flexible properties subject to movement shall be supported in such a way that there is neither mechanical strain on the connection points nor any sharp flexing. When this is achieved by the use of a loop, it shall provide for the cable with a bending radius of at least 10 times the diameter of cable.

14.4.3.3 Cable with flexible properties of machines shall be installed or protected so as to minimize the possibility of external damage due to factors that include the following cable use or potential abuse:

(1) Being run over by the machine itself
(2) Being run over by vehicles or other machines
(3) Coming into contact with the machine structure during movements
(4) Running in and out on cable baskets or on or off cable drums
(5) Acceleration forces and wind forces on festoon systems or suspended cables
(6) Excessive rubbing by cable collector
(7) Exposure to an excessive radiated heat source

14.4.3.4 The cable sheath shall be resistant to the wear from movement and the effects of atmospheric contaminants (e.g., oil, water, coolants, dust).

14.4.3.5 Where cables subject to movement are close to moving parts, precautions shall be taken to maintain a space of at least 25.4 mm (1 in.) between the moving parts and the cables. Where that distance is not practicable, fixed barriers or cable tracks shall be provided between the cables and the moving parts.

14.4.3.6 Cable Handling System.

14.4.3.6.1 The cable handling system shall be so designed that lateral cable angles do not exceed 5 degrees, avoiding torsion in the cable when being wound on and off cable drums and approaching and leaving cable guidance devices.

14.4.3.6.2 Measures shall be taken to ensure that at least two turns of flexible cables always remain on a drum.

14.4.3.6.3 Devices serving to guide and carry a cable with flexible properties shall be designed so that the inner bending radius is not less than the values given in Table 14.4.3.6.3.

Exception: A smaller bending radius shall be permitted if the cable is identified for the purpose.

14.4.3.7 The straight section between two bends in an S-shaped length and a bend into another plane shall be at least 20 times the diameter of the cable.

14.4.3.8 Where flexible conduit is adjacent to moving parts, the construction and supporting means shall prevent damage to the flexible conduit under all conditions of operation. Flexible metallic conduit shall not be used for rapid movements except when specifically designed for that purpose.

14.4.4 Interconnection of Devices on the Machine. Where practicable, for machine-mounted switching devices (e.g., position sensors, pushbuttons) that are connected in series or in parallel, such connections, between those devices, shall be made through terminals forming intermediate test points. Such terminals shall be conveniently placed, protected from the environment, and shown on the relevant diagrams.

14.4.5 Attachment Plug and Receptacle (Plug/Socket) Combinations.

14.4.5.1 Where equipment is removable, connections to it through a polarized attachment plug and receptacle (plug/socket) combination shall be permitted. The male plug shall be connected to the load circuit.

14.4.5.2 Attachment plug and receptacle (plug/socket) combinations shall be listed for the intended use and shall be of the locking type where rated greater than 20 amperes. Where used on circuits of more than 300 volts to ground or 300 volts phase-to-phase, they shall be skirted and constructed to contain any arc generated when a connection is made or broken.

Table 14.4.3.6.3 Minimum Permitted Bending Radii for the Forced Guiding of Flexible Cables

Application	Cable Diameter or Thickness of Flat Cable *(d)*					
	mm	in.	mm	in.	mm	in.
	$d \leq 8$	$d \leq 0.315$	$8 < d \leq 20$	$0.315 < d \leq 0.787$	$d > 20$	$d > 0.787$
Cable drums	6 *d*		6 *d*		8 *d*	
Guide rollers	6 *d*		8 *d*		8 *d*	
Festoon systems	6 *d*		6 *d*		8 *d*	
All others	6 *d*		6 *d*		8 *d*	

14.4.5.3 Attachment plug and receptacle (plug/socket) combinations shall be designed so that both of the following occur:

(1) The equipment grounding (protective bonding) circuit connection is made before any current-carrying connections are made.
(2) The equipment grounding (protective bonding) circuit connection is not disconnected until all current-carrying connections in the plug are disconnected.

Exception: Connections used in PELV circuits or the connectors used only to facilitate assembling and disassembling (multipole connectors) shall not be required to meet these requirements.

14.4.5.4 Attachment plug and receptacle (plug/socket) combinations used for carrying motor loads shall meet the conditions of 5.3.3.3 if the circuit is likely to be opened under load.

14.4.5.5 Where more than one attachment plug and receptacle (plug/socket) combination is used at the same location, they shall be mechanically coded or be clearly identified to prevent incorrect insertion.

14.4.5.6 Attachment plug and receptacle (plug/socket) combinations that are used for industrial power purposes or of a type used for domestic applications shall not be used for control circuits.

14.4.5.7 Means shall be provided to cover externally mounted receptacles (socket) when the plugs are removed.

14.4.6 Dismantling for Shipment. Where it is necessary that wiring be disconnected for shipment and where practicable, terminals or attachment plug and receptacle (plug/socket) combinations shall be provided at the sectional points. Such terminals shall be suitably enclosed and attachment plug and receptacle (plug/socket) combinations shall be protected from the physical environment during transportation and storage. Raceway and enclosure openings shall be sealed prior to shipment.

14.5 Raceways (Ducts), Support Systems (Cable Supports), Connection Boxes, and Other Boxes.

14.5.1 General Requirements.

14.5.1.1 Raceways (ducts), factory elbows and couplings, and associated fittings shall be listed and shall be identified for the environment.

Exception: Raceways (ducts) fabricated as part of the machine that comply with the requirements of 14.5.6 shall not be required to be listed.

14.5.1.2 All sharp edges, burrs, rough surfaces, or threads that the insulation of the conductors can come in contact with shall be removed from raceways (ducts) and fittings. Where necessary, additional protection consisting of a flame-retardant, oil-resistant insulating material shall be provided to protect conductor insulation.

14.5.1.3 Drain holes shall not be permitted in raceways (ducts), junction boxes, and pull boxes where the holes would compromise the intended enclosure integrity. Drain holes of 6.4-mm (¼-in.) diameter shall be permitted in wireways (cable trunking systems), connection boxes, and other boxes used for wiring purposes that are subject to accumulations of oil or moisture.

14.5.1.4 Raceways shall be securely fastened in place and supported.

Exception: Flexible raceways shall not be required to be secured or supported where elsewhere permitted in this chapter.

14.5.2* Percentage Fills of Raceways (Ducts). The combined cross-sectional area of all conductors and cables shall not exceed 50 percent of the interior cross-sectional area of the raceway (duct). The fill provisions shall be based on the actual dimensions of the conductors or cables used.

14.5.3 Rigid Conduit and Fittings.

14.5.3.1 General Requirements.

14.5.3.1.1 The minimum electrical trade size shall be metric designator 16 (trade size ½).

14.5.3.1.2* The maximum electrical trade size shall be metric designator 155 (trade size 6).

14.5.3.1.3 Where conduit enters a box or enclosure, a bushing or fitting providing a smoothly rounded insulating surface shall be installed to protect the conductors from abrasion, unless the design of the box or enclosure is such that it provides the same protection. Where conduit bushings are constructed entirely of insulating material, a locknut shall be provided both inside and outside the enclosure to which the conduit is attached.

Exception: Where threaded hubs or bosses that are an integral part of an enclosure provide a smoothly rounded or flared entry for conductors.

14.5.3.1.4 Conduit bends shall be made in such a manner that the conduit shall not be damaged and the internal diameter of the conduit shall not be effectively reduced. The radius of the curve of any field bend to the center line of the conduit shall be not less than shown in Table 14.5.3.1.4.

14.5.3.1.5 A run of conduit shall contain not more than four quarter bends or a combination of bends totaling 360 degrees between pull points.

Table 14.5.3.1.4 Minimum Radii of Conduit Bends

Conduit Size		One Shot and Full Shoe Benders		Other Bends	
Metric Designator	Trade Size	mm	in.	mm	in.
16	½	101.6	4	101.6	4
21	¾	114.3	4½	127	5
27	1	146.05	5¾	152.4	6
35	1¼	184.15	7¼	203.2	8
41	1½	209.55	8¼	254	10
53	2	241.3	9½	304.8	12
63	2½	266.7	10½	381	15
78	3	330.2	13	457.2	18
91	3½	381	15	533.4	21
103	4	406.4	16	609.6	24
129	5	609.6	24	762	30
155	6	762	30	914.4	36

14.5.3.2 Metal-type Nonflexible Conduit.

14.5.3.2.1 General Requirements.

14.5.3.2.1.1 Conduits shall be securely held in place and supported at each end.

14.5.3.2.1.2 Fittings shall be compatible with the conduit and identified for the application. Fittings and conduits shall be threaded using an electrical conduit die unless structural difficulties prevent assembly. Running threads shall not be used on conduit for connection at couplings. Metallic tubing shall not be threaded. Where threadless fittings are used, the conduit shall be securely fastened to the equipment.

14.5.3.2.2* Rigid Metal Conduit (RMC). Rigid metal conduit and fittings shall be of galvanized steel or of a corrosion-resistant material identified for the conditions of service.

14.5.3.2.3* Intermediate Metal Conduit (IMC). Intermediate metal conduit shall be a steel raceway of circular cross section with integral or associated couplings, approved for the installation of electrical conductors and used with approved fittings to provide electrical continuity.

14.5.3.2.4* Electrical Metallic Tubing (EMT). Electrical metallic (steel) tubing shall be a metallic tubing of circular cross section approved for the installation of electrical conductors when joined together with approved fittings. The maximum size of tubing shall be the 4-in. electrical trade size.

14.5.3.3 Rigid Nonmetallic Conduit (PVC Schedule 80).

14.5.3.3.1* Rigid nonmetallic conduit (PVC Schedule 80) shall be of suitable nonmetallic material approved for the installation of electrical conductors and identified for use where subject to physical damage.

14.5.3.3.2 Conduit shall be securely held in place and supported as specified in Table 14.5.3.3.2. In addition, conduit shall be securely fastened within 900 mm (3 ft) of each box, enclosure, or other conduit termination.

14.5.3.3.3* Expansion fittings shall be installed to compensate for thermal expansion and contraction.

Table 14.5.3.3.2 Support of Rigid Nonmetallic Conduit (RNC)

Conduit Size		Maximum Spacing Between Supports	
Metric Designator	Trade Size	mm or m	ft
16 – 27	½ – 1	900 mm	3
35 – 53	1¼ – 2	1.5 m	5
63 – 78	2½ – 3	1.8 m	6
91 – 129	3½ – 5	2.1 m	7
155	6	2.5 m	8

14.5.3.3.4 All joints between lengths of conduit and between conduit and couplings, fittings, and boxes shall be made with fittings approved for the purpose.

14.5.4 Flexible Metal Conduit and Fittings.

14.5.4.1 General Requirements.

14.5.4.1.1 Flexible metal conduit (FMC) and liquidtight flexible metal conduit (LFMC) minimum electrical trade size shall be metric designator 12 (trade size ⅜).

Exception: Thermocouples and other sensors.

14.5.4.1.2* The maximum size of flexible metal conduit and liquidtight flexible metal conduit shall be metric designator 103 (trade size 4).

14.5.4.1.3 Flexible metal conduit and liquidtight flexible metal conduit shall be installed in such a manner that liquids will tend to run off the surface instead of draining toward the fittings.

14.5.4.1.4 Fittings shall be compatible with the conduit and identified for the application. Connectors shall be the "union" types.

14.5.4.2 Flexible Metal Conduit (FMC). Flexible metal conduit shall be identified for use in the expected physical environment.

14.5.4.3 Liquidtight Flexible Metal Conduit (LFMC). Liquidtight flexible metal conduit shall be identified for use in the expected physical environment.

14.5.5 Liquidtight Flexible Nonmetallic Conduit (LFNC) and Fittings.

14.5.5.1 Definition. Liquidtight flexible nonmetallic conduit (LFNC) is a raceway of circular cross section of the following types:

(1) A smooth, seamless inner core and cover that is bonded together and has one or more reinforcement layers between the core and cover, designated as Type LFNC–A
(2) A smoother inner surface with integral reinforcement within the conduit wall, designated as Type LFNC–B
(3) A corrugated internal and external surface with or without integral reinforcement within the conduit wall, designated as Type LFNC–C

14.5.5.2 Liquidtight flexible nonmetallic conduit shall be resistant to kinking and shall have physical characteristics of the sheath of multiconductor cables.

14.5.5.3 The conduit shall be identified for use in the expected physical environment.

14.5.5.4 Liquidtight flexible nonmetallic conduit minimum electrical trade size shall be ⅜ in.

14.5.5.5* The maximum size of liquidtight flexible nonmetallic conduit shall be 4-in. trade size.

14.5.5.6 Fittings shall be compatible with the conduit and identified for the application.

14.5.5.7 Flexible conduit shall be installed in such a manner that liquids will tend to run off the surface instead of draining toward the fittings.

14.5.6 Wireways (Cable Trunking Systems).

14.5.6.1 Wireways (cable trunking systems) external to enclosures shall be rigidly supported and clear of all moving or contaminating portions of the machine.

14.5.6.2 Covers shall be shaped to overlap the sides; gaskets shall be permitted. Covers shall be attached to wireways by hinges or chains and held closed by means of captive screws or other suitable fasteners. On horizontal wireway, the cover shall not be on the bottom. Hinged covers shall be capable of opening at least 90 degrees.

14.5.6.3 Where the wireway is furnished in sections, the joints between sections shall fit tightly but shall not be required to be gasketed.

14.5.6.4 The only openings permitted shall be those required for wiring or for drainage.

14.5.6.5 Wireways shall not have opened but unused knockouts.

14.5.6.6 Metal thickness and construction of wireways shall comply with UL 870, *Wireways and Auxiliary Gutters*.

14.5.7* Machine Compartments and Wireways. The use of compartments or wireways within the column or base of a machine to enclose conductors shall be permitted provided the compartments or wireways are isolated from coolant or oil reservoirs and are entirely enclosed. Conductors run in enclosed compartments or wireways shall be secured and arranged so that they are not subject to damage.

14.5.8 Connection Boxes and Other Boxes.

14.5.8.1 Connection boxes and other boxes used for wiring purposes shall be readily accessible for maintenance. Those boxes shall provide protection against the ingress of solid bodies and liquids, taking into account the external influences under which the machine is intended to operate.

14.5.8.2 Those boxes shall not have opened but unused knockouts or any other openings and shall be constructed so as to exclude materials such as dust, flyings, oil, and coolant.

14.5.9 Motor Connection Boxes.

14.5.9.1 Motor connection boxes shall enclose only connections to the motor and motor-mounted devices (e.g., brakes, temperature sensors, plugging switches, tachometer generators).

14.5.9.2 Electrical connections at motor terminal boxes shall be made with an identified method of connection. Twist-on wire connectors shall not be used for this purpose.

14.5.9.3 Connectors shall be insulated with a material that will not support combustion.

14.5.9.4 Soldered or insulation-piercing–type connectors (lugs) shall not be used.

14.5.10 Cable Trays. Cable trays to be used for cable or raceway support on industrial machines shall be permitted. Cable trays shall be permitted to support the following:

(1) Single conductors 1/0 or larger that are otherwise permitted on industrial machines
(2) Multiconductor flexible cables that are otherwise permitted on industrial machines
(3) Raceways functionally associated with industrial manufacturing systems.

14.5.10.1 Cords shall not be installed in cable trays.

Chapter 15 Electric Motors and Associated Equipment

15.1* General Requirements. Motors shall be suitable for the environment in which they are installed.

15.2 (Reserved)

15.3* Motor Dimensions. As far as is practicable, the dimensions of the motors shall comply with those given in NEMA MG-1, IEC 60072-1, or IEC 60072-2, as appropriate.

15.4 Motor Mounting and Compartments.

15.4.1 Each motor and its associated couplings, belts and pulleys, or chains and sprockets shall be mounted so that they are adequately protected from physical damage and are easily accessible for inspection, maintenance, adjustment and alignment, lubrication, and replacement. The motor mounting arrangement shall be so that all motor hold-down means can be removed and all terminal boxes are accessible. An adjustable base or other means of adjustment shall be provided when belt or chain drives are used.

15.4.2 Motors shall be mounted so that proper cooling is ensured and the temperature rise remains within the limits of the insulation class.

15.4.3 Motor compartments shall be clean and dry, and, when required, shall be ventilated directly to the exterior of the machine. The vents shall be so that ingress of swarf, dust, or water spray is at an acceptable level.

15.4.4 All openings between the motor compartment and any other compartment shall meet the motor compartment requirements. Where a raceway is run into the motor compartment from another compartment not meeting the motor compartment requirements, any clearance around the raceway shall be sealed.

15.5 Criteria for Selection. The characteristics of motors and associated equipment shall be selected in accordance with the anticipated service and physical environment conditions. The points that shall be considered include the following:

(1) Type of motor
(2) Type of duty cycle
(3) Fixed speed or variable speed operation (and consequent variable influence of the ventilation)
(4) Mechanical vibration
(5) Type of converter for motor speed control
(6) Influence of the harmonic spectrum of the voltage and/or current feeding the motor (when it is supplied from a converter) on the temperature rise
(7) Method of starting and possible influence of the inrush current on the operation of other users, taking into account possible special considerations stipulated by the supply authority
(8) Variation of counter torque load with time and speed
(9) Influence of loads with large inertia
(10) Influence of constant torque or constant power operations
(11) Possible need of inductive reactors between motor and converter

15.6* Protective Devices for Mechanical Brakes. Operation of the overload and overcurrent protective devices for mechanical brake actuators shall initiate the simultaneous de-energization (release) of the associated machine actuators.

15.7 Direction Arrow. Where reverse rotation can produce an unsafe condition or cause damage to connected equipment, a direction arrow shall be installed. The arrow shall be adjacent to the motor and plainly visible.

15.8 Marking on Motors. Motors shall be marked in accordance with Section 430.7 of NFPA 70, *National Electrical Code*.

Chapter 16 Accessories and Lighting

16.1 Accessories.

16.1.1 Receptacles for Accessory Equipment. Where the machine or its associated equipment is provided with receptacle outlets to be used for accessory equipment (e.g., handheld power tools, test equipment), the following conditions shall apply:

(1) Receptacles shall be of the grounding type, 125-volt, single-phase, 15-ampere configuration and listed for the applied voltage.
(2) Receptacles with their associated attachment plugs (plug/sockets) shall be in accordance with 14.4.5.3.
(3) The continuity of the equipment grounding (protective bonding) circuit to the receptacle outlet shall be verified by Section 19.2.

Exception: Verification is not required for PELV circuits in accordance with Section 19.2.

(4) All ungrounded (unearthed) conductors connected to the receptacle outlet shall be protected against overcurrent in accordance with the provisions of 7.2.5, and these circuits shall not be connected to other machine circuits.
(5) Where the power supply to the receptacle outlet is not disconnected by the supply disconnecting device for the machine or section of the machine, the warning and marking requirements of 5.3.5.4 shall apply.
(6) Shall be suitable for the environment. Receptacles mounted external to the enclosure shall be provided with a means to cover the receptacle when the plug is removed.

16.1.2 Receptacles for Maintenance Personnel. Receptacles, which are part of the industrial machine, either internal or external to the control cabinet and intended for use by maintenance personnel, shall have ground-fault circuit-interrupter (GFCI) protection for personnel.

16.2 Local Lighting of the Machine and Equipment.

16.2.1 General.

16.2.1.1 Lighting circuits shall comply with the provisions of Section 8.4.

16.2.1.2 Machine work lights shall not contain switches or receptacles where exposed to liquids or condensing mists unless identified for the purpose. Lampholders shall not incorporate a switch or receptacle. Work lights used in wet locations shall be provided with ground-fault protection.

16.2.1.3 The conductors to stationary lights used as an integral part of the machine shall be Type MTW, and the conductors within the fixtures shall be not smaller than 18 AWG.

16.2.1.4 Flexible cords shall be Type SO, STO, or STOW or Type SJO, SJOW, or SJTO and shall not incorporate in-line switches.

16.2.1.5 Stroboscopic effects from lights shall be avoided.

16.2.2 Supply.

16.2.2.1 The lighting circuit voltage shall not exceed 150 volts between conductors.

16.2.2.2 Lighting circuits shall have overcurrent protection in accordance with 7.2.6 and shall be supplied from one of the following sources:

(1) A separate isolating transformer connected to the load side of the supply disconnecting means. Overcurrent protection shall be provided in the secondary circuit.
(2) A separate isolating transformer connected to the line side of the supply disconnecting means shall be permitted for the supply of a maintenance lighting circuit in control enclosures only. Overcurrent protection shall be provided in the secondary circuit.
(3) A grounded machine circuit that has separate overcurrent protection and does not exceed 150 volts to ground shall be permitted.
(4) An isolating transformer connected to the line side of the supply disconnecting device when a separate primary disconnecting means and secondary overcurrent protection are provided and mounted within the control enclosure adjacent to the supply disconnecting device.
(5) An externally supplied lighting circuit (e.g., factory lighting supply). This shall be permitted in control enclosures and for the machine work light(s) where the total power rating does not exceed 3 kW.

16.2.3 Protection. Local lighting circuits shall be separately protected with overcurrent protection and shall not exceed 15 amperes.

16.2.4 Lighting Fixtures.

16.2.4.1 Adjustable lighting fixtures shall be suitable for the physical environment.

16.2.4.2 The lampholders shall be as follows:

(1) Rated for the voltage and wattage of the lamp
(2) Constructed with an insulating material protecting the lamp so as to prevent unintentional contact

16.2.4.3 Reflectors and protectors shall be supported by a bracket and not the lampholder.

Chapter 17 Marking and Safety Signs

17.1 General.

17.1.1 The electrical equipment shall be marked with the supplier's name, trademark, or other identifying symbol.

17.1.2 Safety signs, nameplates, markings, and identification plates shall be of sufficient durability to withstand the physical environment involved.

17.2 Safety Signs for Electrical Enclosures.

17.2.1 Enclosures that do not clearly show that they contain electrical devices shall be marked with a safety sign in accordance with ANSI Z535 series, which deals with product safety signs.

17.2.2 Safety signs shall be plainly visible on the enclosure door or cover.

17.2.3 It shall be permitted to omit safety signs on the following:

(1) An enclosure equipped with a supply disconnecting device
(2) An operator–machine interface or control station
(3) A single device with its own enclosure (e.g., position sensor)

17.2.4 A safety sign shall be provided adjacent to the disconnecting operating handle(s) where the disconnect(s) that is interlocked with the enclosure door does not de-energize all exposed live parts when the disconnect(s) is in the open (off) position.

17.2.5 Where an attachment plug is used as the disconnecting means, a safety sign shall be attached to the control enclosure door or cover indicating that power shall be disconnected from the equipment before the enclosure is opened.

17.2.6 Where the disconnecting means is remote from the control enclosure, a safety sign shall be attached to the enclosure door or cover indicating that the power shall be disconnected from the equipment before the enclosure is opened and that the enclosure shall be closed before the power is restored.

17.3* Function Identification. Control devices, visual indicators, and displays used in the operator–machine interface shall be clearly and durably marked with regard to their functions either on or adjacent to the unit.

17.4 Machine Nameplate Data.

17.4.1 Control equipment shall be legibly and durably marked in a way that it is plainly visible after the equipment is installed. A nameplate giving the following information shall be attached to the enclosure:

(1) Name or trademark of supplier
(2) Serial number, where applicable
(3) Rated voltage, number of phases and frequency (if ac), and full-load current for each supply
(4) Ampere rating of the largest motor or load
(5) Maximum ampere rating of the short-circuit and ground-fault protective device, where provided
(6) Short-circuit interrupting rating of the machine overcurrent protective device, where furnished as part of the equipment
(7) Electrical diagram number(s) or the number of the index to the electrical drawings

17.4.2 The full-load current shown on the nameplate shall not be less than the full-load currents for all motors and other equipment that can be in operation at the same time under normal conditions of use. Where unusual loads or duty cycles require oversized conductors, the required capacity shall be included in the full-load current specified on the nameplate.

17.4.3 Where more than one incoming supply circuit is to be provided, the nameplate shall state the information in 17.4.1 for each circuit.

17.4.4 Where only a single motor or motor controller is used, the motor nameplate shall be permitted to serve as the electrical equipment nameplate where it is plainly visible.

17.4.5 Where supply conductor and machine overcurrent protection is furnished as part of the machine, the machine shall be marked "Supply conductor and machine overcurrent protection provided at machine supply terminals." A separate nameplate shall be permitted to be used for this purpose.

17.5 Equipment Marking and Identification.

17.5.1 Where equipment is removed from its original enclosure or is placed so that the manufacturer's identification plate is not easily read, an additional identification plate shall be attached to the machine or enclosure.

17.5.2 Where a motor nameplate or connection diagram plate is not visible, additional identification shall be provided where it can be easily read.

17.5.3 Nameplates, identification plates, or safety signs shall not be removed from the equipment.

17.5.4 All control panel devices and components shall be plainly identified with the same designation as shown on the machine drawings or diagram(s). This identification shall be adjacent to (not on) the device or component.

Exception No. 1: Where the size or location of the devices makes individual identification impractical, group identification shall be used.

Exception No. 2: This requirement shall not apply to machines on which the equipment consists only of a single motor, motor controller, pushbutton station(s), and work light(s).

17.5.5 All devices external to the control panel(s) shall be identified by a nameplate with the same designation as shown on the machine drawings or diagram(s) and mounted adjacent to (not on) the device.

Exception: Devices covered by Section 17.3.

17.5.6 Terminations on multiconductor plugs and receptacles shall be plainly marked. The markings on the plug and receptacles and on drawings shall correspond.

17.5.7 Where group protection as provided for in 7.2.10 is used, information specifying the short-circuit protective device for each group protected motor branch circuit shall be included with the equipment.

Chapter 18 Technical Documentation

18.1 General.

18.1.1 The information necessary for installation, operation, and maintenance of the electrical equipment of a machine shall be supplied in the form of drawings, diagrams, charts, tables, and instructions as appropriate. The information provided shall be permitted to vary with the complexity of the electrical equipment. For very simple equipment, the relevant information shall be permitted to be contained in one document provided this document shows all the devices of the electrical equipment and enables the connections to the supply network to be made.

18.1.2 The machinery supplier shall ensure that the technical documentation specified in this chapter is provided with each machine.

18.1.3 Technical documentation shall be supplied in a medium agreed upon by the machinery supplier and the user of the machinery.

18.2 Information to Be Provided. The following information shall be provided with the electrical equipment:

(1) Clear, comprehensive description of the equipment, installation and mounting, and the connection to the electrical supply(ies)
(2) Electrical supply circuit(s) requirements
(3) Overview (block) diagram(s) where appropriate
(4) Schematic diagram(s)
(5) Information (where appropriate) on the following:
    (a) Programming
    (b) Sequence of operation(s)
    (c) Frequency of inspection
    (d) Frequency and method of functional testing
    (e) Adjustment, maintenance, and repair
    (f) Interconnection diagram
    (g) Panel layouts
    (h) Instruction and service manuals
    (i) Physical environment (e.g., lighting, vibration, noise levels, atmospheric contaminants)
(6) A description (including interconnection diagrams) of the safeguards, interacting functions, and interlocking of guards with potentially hazardous motions
(7) A description of the safeguarding means and methods provided where the primary safeguards are overridden (e.g., manual programming, program verification)
(8) Information for safety lockout procedure
(9) Explanation of unique terms
(10) Parts list and recommended spare parts list
(11) Maintenance instructions and adjustment procedures
(12) Reference information (where appropriate) on the following:
    (a) Lubrication diagram
    (b) Pneumatic diagram
    (c) Hydraulic diagram
    (d) Miscellaneous system diagrams (e.g., coolant, refrigerant)

18.3 Requirements Applicable to All Documentation.

18.3.1 The documents shall be prepared in accordance with the requirements of Section 18.4 through Section 18.10.

18.3.2 For referencing of the different documents, the supplier shall select one of the following methods:

(1) Each of the documents shall carry as a cross-reference the document numbers of all other documents belonging to the electrical equipment.
(2) All documents shall be listed with document numbers and titles in a drawing or document list.

The first method shall be used only where the documentation consists of four or fewer documents.

18.3.3 Where appropriate, a table of contents shall appear prominently on the first sheet and shall refer to all major sections of the electrical drawings.

18.4* Basic Information. The technical documentation shall contain, as a minimum, information on the following:

(1) Normal operating conditions of the electrical equipment including the expected conditions of the electrical supply and, where appropriate, the physical environment
(2) Handling, transportation, and storage
(3) Inappropriate use(s) of the equipment

The technical documentation shall be permitted to be presented as a separate document or as part of the installation or operation documentation.

18.5 Installation Diagram.

18.5.1* The installation diagram shall provide all information necessary for the preliminary work of setting up the machine.

18.5.2 The specified position of the electrical supply to be installed on site shall be clearly indicated.

18.5.3* The data necessary for choosing the type, characteristics, rated currents, and setting of the overcurrent protective device(s) for the supply circuit conductors to the electrical equipment of the machine shall be stated.

18.5.4* Where necessary, the size, purpose, and location of any raceways (ducts) in the foundation that are to be provided by the user shall be detailed.

18.5.5* The size, type, and purpose of raceways (ducts), cable trays, or cable supports between the machine and the associated equipment that are to be provided by the user shall be detailed.

18.5.6* Where necessary, the diagram shall indicate where space is required for the removal or servicing of the electrical equipment.

18.5.7* Where it is appropriate, an interconnection diagram or table shall be provided. That diagram or table shall give full information about all external connections. Where the electrical equipment is intended to be operated from more than one source of electrical supply, the interconnection diagram or table shall indicate the modifications or interconnections required for the use of each supply.

18.6* Block (System) Diagrams and Function Diagrams. Where it is necessary to facilitate the understanding of the principles of operation, a system diagram shall be provided.

For the purposes of this chapter, a block diagram shall symbolically represent the electrical equipment together with its functional interrelationships without necessarily showing all of the interconnections.

18.7 Circuit Diagrams.

18.7.1* Diagrams, including machine schematics, of the electrical system shall be provided and shall show the electrical circuits on the machine and its associated electrical equipment. Electrical symbols shall be in accordance with IEEE 315 where included therein. Any electrical symbols not included in IEEE 315 shall be separately shown and described on the diagrams. The symbols and identification of components and devices shall be consistent throughout all documents and on the machine.

Exception: Wiring schematics shall not be required for commercially available or field replaceable components.

18.7.2* Pertinent information such as motor horsepower, frame size, and speed shall be listed adjacent to its symbol.

18.7.3* Where appropriate, a diagram showing the terminals for interface connections shall be provided. Switch symbols shall be shown on the electromechanical diagrams with all supplies turned off (e.g., electricity, air, water, lubricant) and with the machine and its electrical equipment in the normal starting condition and at 20°C (68°F) ambient temperature. Control settings shall be shown on the diagram.

18.7.4 Conductors shall be identified in logical order in accordance with Section 14.2.

18.7.5* Circuit Characteristics.

18.7.5.1 Circuits shall be shown in a way so as to facilitate the understanding of their function as well as maintenance and fault location.

18.7.5.2 A cross-referencing scheme shall be used in conjunction with each relay, output device, limit switch, and pressure switch so that any contact associated with the device can be readily located on the diagrams.

18.7.6 Control circuit devices shall be shown between vertical lines that represent control power wiring. The left vertical line shall be the control circuit's common and the right line shall be the operating coil's common, except where permitted by Chapter 9 design requirements. Control devices shall be shown on horizontal lines (rungs) between the vertical lines. Parallel circuits shall be shown on separate horizontal lines directly adjacent to (above or below) the original circuit.

Exception: Upon agreement between the machine manufacturer and the user, an alternate convention shall be permitted (e.g., one of the IEC standard presentation methods).

18.7.7 An interconnection diagram shall be provided on large systems having a number of separate enclosures or control stations. It shall provide full information about the external connections of all of the electrical equipment on the machine.

18.7.8 Interlock wiring diagrams shall include devices, functions, and conductors in the circuit where used.

18.7.9 Plug/receptacle pin identification shall be shown on the diagram(s).

18.8 Operating Manual.

18.8.1* The technical documentation shall contain an operating manual detailing proper procedures for set-up and equipment use.

18.8.2 Where the operation of the equipment can be programmed, detailed information on methods of programming, equipment required, program verification, and additional safety procedures (where required) shall be provided.

18.9 Maintenance Manual.

18.9.1* The technical documentation shall contain a maintenance manual detailing proper procedures for adjustment, servicing and preventive inspection, and repair.

18.9.2 Where methods for the verification of proper operation are provided (e.g., software testing programs), the use of those methods shall be detailed.

18.10* Parts List.

18.10.1 The parts list shall comprise, as a minimum, information necessary for ordering spare or replacement parts (e.g., components, devices, software, test equipment, technical documentation) required for preventive or corrective maintenance, including those that are recommended to be carried in stock by the equipment user.

18.10.2 The parts list shall show the following for each item:

(1) Reference designation used in the documentation
(2) Its type designation
(3) Supplier (and supplier's part number)
(4) Its general characteristics where appropriate
(5) Quantity of items with the same reference designation

Chapter 19 Testing and Verification

19.1* General. The verification of the continuity of the equipment grounding (protective bonding) circuit shall be conducted and documented. When the electrical equipment is modified, the requirements in Section 19.7 shall apply. Applicable tests shall be performed where deemed necessary in accordance with the references in the following list:

(1) Verification that the electrical equipment is in compliance with the technical documentation *(see Chapter 18)*
(2) Insulation resistance test *(see Section 19.3)*
(3) Voltage test *(see Section 19.4)*
(4) Protection against residual voltages test *(see Section 19.5)*
(5) Functional test *(see Section 19.6)*

19.2* Continuity of the Equipment Grounding (Protective Bonding) Circuit. One of the following methods shall be used to verify the continuity of the equipment grounding circuit:

(1) Use an impedance measuring device, take into account any impedance in the measuring circuit. The measured impedance shall be 0.1 ohm or less.
(2) Apply a current of at least 10 amperes, 50 Hz or 60 Hz, derived from a SELV source. The tests are to be made between the equipment grounding (PE) terminal and relevant points that are part of the equipment grounding (protective bonding) circuit; the measured voltage between the equipment grounding (PE) terminal and the points of test is not to exceed the values given in Table 19.2.

19.3 Insulation Resistance Tests. The insulation resistance measured at 500 volts dc between the power circuit conductors and the equipment grounding (protective bonding) circuit shall not be less than 1 megohm. The test shall be permitted to be made on individual sections of the machine.

Table 19.2 Verification of Continuity of the Equipment Grounding (Protective Bonding) Circuit

Minimum Equipment Grounding (Protective Bonding) Conductor Cross-Sectional Area of the Branch Under Test (AWG)	Maximum Measured Voltage Drop* (V)
18	3.3
16	2.6
14	1.9
10	1.4
>8	1.0

*Values are given for a test current of 10 amperes.

19.4* Voltage Tests. The machine shall withstand without breakdown a test voltage gradually applied from 0 to 1500 volts ac or 2121 volts dc and held at the maximum value for a period of at least 1 second between the conductors of all primary circuits and the equipment grounding (protective bonding) circuit. The test voltage shall be supplied from an isolated power supply with a minimum rating of 500 volt amperes. Components that are not rated to withstand the test voltage shall be disconnected during testing.

19.5 Protection Against Residual Voltages. Residual voltage tests shall be performed to ensure compliance with Section 6.4.

19.6 Functional Tests. The functions of electrical equipment, particularly those related to safety and safeguarding, shall be tested.

19.7 Retesting. Where a portion of the machine and its associated equipment is changed or modified, that portion shall be reverified and retested as appropriate.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.1 In this standard, the term *electrical* includes both electrical and electronic equipment. Requirements that apply only to electronic equipment are so identified.

The general terms *machine* and *machinery* as used throughout this standard mean industrial machinery. See Annex C for examples of industrial machines covered by this standard.

A.1.5 Motor design letter designations are found in ANSI/NEMA MG 1 and ANSI/IEEE 100.

A.3.1 Chapter 3 contains only those definitions essential to the proper application of this standard. It is not intended to include commonly defined general terms or commonly defined technical terms from related codes and standards. In general, only those terms that are used in two or more places are defined. Spelling and definitions of general words and terms follow *Webster's Collegiate Dictionary*, 10th edition.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.3 Actuator. The actuator can take the form of a handle, knob, pushbutton, roller, plunger, and so forth. There are some actuating means that do not require an external actuating force but only an action. See also 3.3.3.1, Machine Actuator.

A.3.3.4 Adjustable Speed Drives. This includes ac and dc voltage modes and frequency mode controls. Belt, chain, or roller shifting controllers are not included.

A.3.3.5 Ambient Temperature. Ambient air temperature as applied to an enclosure or housing is the average temperature of the surrounding air that comes in contact with the enclosure or housing. Ambient air temperature as applied to a component or device within the enclosure is the average temperature of the surrounding air that comes in contact with the component.

A.3.3.7 Attachment Plug (Plug Cap) (Plug). A plug/socket combination is a plug and socket outlet, a cable coupler, or an appliance coupler.

A.3.3.9 Bonding (Bonded). See 3.3.76, Protective Bonding Circuit.

A.3.3.13 Cable Trunking System. See 3.3.108, Wireway.

A.3.3.14 Circuit Breaker. The automatic opening means can be integral, direct acting with the circuit breaker, or remote from the circuit breaker.

A.3.3.15 Color Graphic Interface Device. This does not include monochrome or black and white displays.

A.3.3.19 Control Circuit (of a machine). Power circuit protection can be provided by control shunt-tripping.

A.3.3.29 Duct. Conduits, cable trunking systems *(see 3.3.12)*, and underfloor channels are types of duct. See also 3.3.79, Raceway.

A.3.3.42 Failure (of equipment). After failure the item has a fault. "Failure" is an event, as distinguished from "fault," which is a state. This concept as defined does not apply to items consisting of software only.

A.3.3.43 Fault. A fault is often the result of a failure of the item itself, but can exist without prior failure.

A.3.3.51 Guard. Depending on its construction, a guard can be called casing, cover, screen, door, enclosing guard.

A.3.3.54 Identified (as applied to equipment). Some examples of ways to determine suitability of equipment for a specific purpose, environment, or application include investigations by a qualified testing laboratory (listing and labeling), an inspection agency, or other organizations concerned with product evaluation.

A.3.3.62 Interrupting Rating. Equipment intended to interrupt current at other than fault levels can have its interrupting rating implied in other ratings, such as horsepower or locked motor current.

A.3.3.70 Overcurrent. A current in excess of rating may be accommodated by certain equipment and conductors for a given set of conditions. Therefore, the rules for overcurrent protection are specific for particular situations.

A.3.3.71 Overload. Overload should not be used as a synonym for overcurrent.

A.3.3.75 Programmable Electronic System (PES). This term includes all elements in the system extending from sensors to other input devices via data highways or other communication paths to the actuators or other output devices.

A.3.3.76 Protective Bonding Circuit. See 3.3.9, Bonding.

A.3.3.80 Receptacle. A plug/socket combination is a plug and socket outlet, a cable coupler, or an appliance coupler.

A.3.3.84 Risk. One reference to risk assessment is ANSI B11.TR3:2000, *Risk Assessment and Risk Reduction — A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools.*

A.3.3.98 Supplementary Overcurrent Protective Device. Supplementary overcurrent protective devices are not general use devices, as are branch circuit devices, and must be evaluated for appropriate application in every instance where they are used. Supplementary overcurrent protective devices are extremely application oriented, and prior to applying the devices, the differences and limitations for these devices must be investigated. Such a device is allowed to be incomplete in construction or restricted in performance. Such a device is not suitable for branch circuit protection, and is not used where branch circuit protection is required.

One example of the difference and limitations is that a supplementary overcurrent protective device may have spacing, creepage and clearance that are considerably less than that of a branch circuit overcurrent protective device.

Example: A supplemental protector, UL 1077, has spacing that are 9.5 mm (0.375 in.) through air and 12.7 mm (0.5 in.) over surface. A branch circuit rated UL 489 molded case circuit breaker has spacing that are 19.1 mm (0.75 in.) through air and 31.8 mm (1.25 in.) over surface.

Another example of differences and limitations is that branch circuit overcurrent protective devices have standard overload characteristics to protect branch circuits and feeder conductors. Supplementary overcurrent protective devices do not have standard overload characteristics and may differ from the standard branch circuit overload characteristics. Also, supplementary overcurrent protective devices have interrupting ratings that can range from 32 amperes to 100,000 amperes. When supplementary overcurrent protective devices are considered for proper use, it is important to be sure that the device's interrupting rating equals or exceeds the available short-circuit current and that the device has the proper voltage rating for the installation (including compliance with slash voltage rating requirements, if applicable).

Examples of supplemental overcurrent protective devices include, but are not limited to, the following:

(1) UL 248.14, *Supplemental Fuses*
(2) UL 1077, *Supplemental Protectors (Mini Circuit Breakers)*

A.3.3.99 Supplier. The user can also act in the capacity of a supplier to him or herself.

A.3.3.104 Undervoltage Protection. The principal objective of this device is to prevent automatic restarting of the equipment. Standard undervoltage or low-voltage protection devices are not designed to become effective at any specific degree of voltage reduction.

A.4.1 A sample inquiry form is provided in Annex B for use in facilitating an agreement between the supplier and the user.

Hazards can include, but are not limited to, the following:

(1) Failures or faults in the electrical equipment resulting in the possibility of electrical shock or electrical fire
(2) Failures or faults in control circuits (or components and devices associated with these circuits) resulting in malfunctioning of the machine
(3) Disturbances or disruptions in power sources as well as failures or faults in the power circuits resulting in the malfunctioning of the machine
(4) Loss of continuity of circuits that depend upon sliding or rolling contacts resulting in a failure of a safety function
(5) Electrical disturbances (e.g., electromagnetic, electrostatic, or radio interference) either from outside the electrical equipment or internally generated
(6) Stored energy (either electrical or mechanical)
(7) Audible noise at levels that cause health problems to persons

Safety measures are a combination of the measures incorporated at the design stage and those measures required to be implemented by the user.

Design and development should be the first consideration in the reduction of risks. Where this is not possible, safeguarding should be considered. Safeguarding includes the use of safeguards, awareness means, and safe working procedures.

A.4.3.1 See Annex B.

A.4.3.2 The short time value for the frequency can be specified by the user *(see Annex B).*

A.4.4 See Annex B.

A.4.4.1 See Annex B.

A.4.4.2 The electrical interferences generated by the equipment itself should not exceed levels specified in the relevant equipment standards and others dealing with electromagnetic compatibility (EMC) levels. The levels allowed should be determined for the specific application.

Generated interference signals can be kept to a minimum by the following:

(1) Suppression at the source by using capacitors, inductors, diodes, Zener diodes, varistors, or active devices, or a combination of these
(2) Equipment screening in a bonded electrically conductive enclosure to provide segregation from other equipment

Undesirable effects of electrostatic discharge, radiated electromagnetic energy, and supply conductor (mains borne) interference should be avoided (e.g., use of appropriate filters and time delays, choice of certain power levels, suitable wiring types and practices).

The effects of interference on equipment can be reduced by the following:

(1) *Reference potential circuit or common connections.* Each common connection treated as a single circuit and connected to one of several central reference points that are connected to ground (wired to earth) by insulated conductors of large cross-sectional area.
(2) *Frame connections.* In each piece of equipment all frame connections are to be taken to a common point with a conductor of large cross-sectional area (e.g., braided conductors, foil strips having a width much greater than the thickness) used between slides and enclosures. The connections to the frame are to be as short as possible.
(3) *Transmission of signals.* Electrostatic screens, electromagnetic shields, twisted conductors, and orientation (i.e., crossing cable runs at as near to 90 degrees as practicable) as necessary to ensure that the low level signal wiring is not affected by interference from control or power cables, or running the connections parallel to the ground plane as necessary.
(4) *Separation of equipment.* Separating and/or shielding sensitive equipment (e.g., units working with pulses and/or at low signal levels) from switching equipment (e.g., electromagnetic relays, thyristors). Separation of low level signal wiring from control and power cables.

A.4.4.3 For very hot environments (e.g., hot climates, steel mills, paper mills) and for cold environments, extra requirements may be necessary. See Annex B.

A.4.4.4 For extremely dry or moist environments, extra requirements may be necessary to prevent static discharge.

A.4.4.5 See Annex B.

A.4.4.6 See Annex B.

A.4.4.7 Where equipment is subject to radiation (e.g., microwave, ultraviolet, lasers, x-rays), additional measures should be taken to avoid malfunctioning and accelerated deterioration of the insulation.

A.5.1.1 For large complex machinery comprising a number of widely spaced machines working together in a coordinated manner, more than one incoming supply circuit might be needed depending upon the site supply circuit arrangements *(see 5.3.1)*.

A.5.1.3 See Question 14 in Annex B.

A.5.2 For additional information on the grounding terminal, see 8.2.1.2.

A.6.2.3.1.1 See NFPA 70E, *Standard for Electrical Safety Requirements for Employee Workplaces*, for additional information on work practices.

A.6.3.1.1(1) Ripple-free is conventionally defined for a sinusoidal ripple voltage as a ripple content of not more than 10 percent rms.

A.6.3.1.1(3) For additional information on isolating transformers, refer to IEC 60742 and IEC 61558-1.

A.7.2.1 Figure A.7.2.1(a) and Figure A.7.2.1(b) show typical circuits acceptable for the protection of current-carrying and current-consuming electrical machine components. Protective interlocks are not shown.

A.7.2.2 See 7.2.10 and Section 18.5. The size and overcurrent protection of the supply conductors to a machine are covered by Article 670 of NFPA 70, *National Electrical Code*.

A.7.2.9 Proper application of molded case circuit breakers on 3-phase systems, other than solidly grounded wye, particularly on corner grounded delta systems, considers the circuit breakers' individual pole interrupting capability.

A.7.2.10.1 In Note 6 of Table 1 of IEC 60947-4, the terms Type 1 and Type 2 coordinated protection are defined as follows:

"(1) *Type 1 protection.* Under short-circuit conditions the contactor or starter may not be suitable for further use without repair or replacement.

"(2) *Type 2 protection.* Under short-circuit conditions the contactor or starter shall be suitable for further use.

The maximum allowable values in Table 7.2.10.1 do not guarantee Type 2 protection. Type 2 protection is recommended for use in applications where enhanced performance and reliability are required."

A.7.2.10.4(1) The short-circuit current rating includes the following:

(1) The class and rating of the short-circuit protective device
(2) The maximum nominal application voltage
(3) The maximum available fault current

A.7.3.1.2 See 7.3.2 concerning automatic resetting.

A.7.4 An example could be a resistance heating circuit that is short-time rated or that loses its cooling medium.

A.7.6.1 Overspeed protection means include, but are not necessarily limited to, the following:

(1) A mechanical overspeed device incorporated in the drive to remove armature voltage upon motor overspeed.
(2) An electrical overspeed detector that will remove armature voltage upon motor overspeed.
(3) Field loss detection to remove armature voltage upon the loss of field current.
(4) Voltage-limiting speed-regulated drives that operate with constant full field. In this case, protection is obtained individually for the loss of field or tachometer feedback; however, protection against simultaneous loss of field and tachometer is not provided.

A.7.8 Conditions of use that can lead to an incorrect phase sequence include the following:

(1) A machine transferred from one supply to another
(2) A mobile machine with a facility for connection to an external power supply

A.7.10.1 See 7.2.1 and 7.2.10.

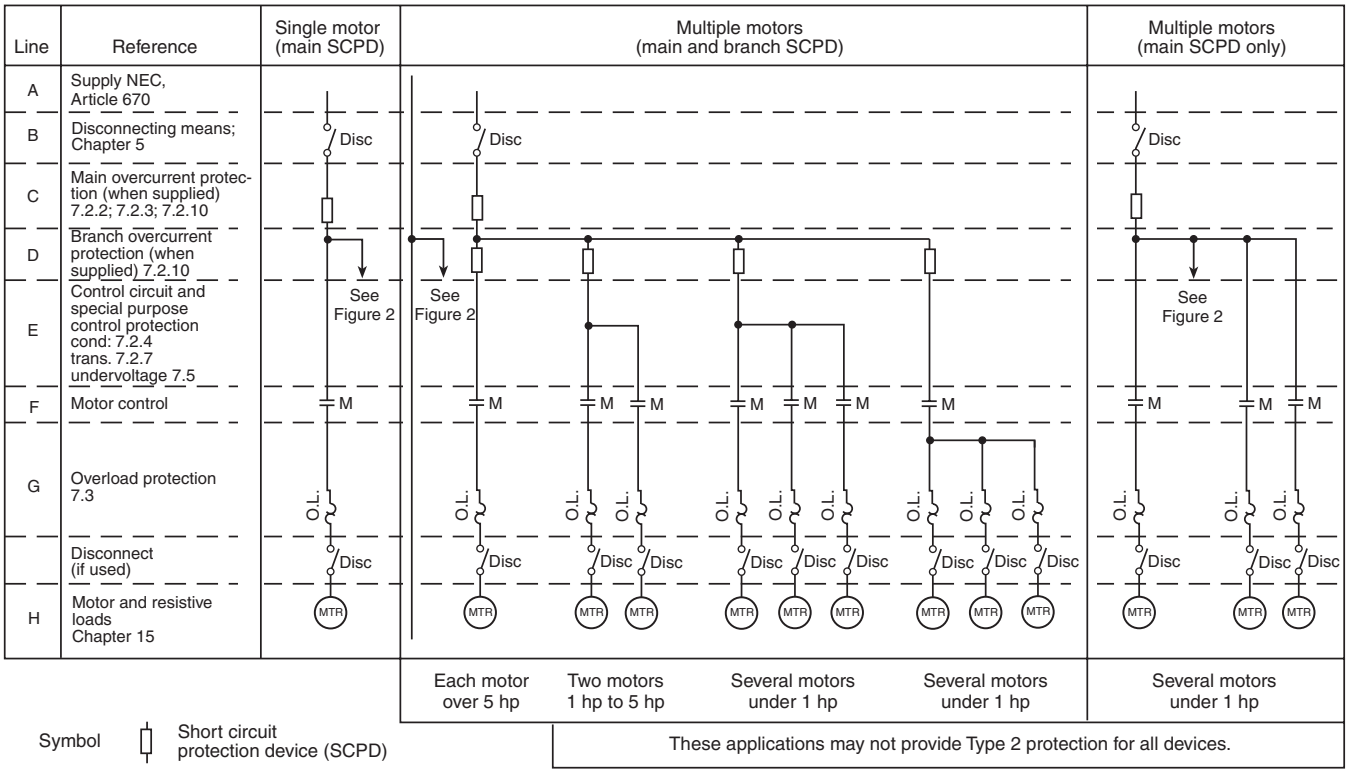


FIGURE A.7.2.1(a) One Line Representation of Electrical System Power Distribution.

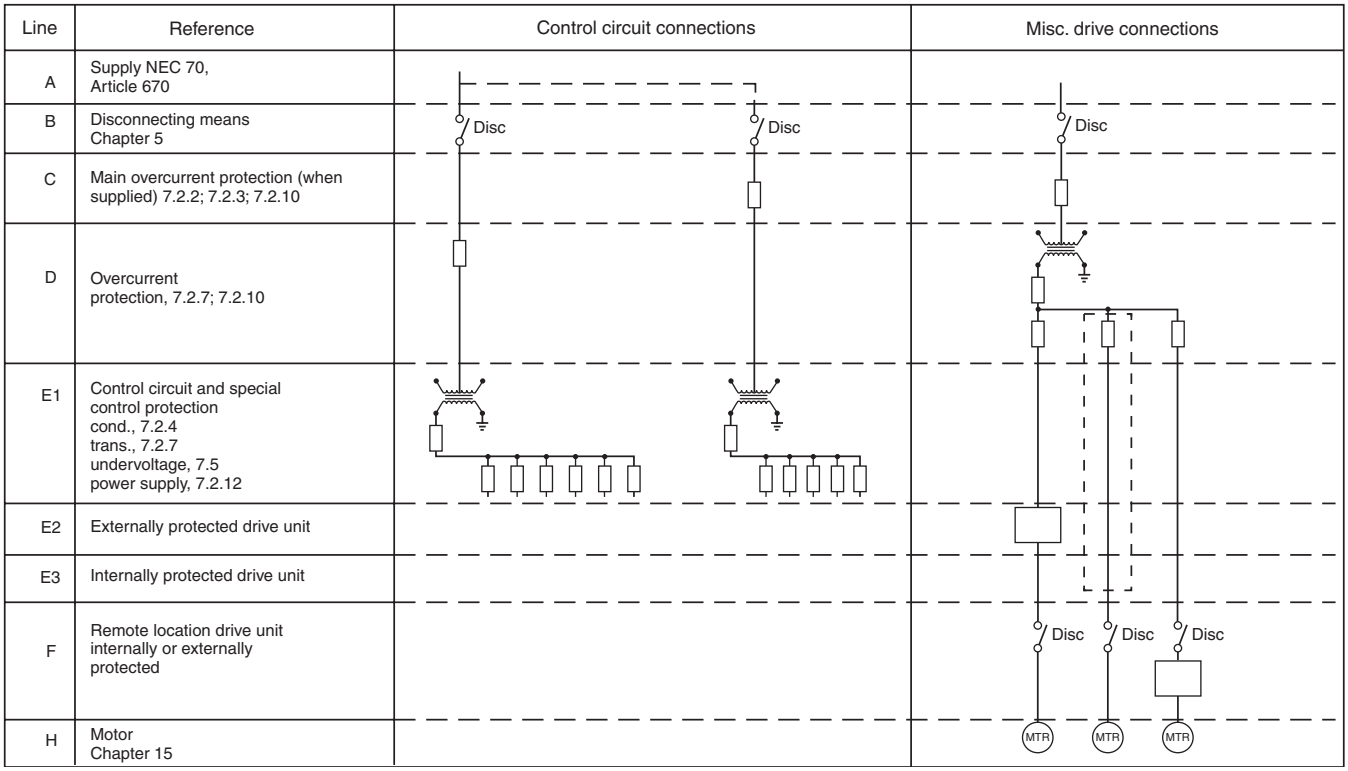


FIGURE A.7.2.1(b) One Line Representation of Electrical System Power Protection.

A.8.1 The terms *protective earthing conductor, protective bonding conductor, protective conductor, neutral,* and *earth* are used in other countries.

A.8.2.1.2 The minimum cross-sectional area of the external protective copper conductor can be required to be larger for IEC applications. See Table 1 in IEC 60204-1 for these requirements.

A.8.2.1.2.4 Some other standards require the letters PE for the connection to the external protective earthing system.

A.8.2.4 For additional information, see 14.4.5.3.

A.8.2.5.2 The letters PE or the bicolor GREEN-AND-YELLOW is used in some countries.

A.9.2.2 With the exception of emergency stop and depending upon the risk assessment, removal of power can be accomplished by the use of either electromechanical or solid-state components.

A.9.2.3.3 See 9.2.4 for overriding of safeguards under special conditions.

A.9.2.5.4 For other safety-related stop functions, see 11.3.4.

A.9.2.5.6 See Annex B.

A.9.2.7.3.2(3) A valid signal also includes the signal that confirms communication is established and maintained. *(See Annex B.)*

A.9.2.7.4 One way to determine applicable error detection methods is to refer to IEC 60870-5-1, *Telecontrol equipment and systems.*

A.9.4.1 See Annex I.

A.9.4.3 IEC 61508 provides requirements for the design of control systems incorporating the use of software and firmware based controllers to performing safety-related functions.

A.10.1.1 For further information on device selection, mounting, identification, and coding, see IEC 60073 and IEC 60447.

A.10.1.3 For further information on degrees of protection, see Annex F. Also, see additional publications such as NEMA 250, UL 50, UL 508, and IEC 60529.

A.10.1.4.2 For further information on positive (direct) opening operation, see IEC 60947-5-1.

A.10.7.2.2 For further information on positive (direct) opening operation, see IEC 60947-5-1.

A.10.9 Displays intended to be warning devices are recommended to be of the flashing or rotary type and be provided with an audible warning device.

A.11.3.4 IEC 61508 provides requirements for the design of software and firmware based controllers for use in control systems performing safety-related functions.

A.12.2.1.4 Where access is required for regular maintenance or adjustment, the location of relevant devices is recommended to be between 0.4 m (15.75 in.) and 2.0 m (6½ ft) above the servicing level to facilitate maintenance. The location of the terminals is recommended to be at least 0.2 m (7.88 in.) above the servicing level and be so placed that conductors and cables can be easily connected to them.

A.12.2.1.7 For additional information on attachment plug and receptacle (plug/socket) combinations, see 14.4.5.

A.12.3.1 The degrees of protection against ingress of water and other liquids are covered by NEMA 250. See also Annex F.

A.12.4.6 Windows provided for viewing internally mounted indicating devices should be of a material suitable to withstand mechanical stress and chemical attack [e.g., toughened glass, polycarbonate sheet of 3-mm (⅛-in.) thickness].

A.13.1.1 Typical operating conditions include the following:

(1) Voltage
(2) Current
(3) Protection against electric shock
(4) Grouping of cables

External influences include the following:

(1) Ambient temperature
(2) Presence of water, oil, or other fluid substances
(3) Radiation
(4) Ultraviolet light
(5) Corrosive substances
(6) Mechanical stresses
    (a) Installation
    (b) Fire hazards

A.13.6.4 Examples of special wiring applications include solderless wrap, wire clip type connectors, shielded conductors, or the like.

A.13.7.1.2 Cables for such conditions are specified in relevant national standards.

The operational life of the cable will be reduced where unfavorable operating conditions such as high tensile stress, small radii, bending into another plane, and/or where frequent duty cycles coincide.

A.13.7.3 Where cables of circular cross-sectional area are installed on drums, the maximum current-carrying capacity in free air should be derated in accordance with Table 13.7.3. For additional information, also refer to Clause 44 of IEC 60621-3.

A.14.1.1.10 A single tag bearing the complete identification is preferred.

A.14.1.1.11 For additional information on terminal blocks, refer to IEC 60947-7-1, "Low-voltage switchgear and control gear."

A.14.1.5.1 For additional information on flexible cords, refer to ANSI/UL 62, *Flexible Cord and Fixture Wire.*

A.14.2.2.1 The international standards reserve the use of the bicolor combination GREEN-AND-YELLOW for this purpose. The bicolor combination is such that on any 15-mm (0.6-in.) length, one of the colors covers at least 30 percent and not more than 70 percent of the surface of the conductor, and the other color covers the remainder of the surface.

A.14.2.3.1 IEC 60204-1 reserves the use of the color LIGHT BLUE for the neutral conductor and requires its use when identification is by color.

A.14.2.4.1 IEC 60204-1 recommends the use of the color ORANGE for this purpose where identification is by color. For further information on excepted circuits, see 5.3.5.

A.14.3.1 For additional information on flame-retardant materials, refer to IEC 60332-1, *Tests on Electric Cables Under Fire Conditions.*

A.14.5.2 It should be recognized that, for certain conditions, a larger size raceway or a lesser raceway fill should be considered.

A.14.5.3.1.2 Metric designators and trade sizes for conduit, tubing, and associated fittings and accessories are designated in Table A.14.5.3.1.2.

Table A.14.5.3.1.2 Metric Designator and Trade Sizes

Metric Designator	Trade Size
12	⅜
16	½
21	¾
27	1
35	1¼
41	1½
53	2
63	2½
78	3
91	3½
103	4
129	5
155	6

Note: The metric designators and trade sizes are for identification purposes only and are not actual dimensions.

A.14.5.3.2.2 The use of dissimilar metals in contact that can cause galvanic action should be avoided.

A.14.5.3.2.3 The use of dissimilar metals in contact that can cause galvanic action should be avoided.

A.14.5.3.2.4 The use of dissimilar metals in contact that can cause galvanic action should be avoided.

A.14.5.3.3.1 For additional information about rigid nonmetallic conduit, refer to UL 651.

A.14.5.3.3.3 For additional information see Table 347-9(A) of NFPA 70, *National Electrical Code,* 1999, Expansion Characteristics of PVC Rigid Nonmetallic Conduit Coefficient of Thermal Expansion = 3.38×10^{-5} in./in./°F.

A.14.5.4.1.2 Metric trade numerical designations for flexible metal conduit and liquidtight flexible metal conduit are ⅜ = 12, ½ = 16, ¾ = 21, 1 = 27, 1¼ = 35, 1½ = 41, 2 = 53, 2½ = 63, 3 = 78, 3½ = 91, and 4 = 103.

A.14.5.5.5 Metric trade numerical designations for liquidtight flexible nonmetallic conduit are ⅜ = 12, ½ = 16, ¾ = 21, 1 = 27, 1¼ = 35, 1½ = 41, 2 = 53, 2½ = 63, 3 = 78, 3½ = 91, and 4 = 103.

A.14.5.7 See Section 17.2 for information on warning marking and signs.

A.15.1 For additional information related to motor standards, refer to UL 1004, NEMA MG-1, IEEE 841, or IEC 60034-1.

The protection requirements for motors and associated equipment are given in Section 7.2 for overcurrent protection, in Section 7.3 for overload protection, and in Section 7.6 for overspeed protection.

A.15.3 For a comparison between kilowatt and horsepower size, see Annex G, Table G.1 and Table G.2.

A.15.6 Associated machine actuators are those associated with the same motion (e.g., cable drums and long-travel drives).

A.17.3 Such markings can be as agreed between the user and the supplier of the equipment. See Annex B for additional information.

For further information on symbols, see IEC 60417 and ISO 7000.

Consideration should be given to the use of IEC symbols for pushbuttons. See Figure A.17.3(a) through Figure A.17.3(d).

FIGURE A.17.3(a) Symbol that Represents Start or On — IEC Symbol Number 5007.

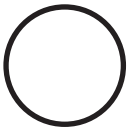


FIGURE A.17.3(b) Symbol that Represents Stop or Off — IEC Symbol Number 5008.

FIGURE A.17.3(c) Symbol that Represents Alternatively Act as Start and Stop or On and Off — IEC Symbol Number 5010.

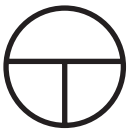


FIGURE A.17.3(d) Symbol that Represents Movement When Pressed and Stop Movement When Released (Jogging) — IEC Symbol Number 5011.

A.18.4 The technical documentation should also contain, where appropriate, information regarding load currents, peak starting currents, and permitted voltage drops. That information should be contained in either the system or circuit diagram(s).

A.18.5.1 In complex cases, it can be necessary to refer to the assembly drawings for details.

A.18.5.3 For further information regarding supply circuit conductors, see 7.2.2.

A.18.5.4 For recommendations concerning supplier agreements, see Annex B.

A.18.5.5 For recommendations concerning supplier agreements, see Annex B.

A.18.5.6 Examples of installation diagrams can be found in Annex D.

A.18.5.7 Examples of interconnection diagrams/tables can be found in Annex D.

A.18.6 Examples of block diagrams, further rules, and examples can be found in Annex D.

Function diagrams can be used as either part of, or in addition to, the block diagram. Examples of function diagrams can be found in Annex D.

A.18.7.1 See Annex D for examples of electrical diagrams.

A.18.7.2 Examples of circuit diagrams can be found in Annex D.

A.18.7.3 The diagram showing the terminals for interface connections can be used in conjunction with the circuit diagram(s) for simplification. The diagram should contain a reference to the detailed circuit diagram of each unit shown.

A.18.7.5 See Annex E for examples of devices and component designations.

A.18.8.1 Particular attention should be given to the safety measures provided and to the improper methods of operation that are anticipated.

A.18.9.1 Recommendations on maintenance/service records should be part of that manual. Troubleshooting information and suggestions for locating and replacing faulty components, suggested preventative maintenance schedules, and related data should be included.

A.18.10 See Annex D, Figure D.1(o), Sample Parts list.

A.19.1 It is recommended that the sequence listed be followed. Following this order will help ensure the accuracy of the tests results and the safety of personnel. Refer to SEMI S9 for additional information on performing the testing described in Section 19.1.

A.19.2 The concepts of SELV are further explained in UL 1950, UL 3101-1, and IEC 60364-411.1.

A.19.4 Refer to SEMI S9 for additional information on performing this dielectric withstand (hypot) test.

Annex B Inquiry Form for the Electrical Equipment of Machines

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 It is recommended that the information in Figure B.1 be provided by the intended user of the equipment. It facilitates an agreement between the user and supplier on basic conditions and additional user requirements to ensure proper design, application, and utilization of the electrical equipment of the machine *(see Section 4.1)*.

INQUIRY FORM FOR THE ELECTRICAL EQUIPMENT OF MACHINES

Name of manufacturer/supplier _____

Name of end user _____

Tender/Order No. _____ Date _____

Type of Machine/Serial Number _____

1. Are there to be modifications as allowed for within this standard? ❑ Yes ❑ No

Operating Conditions — Special requirements (see Section 4.4)

2. Ambient temperature range _____
3. Humidity range _____
4. Altitude _____
5. Environmental (e.g., corrosive atmospheres, particulate matter, EMC) _____
6. Non-ionizing radiation _____
7. Vibration, shock _____
8. Special installation and operation requirements (e.g., additional flame-retardant requirements for cables and conductors)

   _____

Power supply(ies) and related conditions (see Section 4.3)

9. Anticipated voltage fluctuations (if more than ±10 %) _____
10. Anticipated frequency fluctuations (if more than in 4.3.2.2) _____

    Specification of short-term value _____
11. Indicate possible future changes in electrical equipment that will require an increase in the electrical supply requirements _____
12. Indicate for each source of electrical supply required:

    Nominal Voltage (V) _____ ac _____ dc

    If ac, number of phases _____ frequency _____ Hz

    Prospective short-circuit current at the point of supply to the machine _____ kA rms *(see also question 15)*

    Fluctuations outside values given in 4.3.2 _____
13. Type of power supply system grounding:

    Wye phases midpoint grounded _____ Delta phase midpoint grounded _____

    Delta phases corner grounded _____ High impedance grounded _____

    Wye phases midpoint ungrounded _____ Delta phases ungrounded _____
14. Is the electrical equipment to be connected to a grounded supply conductor? *(see Section 5.1)* ❑ Yes ❑ No
15. Does the user or the supplier provide the overcurrent protection of the supply conductors? *(see 7.2.2)*

    Type and rating of overcurrent protective devices _____
16. Supply disconnecting device

    — Is the disconnection of the grounded conductor required? ❑ Yes ❑ No

    — Is a link for the grounded conductor permissible? ❑ Yes ❑ No
17. Type of disconnecting device to be provided _____

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FIGURE B.1 Inquiry Form for the Electrical Equipment of Machines.

18. Limit of power up to which three-phase AC motors can be started directly across the incoming supply lines? _____ HP
19. Can the number of motor overload detection devices be reduced? *(see Section 7.3)* ❑ Yes ❑ No
20. Where the machine is equipped with local lighting:

    — Highest permissible voltage _____ V

    — If lighting circuit voltage is not obtained directly from the power supply, state preferred voltage _____ V

Other Considerations

21. Functional identification *(see Section 17.3)* _____
22. Inscriptions/special markings _____
23. Mark of certification ❑ Yes ❑ No If YES, which one? _____

    On electrical equipment? _____ In which language? _____
24. Technical documentation *(see Section 18.1)*

    On what media? _____ In which language? _____
25. Size, location, and purpose of ducts, open cable trays, or cable supports to be provided by the user *(see Section 18.5)* (additional sheets to be provided where necessary)

    _____

    _____

    _____
26. For which of the following classes of persons is access to the interior of enclosures required during normal operation of the equipment?

    — Skilled persons _____

    — Instructed persons _____
27. Are locks with removable keys to be provided for fastening doors or covers? *(see 6.2.2)* _____
28. Indicate if special limitations on the size or weight affect the transport of a particular machine or control equipment to the installation site:

    — Maximum dimensions _____

    — Maximum weight _____
29. In the case of machines with frequent repetitive cycles of operation dependent on manual control, how frequently will cycles of operation be repeated?

    _____ per hour
30. For what length of time is it expected that the machine will be operated at this rate without subsequent pause?

    _____ minutes
31. In the case of specially built machines, is a certificate of operating tests with the loaded machine to be supplied? ❑ Yes ❑ No
32. In the case of other machines, is a certificate of operating-type tests on a loaded prototype machine to be supplied? ❑ Yes ❑ No
33. For cableless control systems, specify the time delay before automatic machine shutdown is initiated in the absence of a valid signal *(see 9.2.7.3)*: _____ seconds
34. Do you need a specific method of conductor identification to be used for the conductors referred to in 14.2.4?

    ❑ Yes ❑ No Type _____

(NFPA 79, 2 of 2)

FIGURE B.1 ***Continued***

Annex C Examples of Industrial Machines Covered by NFPA 79

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Machine Tools. Examples of machine tools are as follows:

(1) Metal cutting
(2) Metal forming

C.2 Plastics Machinery. Examples of plastics machinery are as follows:

(1) Injection molding machines
(2) Extrusion machinery
(3) Blow molding machines
(4) Specialized processing machines
(5) Thermoset molding machines
(6) Size reduction equipment

C.3 Wood Machinery. Examples of wood machinery are as follows:

(1) Woodworking machinery
(2) Laminating machinery
(3) Sawmill machines

C.4 Assembly Machines.

C.5 Material-Handling Machines. Examples of material-handling machines are as follows:

(1) Industrial robots
(2) Transfer machines
(3) Sortation machines

C.6 Inspection/Testing Machines. Examples of inspection/testing machines are as follows:

(1) Coordinate measuring machines
(2) In-process gauging machines

Annex D Technical Documentation

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 Figure D.1(a) through Figure D.1(q) are not intended to be (design) guidelines. They are included only to illustrate documentation methods.

Company emblem

Designed by: Machine Supplier, Inc.
Address 1
Address 2
Address 3
Postal code(s)
E-mail address

Customer: Customer
Project: Project number, Name
Subject: Sample drawings

Utility Usage — Ratings		
Electrical		xx fla
Compressed air	psig	xx psig xx scfm
Plant water	psig	xx gpm xx °F/°C
Recirc. chill water	psig	xx gpm xx °F/°C
Steam	psig	xx lb/hr
Natural gas	psig	xx psig
Other		

Electrical Characteristics	
3-phase, + earth	60 Hz
Main line voltage	460 V
Control voltage	115 V ac
Total motor full load	x.xx kW
Full load current	xxx A
Disc or circuit breaker rating	
Main line rated fuse capacity	
Machine serial number	
Manufactured in year	2 xxx
Electrical diagram number	

Sheet #	Description of Sheet
1	Machine cover sheet & sheet index
2	System layout & installation diagram
3	Block (system) diagram
4	Inter-connection diagram
5	Elementary schematic
6	PLC input diagram
7	PLC output diagram
8	Sample enclosure layout
9	Sample enclosure layout
10	Sequence of operations — graphical
11	Sequence of operations — descriptive
12	Sample servo diagram
13	Sample PLC network — station layout
14	Sample operator station
15	Sample parts list
16	ISO (A3) drawing standard framework
17	(Selected) ANSI Y32.2 / IEEE315/315A symbol table
18	
19	
20	
21	
22	
23	
24	
25	

Doc. #	References to Additional Technical
1	Operating manual — manual number
2	Maintenance manual — manual number
3	PLC programming manual — manual name and number
4	Network installation manual — manual number
5	AC servo drive manual — manual number

FIGURE D.1(a) Cover Sheet and Sheet Index.

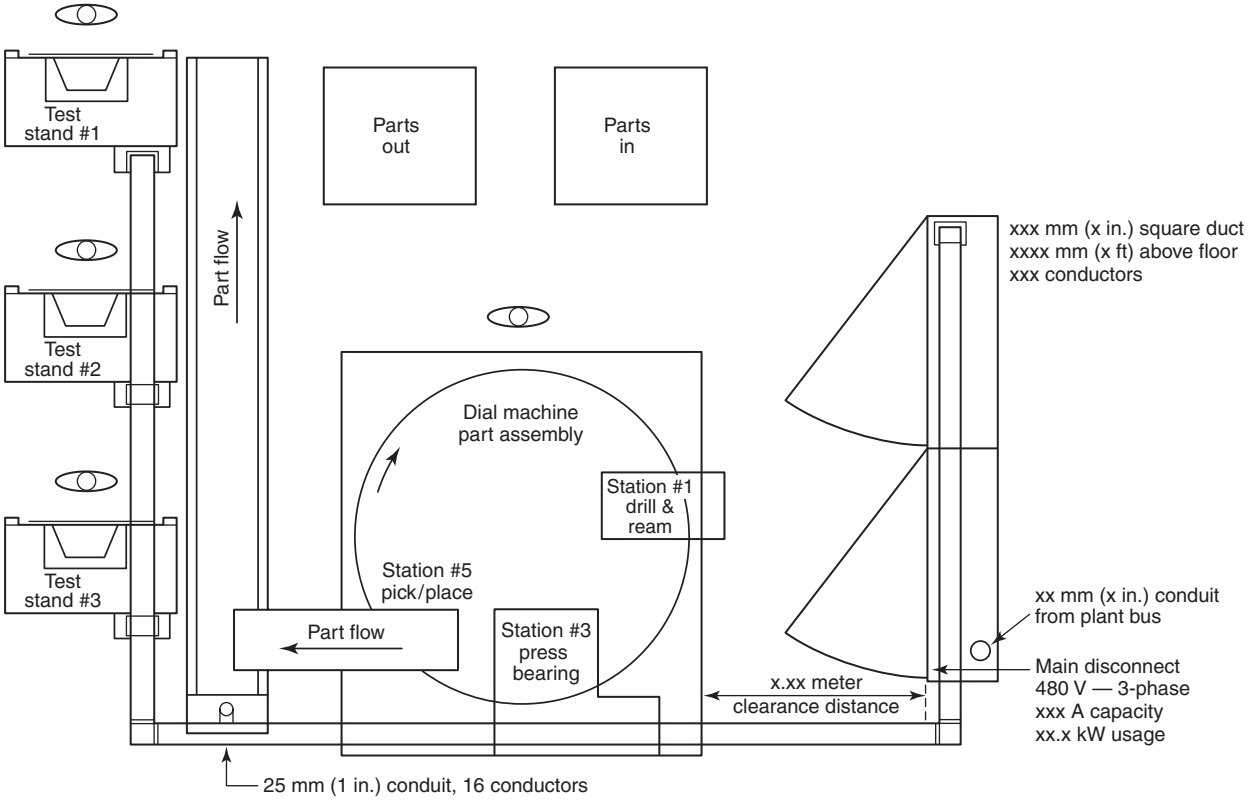


FIGURE D.1(b) System Layout and Installation Diagram.

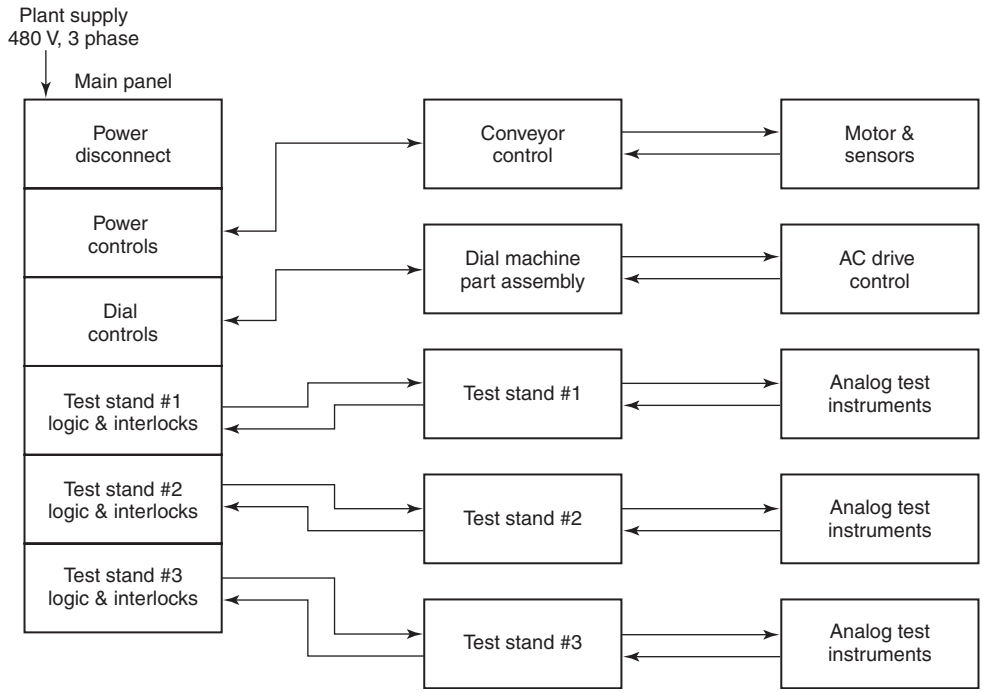


FIGURE D.1(c) Block (System) Diagram.

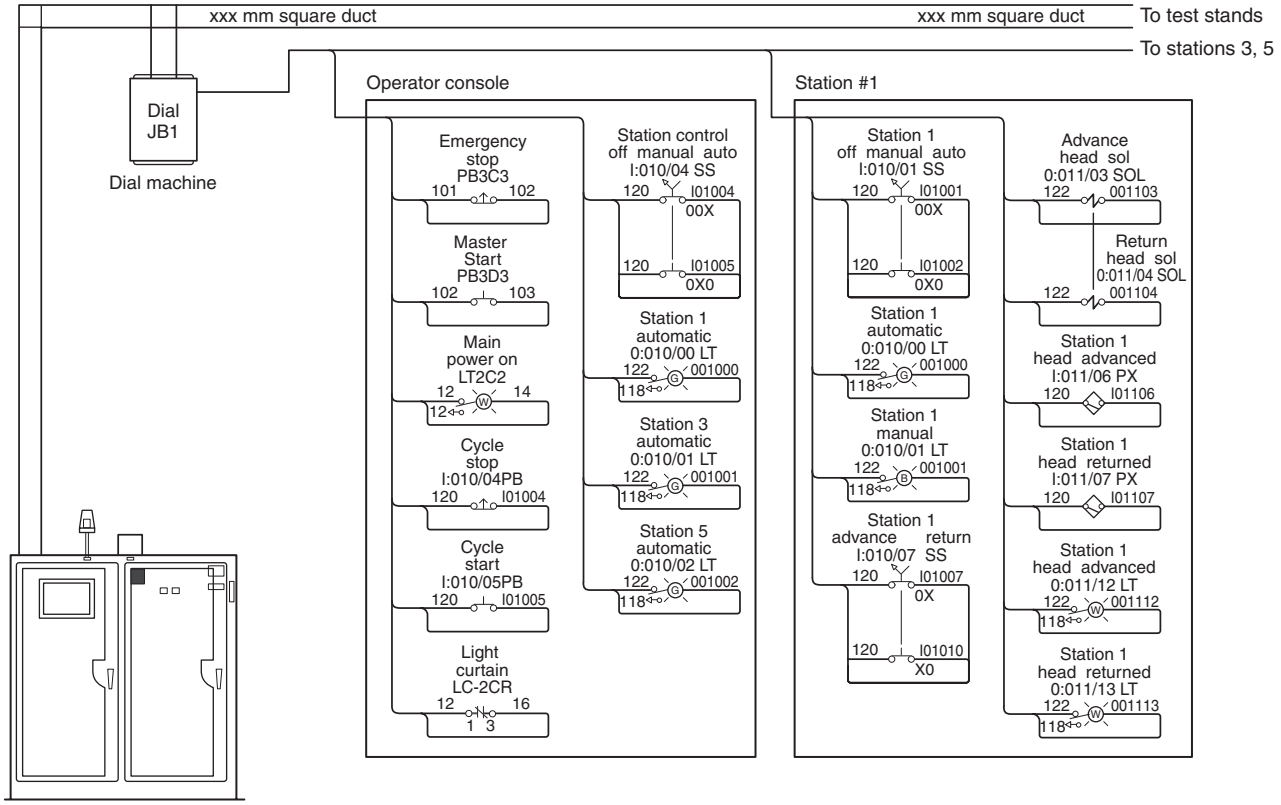


FIGURE D.1(d) Interconnection Diagram.

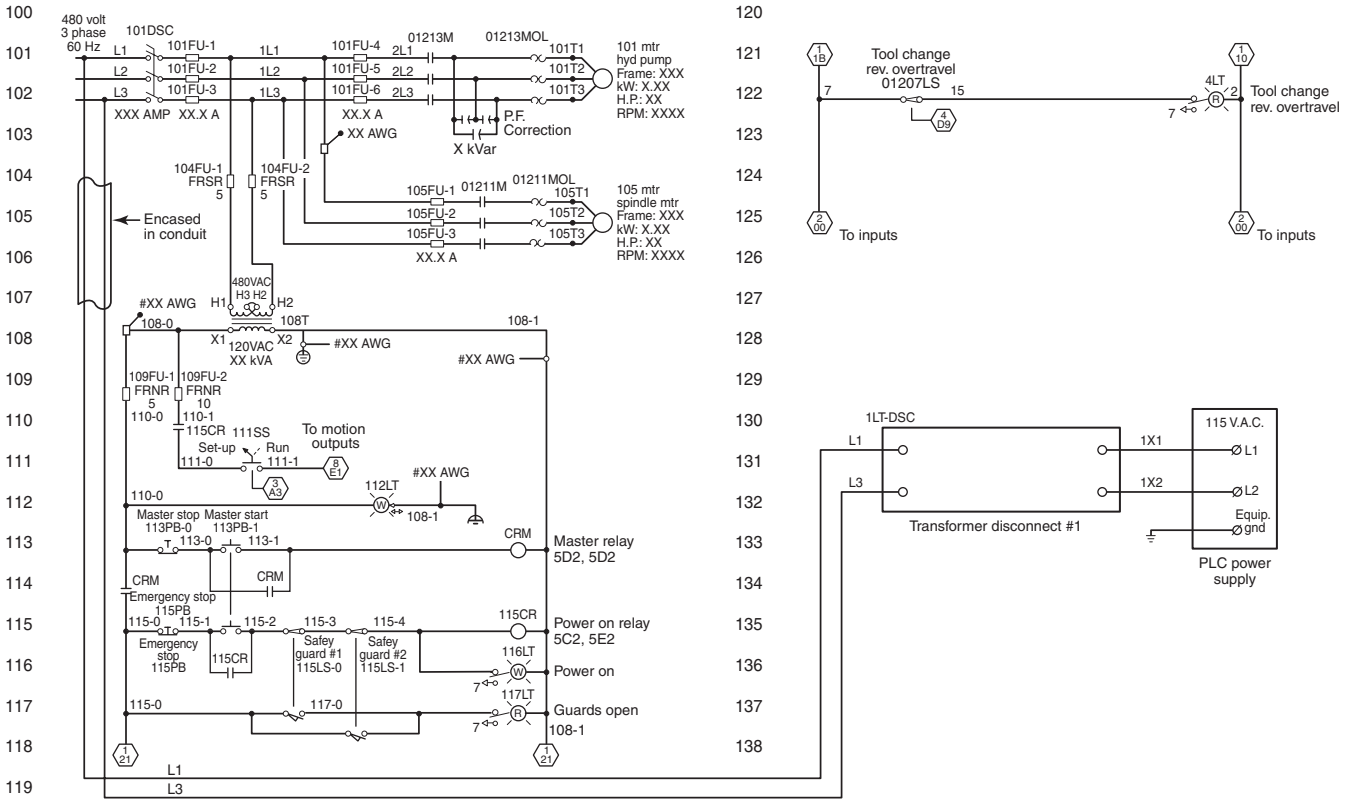


FIGURE D.1(e) Elementary Schematic.

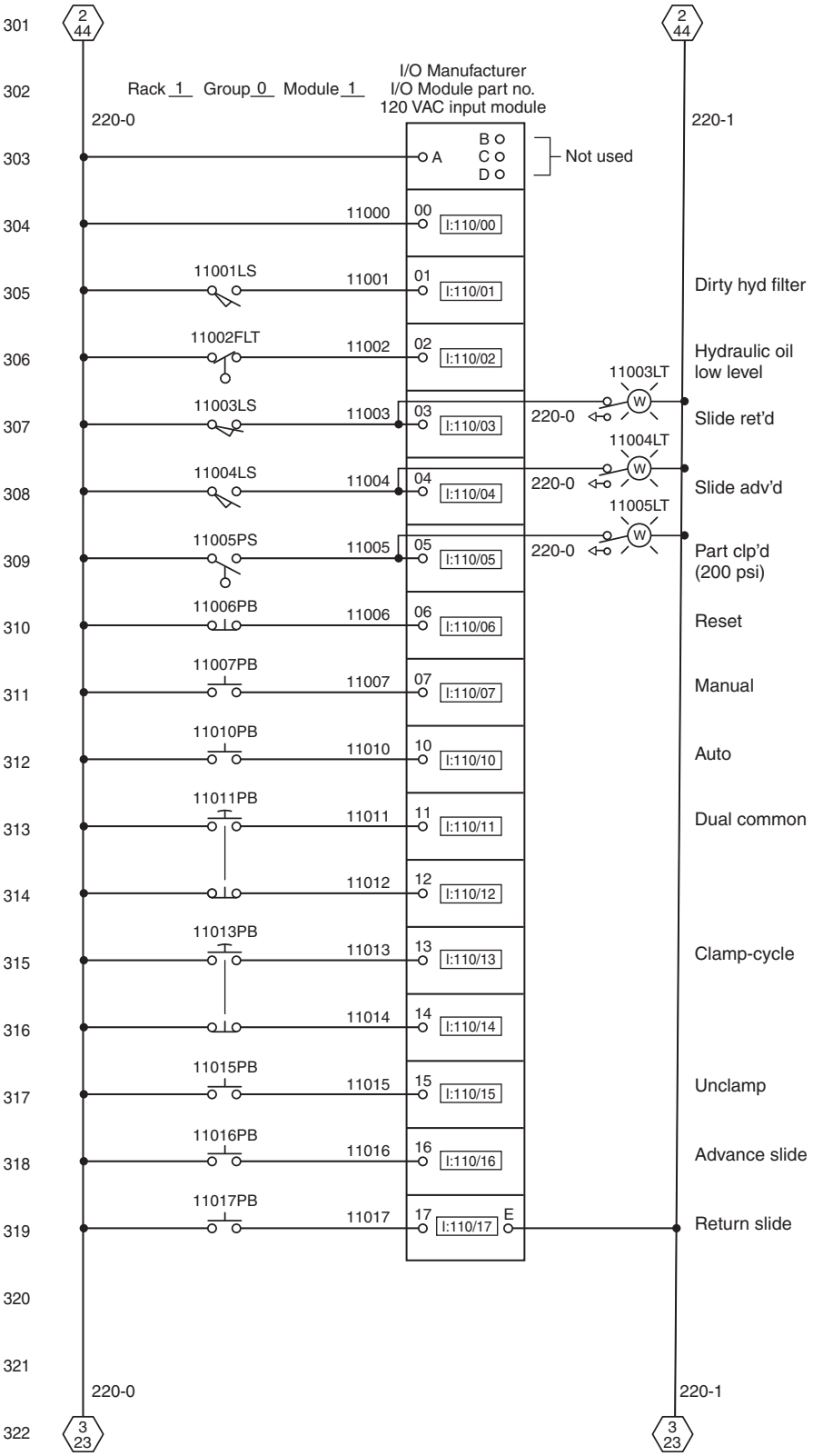


FIGURE D.1(f) PLC Input Diagram.

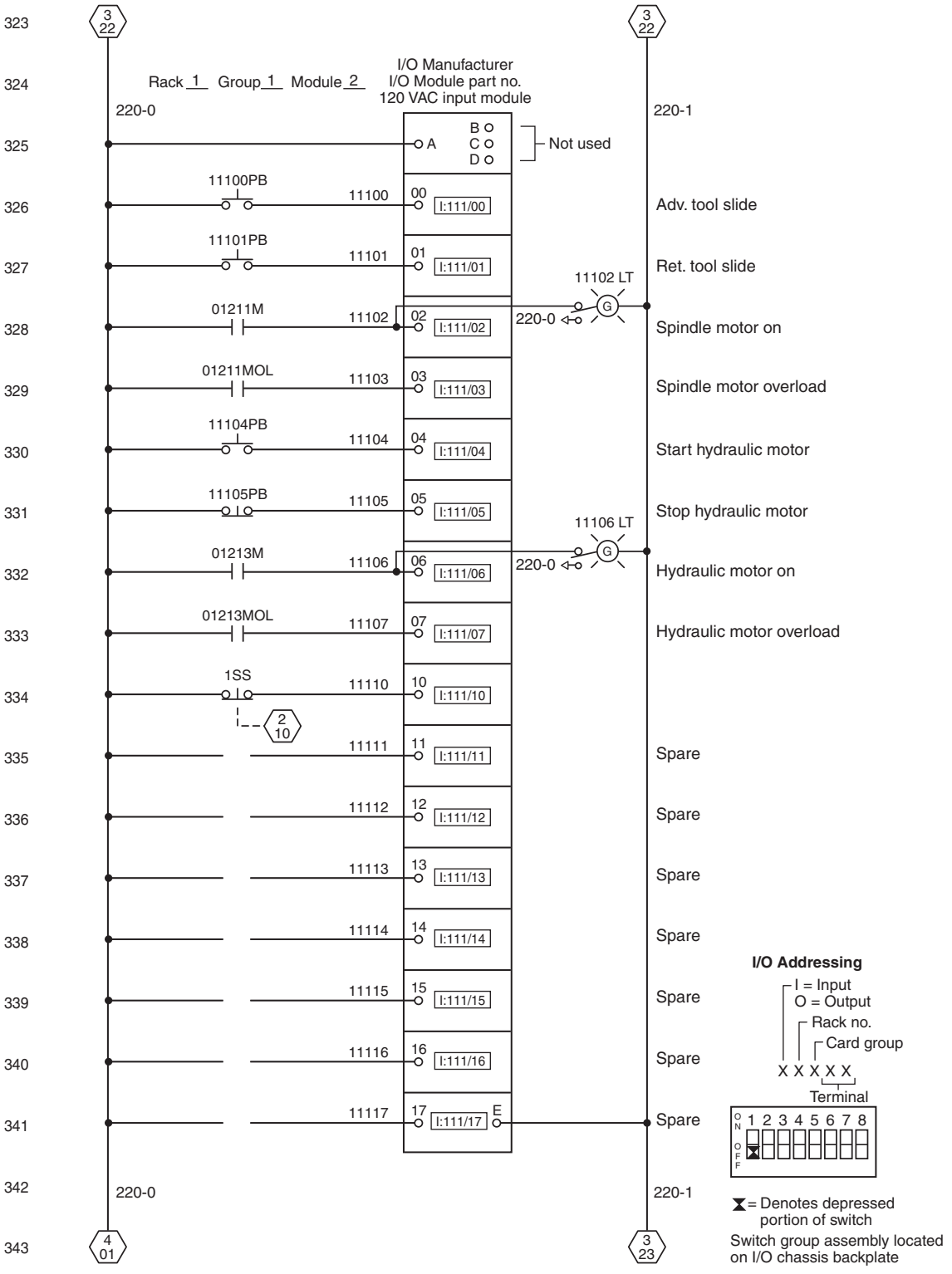


FIGURE D.1(f) ***Continued***

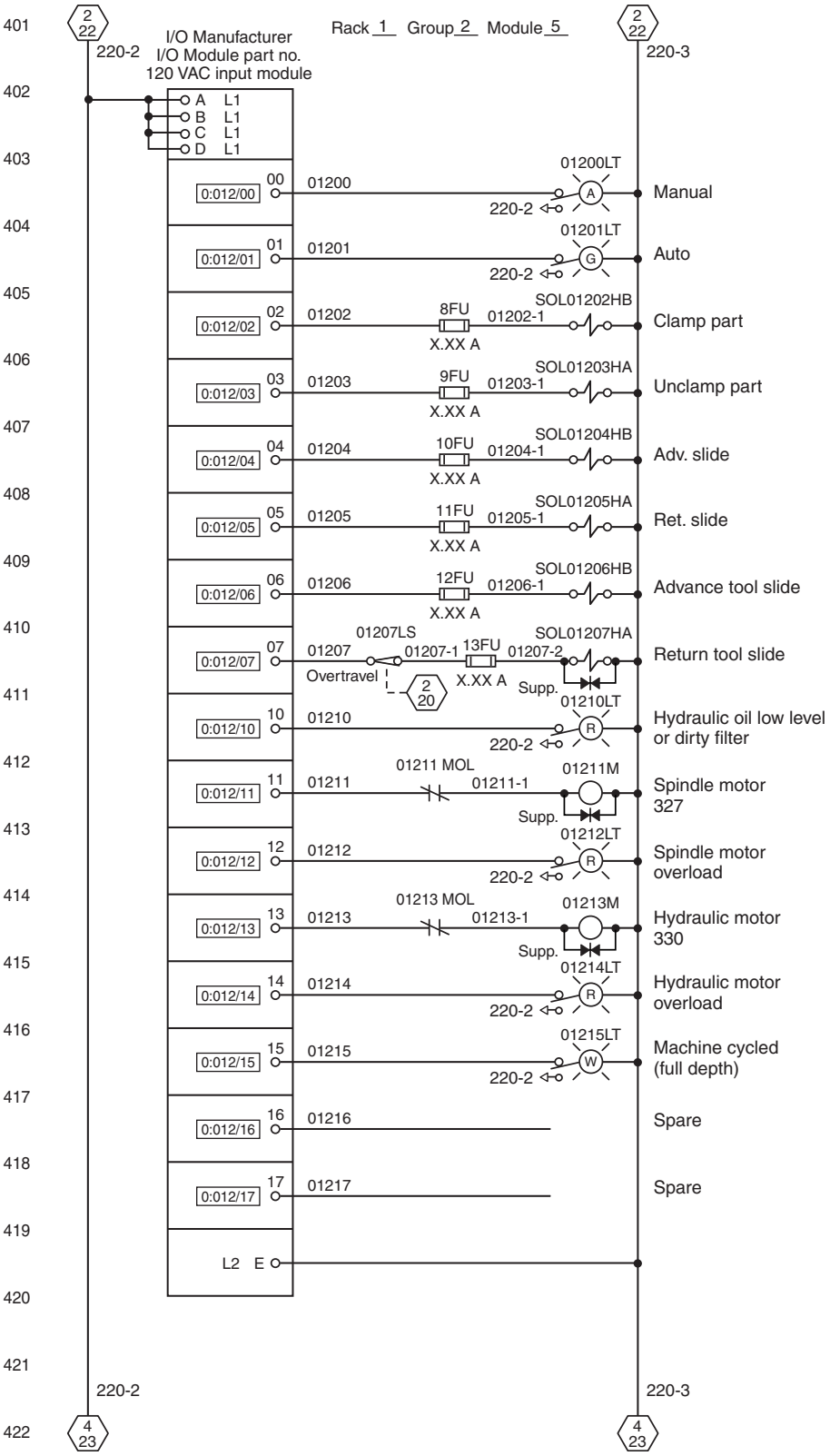


FIGURE D.1(g) PLC Output Diagram.

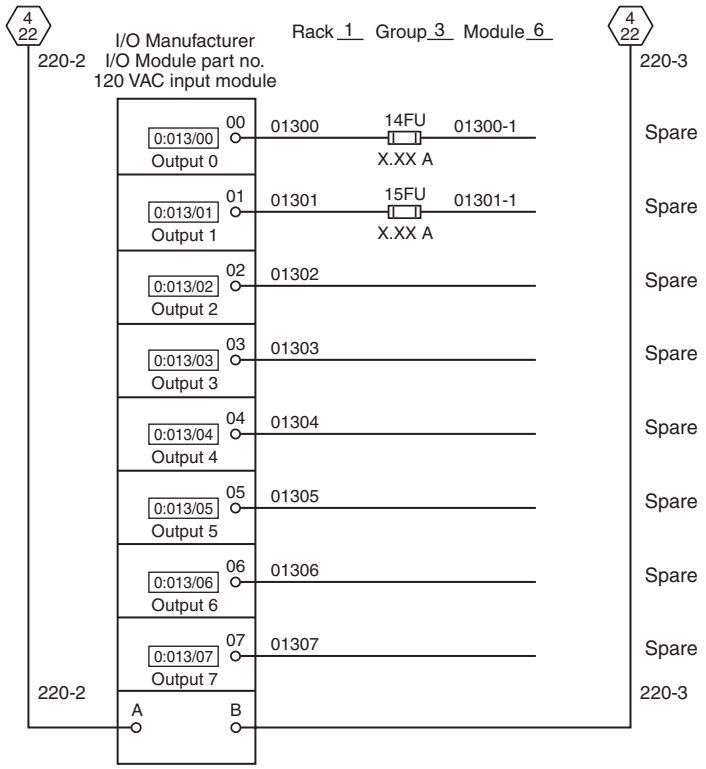


FIGURE D.1(g) ***Continued***

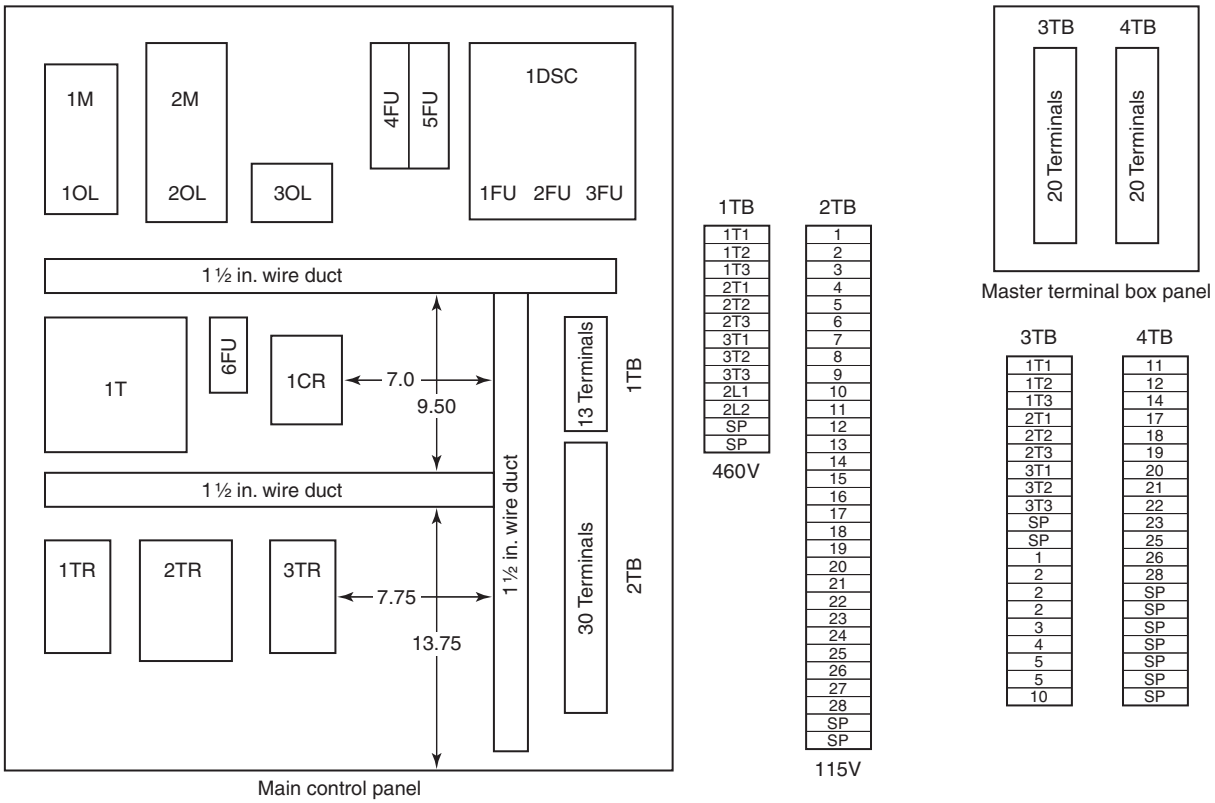


FIGURE D.1(h) Sample Enclosure Layout: Interior.

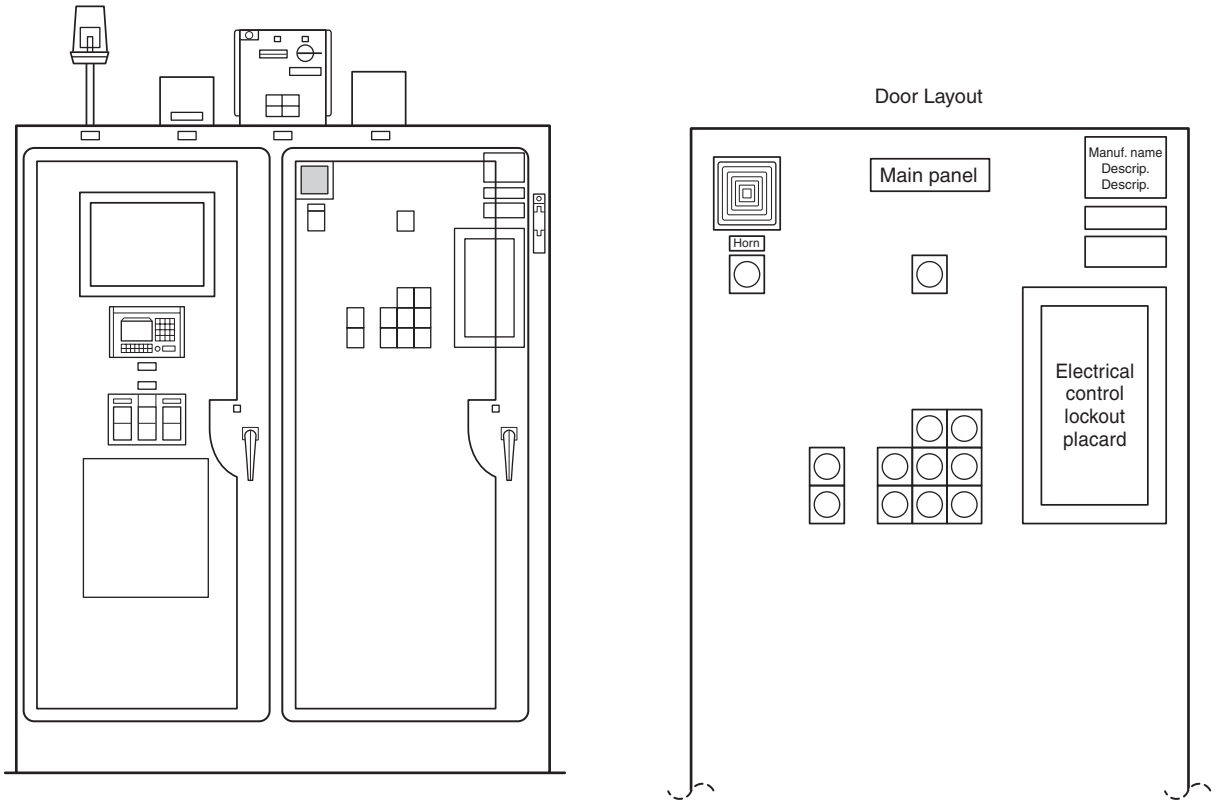


FIGURE D.1(i) Sample Enclosure Layout: Exterior.

Solenoid No.	Air or Hyd	Action Energized Input Sensor No.	Seq. No.	Sequence Description	Cycle Time (sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
—	—	I:XXX/XX PRS	1	Part present escapement delay	.5																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	2	Escapement opens	.75																									
—	—	—	3	Part travel to shuttle	.75																									
—	—	I:XXX/XX PRS	4	Part present shuttle delay	.5																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	5	Escapement closes	.75																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	6	Shuttle shifts to track #1	1.0																									
0:XXX/XX SOL	AIR	—	7	Part accel track #1 energizes	3.5																									
—	—	I:XXX/XX PRS	8	Part present loader #1 delay	.5																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	9	Shuttle shifts to center	1.0																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	10	Loader track #1 advances	1.0																									
—		—	11	Loaded track #1 advanced dwell	.5																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	12	Loaded track #1 returns	1.0																									
—	—	—	13	Part present escapement delay	.5																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	14	Escapement opens	.75																									
—	—	—	15	Part travel to shuttle	.75																									
—	—	I:XXX/XX PRS	16	Part present shuttle delay	.5																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	17	Escapement closes	.75																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	18	Shuttle shifts to track #2	1.0																									
0:XXX/XX SOL	AIR	—	19	Part accel track #2 energizes	3.5																									
—	—	I:XXX/XX PRS	20	Part present loader #2 delay	.5																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	21	Shuttle shifts to center	1.0																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	22	Loader track #2 advances	1.0																									
—	—	—	23	Loaded track #2 advanced dwell	.5																									
0:XXX/XX SOL	AIR	I:XXX/XX PRS	24	Loaded track #2 returns	1.0																									

Cycle time for one part/one track = 11.0 sec.
Cycle time for one part each track = 19.0 sec.

FIGURE D.1(j) Sequence of Operations — Graphical.

Sequence of Operation

A. Machine operation: press "Motors Start" pushbutton 2PB. Motors start.

B. Select spindle speed by turning selector switch to 1SS to 1NC, energizing 3SOL, to increase or to DEC, energizing 4SOL, to decrease setting.

C. With correct spindle direction selected, limit switch 1LS is actuated. Press "Spindle Start" pushbutton 4PB, energizing relay 1CR, which energizes 1SOL. Spindle starts and pressure switch 1PS is actuated, 1PS energizes 1TR, and after a time delay 2SOL is energized, permitting movement of machine elements at selected feed rates.

D. Pressing "Spindle Stop" pushbutton 3PB stops spindle and feeds movements simultaneously.

E. Lubrication operation.

F. Pressure switch 2PS is closed.
   1. Timer 2TR clutch is energized when motors start.
   2. Contact 2TR1 closes and energizes timer motor MTR, starting lube timing period.
   3. Contact 2TR3 closes and energizes timer 3TR.

G. Timer 2TR times out.
   1. Contact 2TR1 opens, deenergizing timer motor MTR.
   2. Contact 2TR2 closes, energizing 5SOL.
   3. Contact 2TR3 opens, deenergizing timer 3TR.
   4. Lubrication pressure actuates pressure switch 2PS, deenergizing and resetting timer 2TR. Contacts 2TR1, 2TR2, and 2TR3 open.
   5. Contact 2TR2 opening, deenergizes 5SOL.

H. Reduced lubrication pressure deactuates pressure switch 2PS and sequence repeats.

Switch Operation

1LS (115) actuated by spindle direction lever engaged

1PS (118) operated when spindle clutch engaged

2PS (126) operated by normal lube pressure

1FS (129) operated by adequate lube supply

For panels and control station layout see Sheet 2

For hydraulic diagram see _____

For lubrication diagram see _____

Last wire number used 28

Last relay number used 1CR

Supplier's dwg. no. _____

Supplier's name _____

Purchase order no. P.O. 91011

Serial no. of machine TYP 121314

These diagrams used for machine no. _____

FIGURE D.1(k) Sequence of Operations — Descriptive Graphical.

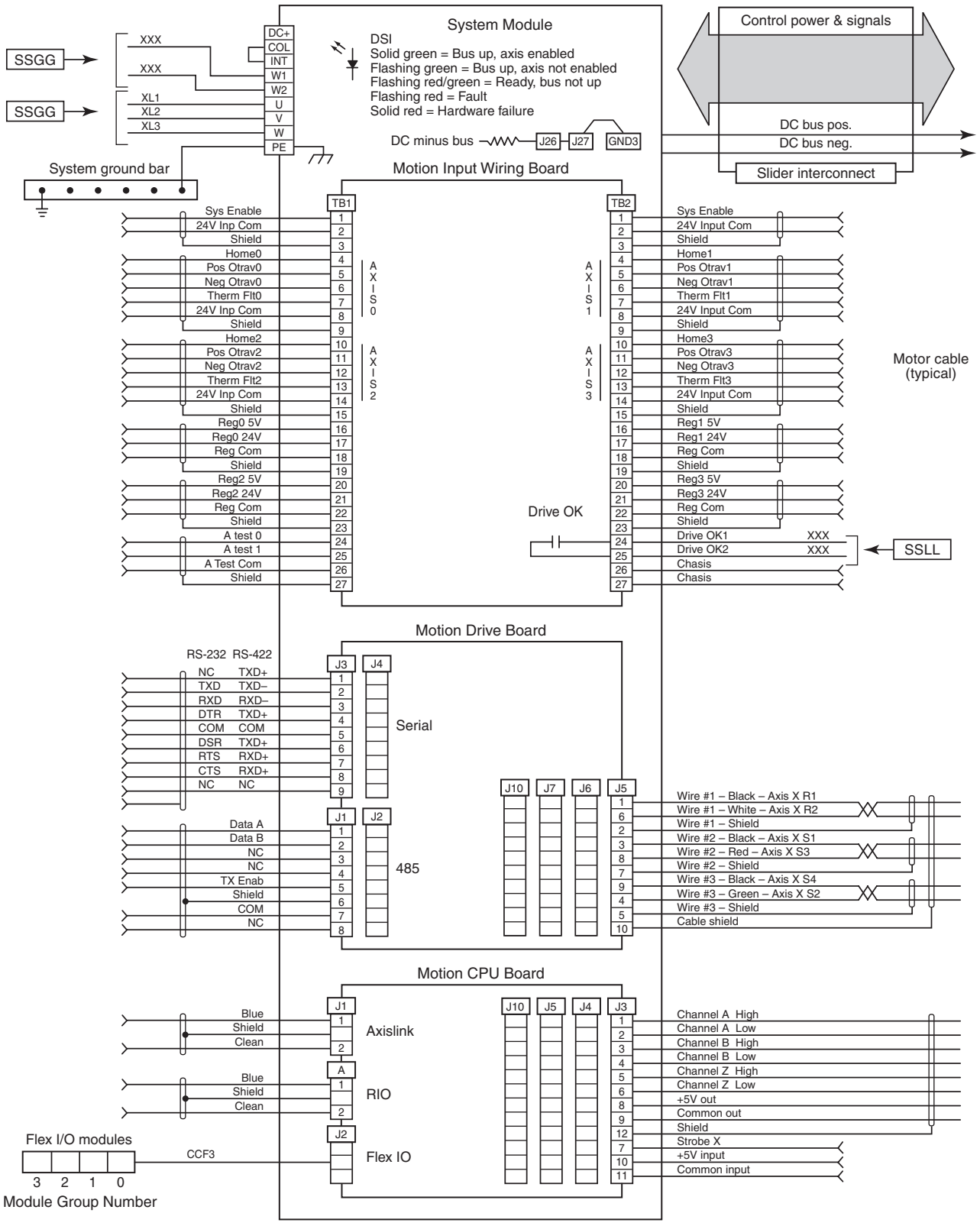
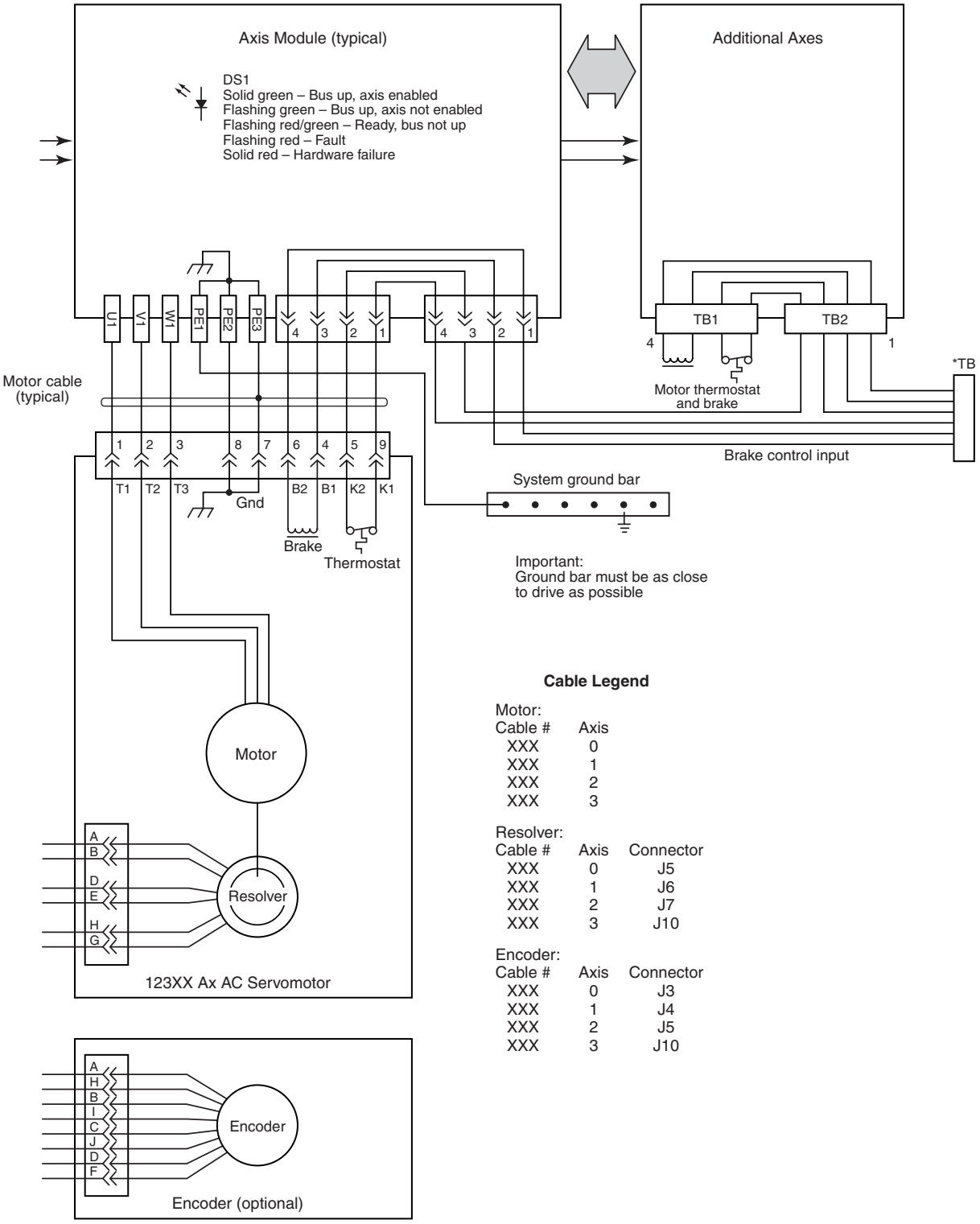


FIGURE D.1(l) Sample Servo Diagram.



Cable Legend

Motor:

Cable #	Axis
XXX	0
XXX	1
XXX	2
XXX	3

Resolver:

Cable #	Axis	Connector
XXX	0	J5
XXX	1	J6
XXX	2	J7
XXX	3	J10

Encoder:

Cable #	Axis	Connector
XXX	0	J3
XXX	1	J4
XXX	2	J5
XXX	3	J10

FIGURE D.1(l) ***Continued***

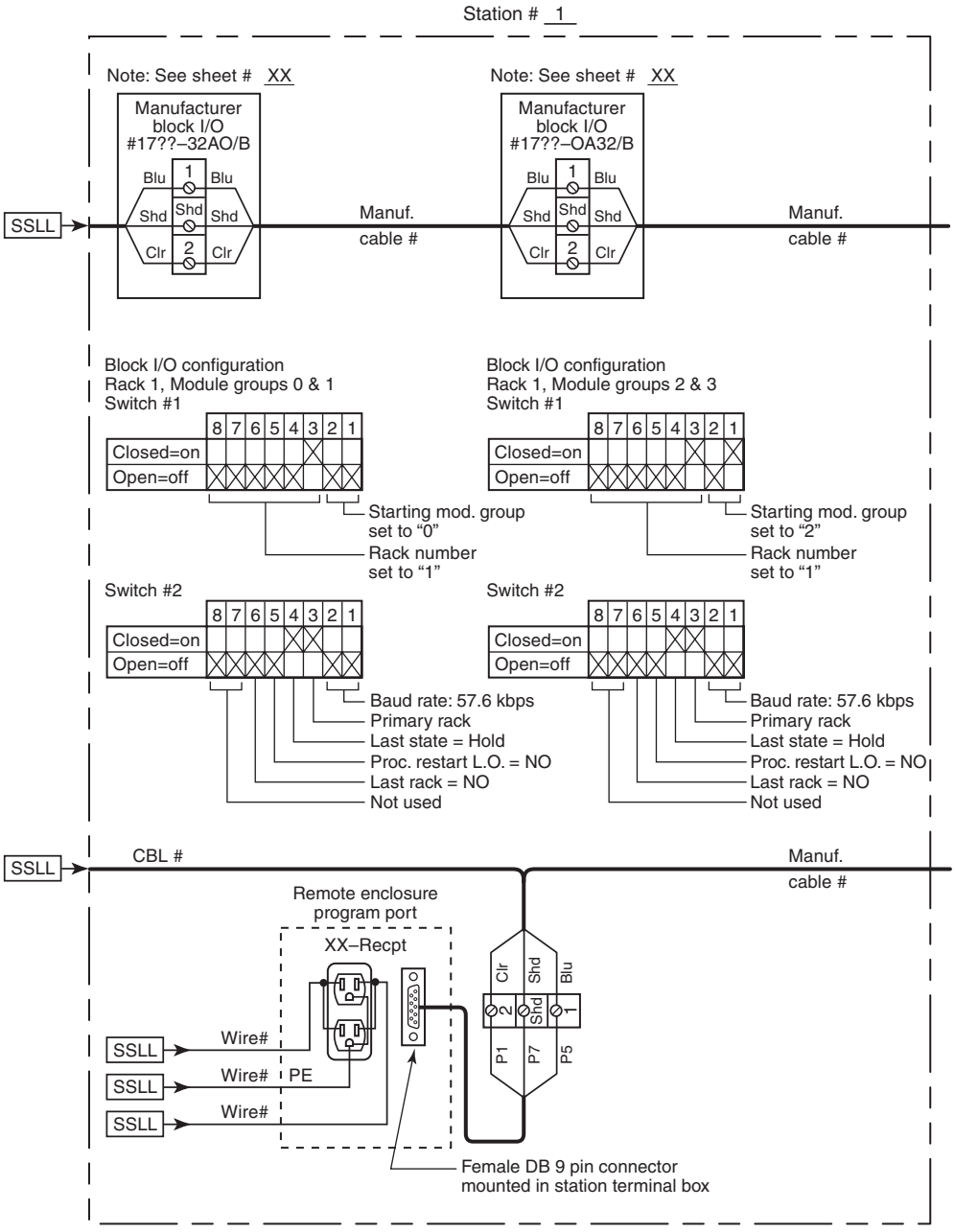


FIGURE D.1(m) Sample PLC Network — Station Layout.

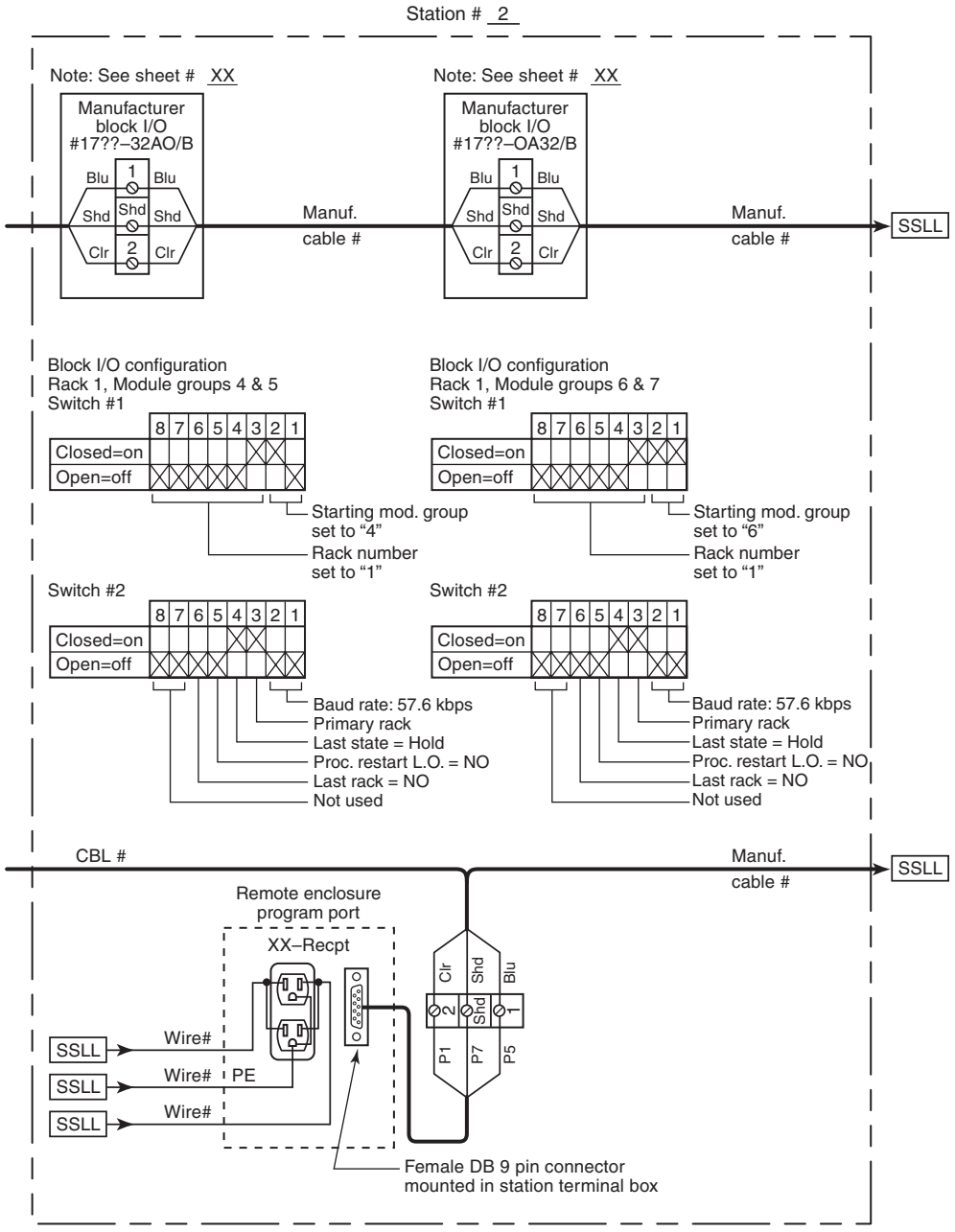
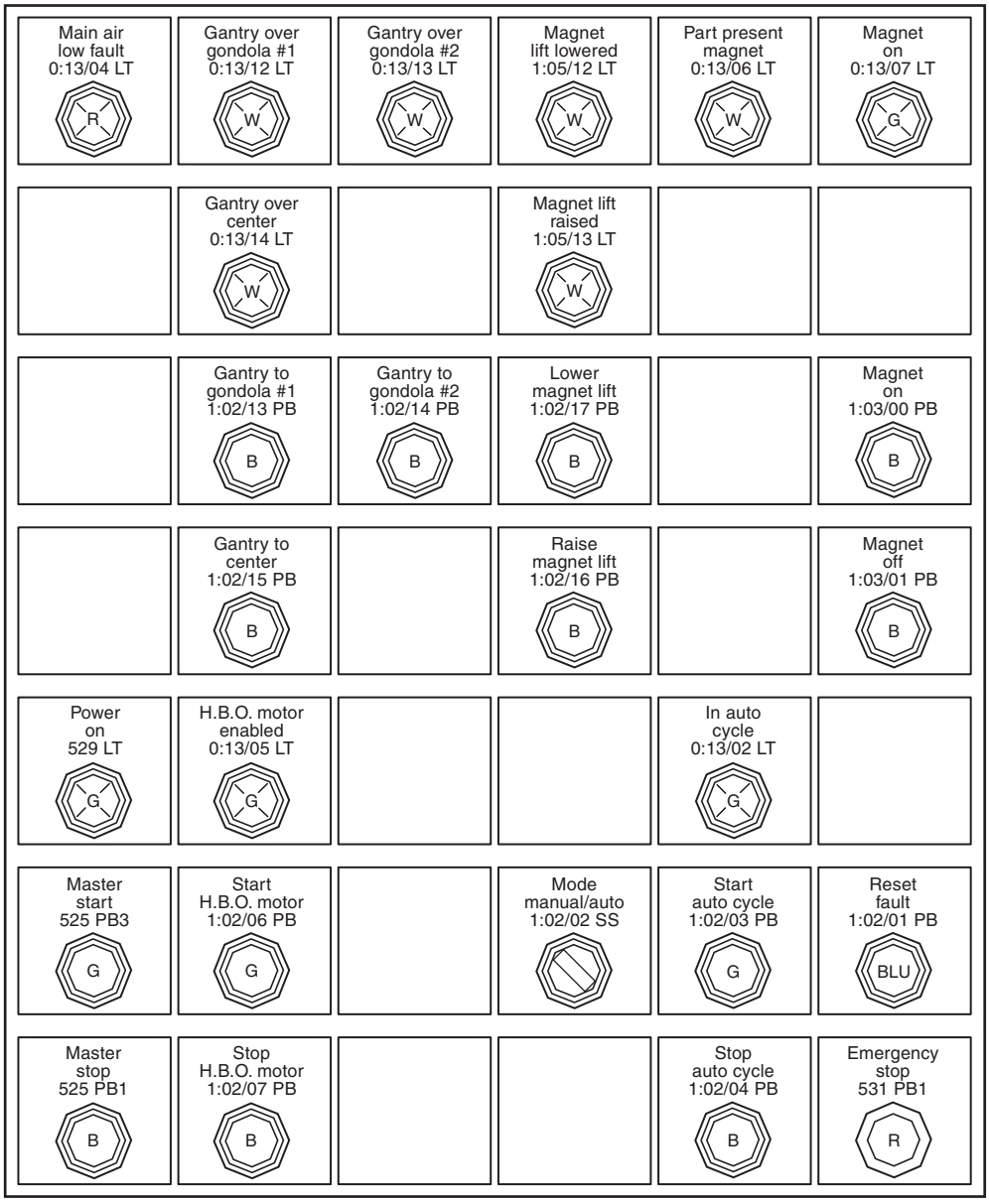
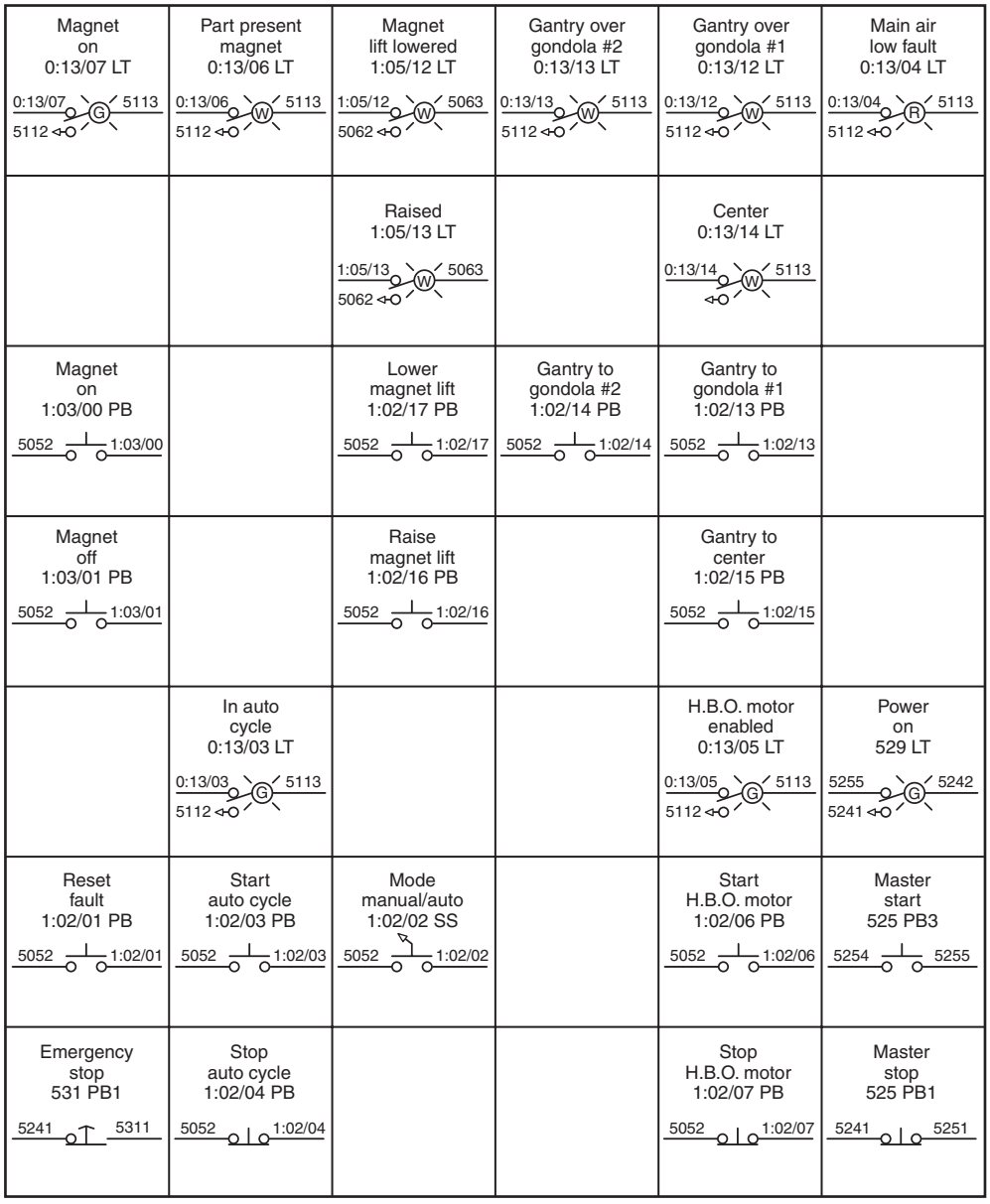


FIGURE D.1(m) ***Continued***



Front View

FIGURE D.1(n) Sample Operator Station.



Rear View

FIGURE D.1(n) ***Continued***

Parts List						
Detail	Qty.	Identifier	Location	Manufacturer	Part Number	Description
0001	1	Enclosure	—	Supplier name	A–72X7318LP	2-door enclosure, 72.12X73.12X18.12
0002	1	Panel 1	—	Supplier name	A–72P72	72X72 sub-panel
0003	1	206M	Panel	Supplier name	5KE200LBIG3522	Motor, 22KW, 1200 RPM, Fr. 200L, B3 mount
0004	1	1PWRPLG	—	Supplier name	GE–0100–60	Bus fuse — Fusible, 100A, 600V
0005	1	204CB	—	Supplier name	SELA36AT0060	3 pole/100A circuit breaker, SE100 frame
0006	1	206M	—	Supplier name	CL06A311MJ	FVNR contactor, 30HP/460V, 48.0A, 120VAC coil
0007	1	211LTDSC	—	Supplier name	TF1000–JFB	Lighting disconnect, 1000VA, 480/120V enclosed
0008	12	XXFU	—	Supplier name	Type AGT	Fuse, 600V, XX AMP
0009	2	SQ2A3, SQ2B3	Machine	Supplier name	301AEP115	Proximity switch, 115VAC, 3 pin

FIGURE D.1(o) Sample Parts List.

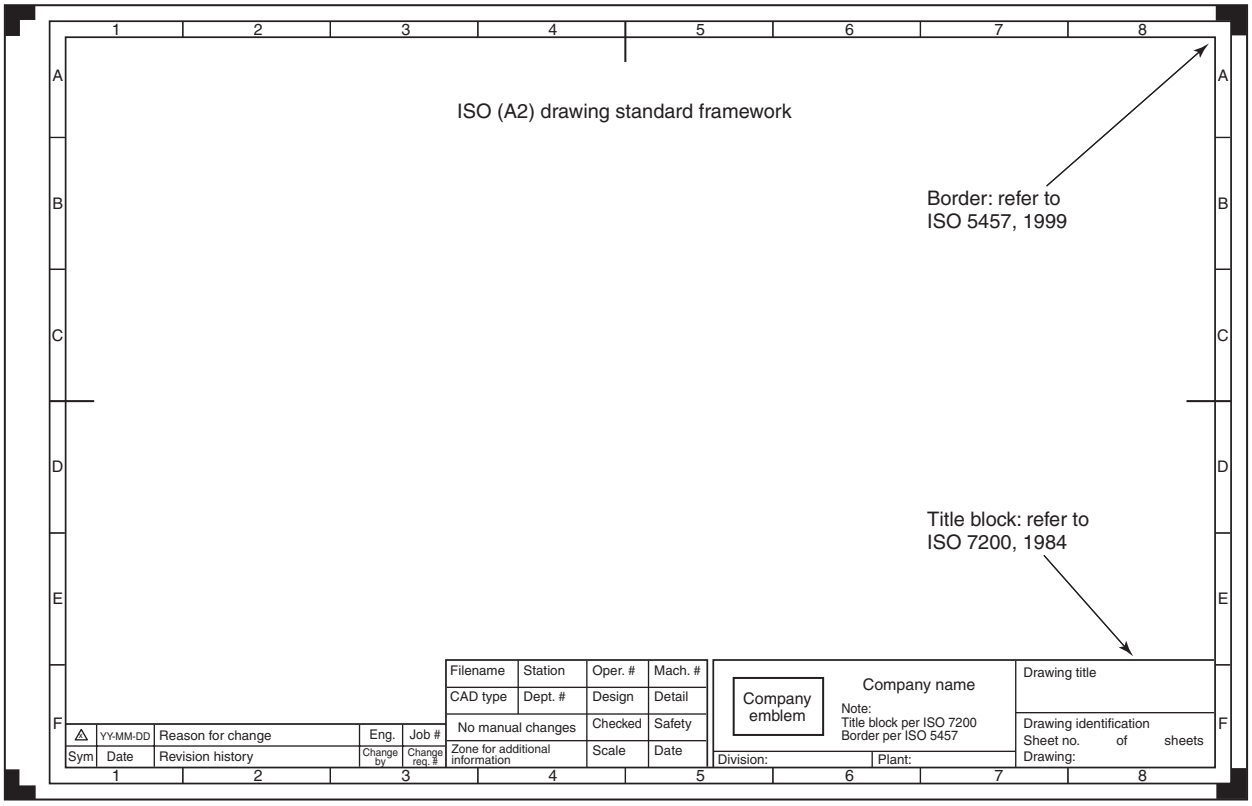


FIGURE D.1(p) ISO (A2) Drawing Standard Framework.

ANSI Symbol	ANSI Code	IEC 617 Symbol	IEC Code	Description
	CON		KM	Contactor contact open
	CON		KM	Contactor contact closed
	CR		KA	Relay contact open
	CR		KA	Relay contact closed
	TR		KT	Timed contact, N.O. – on delay (TDE)
	TR		KT	Timed contact, N.C. – on delay (TDE)
	TR		KT	Timed contact, N.C.– off delay (TDD)
	TR		KT	Timed contact, N.O. – off delay (TDD)
	SS		SA	Selector switch
	PB		SB	Pushbutton N.O.
	PB		SB	Pushbutton N.C.
	PB		SB	Pushbutton mushroom head
	FL		SL	Liquid level switch
	FLS	F	SF	Flow switch
	PS	P	SP	Pressure switch
	TS		ST	Temperature switch
	LS		SQ	Limit switch
	PRS		SQ	Proximity switch
A	LT	A	HL	Indicating light
	PL		XS	Plug and socket
CR	CR		KA	Control relay coil
C1	CON		KM	Contactor coil
M1	M		KM	Motor starter coil
TR	TR		KA	Timer coil
	SOL		YV	Solenoid coil
	CTR		EC	Electromechanical counter
	CB		QF	Circuit breaker
	T1		X1 XT	Terminals (reference) Fused terminals (reference)
	FU		FU	Fuse, protective

FIGURE D.1(q) Selections from ANSI Y32.2/IEEE 315/315A Symbol Table.

Annex E Device and Component Designations

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

E.1 Device and Compound Designations. The device and component designations given in Table E.1 are intended for use on diagrams in connection with the corresponding graphical symbols to indicate the function of the particular device. These device and component designations are based on the assignment of a standard letter or letters to the fundamental function that is performed by a component or device. Suitable numbers (1, 2 ,3, etc.) and letters (A, B, C, etc.) can be added to the basic designation to differentiate between devices performing similar functions.

The assignment of a designation to a device on specific equipment is governed by the function of that device on that equipment and not by the type or nature of the device or its possible use for other functions on other equipment. The same type of device can perform different functions on different equipment or even on the same equipment and, consequently, can be identified by different designations.

Table E.1 Device and Component Designations

Designation	Device
ABE	Alarm or Annunciator Bell
ABU	Alarm or Annunciator Buzzer
AH	Alarm or Annunciator Horn
AM	Ammeter
AT	Autotransformer
CAP	Capacitor
CB	Circuit Breaker
CI	Circuit Interrupter
CNC	Computerized Numerical Controller
CON	Contractor
COs	Cable-Operated (Emergency) Switch
CPU	Central Processing Unit
CR	Control Relay
CRA	Control Relay, Automatic
CRH	Control Relay, Manual
CRL	Control Relay, Latch
CRM	Control Relay, Master
CRT	Cathode Ray Tube, Monitor or Video Display Unit
CRU	Control Relay, Unlatch
CS	Cam Switch
CT	Current Transformer
CTR	Counter
D	Diode
DISC	Disconnect Switch
DISP	Display
DR	Drive
EMO	Emergency (Machine) Off Device
END	Encoder
ESTOP	Emergency Stop
FLD	Field
FLS	Flow Switch
FS	Float Switch
FTS	Foot Switch
FU	Fuse
GEN	Generator
GRD, GND	Ground
GUI	Graphical User Interface
HM	Hour Meter
HTR	Heating Element
IC	Integrated Circuit
INST	Instrument
IOL	Instantaneous Overload
I/O	Input/Output Device
L	Inductor
LED	Light Emitting Diode
LS	Limit Switch
LT	Pilot Light
LVDT	Linear Variable Differential Transformer
M	Motor Starter
MD	Motion Detector
MF	Motor Starter – Forward
MG	Motor – Generator
MR	Motor Starter – Reverse
MTR	Motor
OIT	Operator Interface Terminal
OL	Overload Relay
PB	Pushbutton
PBL	Pushbutton, Illuminated
PC	Personal Computer
PCB	Printed Circuit Board
PEC	Photoelectric Device
PL	Plug
PLC	Programmable Logic Controller
POT	Potentiometer
PRS	Proximity Switch
PS	Pressure Switch
PWS	Power Supply
Q	Transistor
QTM	Thermistor
REC	Rectifier
RECP	Receptacle
RES	Resistor
RH	Rheostat
S	Switch
SCR	Silicon Controlled Rectifier
SOL	Solenoid
SNSR	Sensor
SS	Selector Switch
SSL	Selector Switch, Illuminated
SSR	Solid State Relay
ST	Saturable Transformer
SUP	Suppressor
SYN	Synchro or Resolver
T	Transformer
TACH	Tachometer Generator
TAS	Temperature-Actuated Switch
TB	Terminal Block
T/C	Thermocouple
TR	Timer Relay
TSDR	Transducer
TWS	Thumbwheel Switch
V	Electronic Tube
VAR	Varistor
VM	Voltmeter

Table E.1 *Continued*

Designation	Device
VR	Voltage Regulator
VS	Vacuum Switch
WLT	Worklight
WM	Wattmeter
X	Reactor
ZSS	Zero Speed Switch

Annex F Electrical Enclosure Ratings: Type-Rating Versus IP-Rating

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

F.1 Disclaimer. Only IEC 60529 should be considered the source document for accurate information regarding IP-rating and UL 50, UL 508, and/or NEMA 250 should be considered the source documents regarding type-rating. The information presented in Annex F is limited and intended as introductory information. This annex is meant to give the user a sense of the IP-rating system and how it differs from the NEMA 250 type-rating system.

F.2 Rating for Electrical Enclosures. Electrical enclosures are type-rated according to NEMA 250/UL 50 and UL 508 or IP-rated according to IEC 60529 based upon the degree of protection provided.

F.2.1 Type-rated and IP-rated electrical enclosures have only the following in common:

(1) A degree of protection for persons from hazardous components inside the enclosure
(2) A degree of protection for equipment inside the enclosure from ingress of solid foreign objects, including dust
(3) A degree of protection for equipment inside the enclosure from ingress of water

F.3 Type-Rating System. The type-rating system, in a single electrical enclosure document, points out additional requirements that a type-rated enclosure meets, which include the following:

(1) Mechanical impact on enclosure walls
(2) Gasket aging and oil resistance
(3) Corrosion resistance (indoor and outdoor)
(4) Door and cover latching requirements

F.4 IP-Rating System. The IEC 60529 designation consists of the letters IP followed by two numerals with optional letters.

F.4.1 The first characteristic numeral indicates the degree of protection provided by the enclosure with respect to persons and solid foreign objects entering the enclosure.

F.4.2 The second characteristic numeral indicates the degree of protection provided by the enclosure with respect to the harmful ingress of water.

F.4.3 The additional letter indicates the degree of protection for a person against access to hazardous parts. A brief description of the additional letter is in Table F.5.1.

F.5 This section contains general information related to degree of protection provided by an enclosure that is indicated by the IP code.

F.5.1 The arrangement of the IP code, which is the degree of protection indicated by the IP code, is shown in Table F.5.1.

Table F.5.1 Arrangement of the IP Code

Code letters	International Protection	IP
First characteristic numeral	Numerals 0 to 6, or letter X	N (or letter X)
Second characteristic numeral	Numerals 0 to 8, or letter X	N (or letter X)
Additional letter (optional)	Letters A, B, C, D	L
Supplementary letter (optional)	Letters H, M, S, W	L
Example:	IP 23CH	TB type

Note: Where a characteristic numeral is not required to be specified, it is replaced by the letter "X" ("XX" if both numerals are omitted). Additional letters and/or supplementary letters may be omitted without replacement.

F.5.2 A brief description and definitions for the degree of protection against access to hazardous parts are shown in Table F.5.2.

F.5.3 A brief description of the IP code elements is contained in Table F.5.3.

Table F.5.2 Degrees of Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral

First Characteristic Numeral	Degree of Protection	
	Brief Description	**Definition**
0	Nonprotected	—
1	Protected against access to hazardous parts with the back of a hand	The access probe, sphere of 50 mm Ø, has to have adequate clearance from hazardous parts.
2	Protected against access to hazardous parts with a finger	The jointed test finger of 12 mm Ø, 80 mm length, has to have adequate clearance from hazardous parts.
3	Protected against access to hazardous parts with a tool	The access probe of 2.5 mm Ø is not to penetrate.
4	Protected against access to hazardous parts with a wire	The access probe of 1.0 mm Ø is not to penetrate.
5	Protected against access to hazardous parts with a wire	The access probe of 1.0 mm Ø is not to penetrate.
6	Protected against access to hazardous parts with a wire	The access probe of 1.0 mm Ø is not to penetrate.

Note: In the case of the first characteristic numeral 3, 4, 5, and 6, protection against access to hazardous parts is satisfied if adequate clearance is kept.

Table F.5.3 IP Code Elements and Their Meaning

Element	Numerals or Letters	Meaning for the Protection of Equipment	Meaning for the Protection of Persons
Code Letters	**IP**		
First Characteristic Numerals		*Against ingress of solid foreign objects*	*Against access to hazardous parts with the following:*
	0	Nonprotected	Nonprotected
	1	50 mm diameter	Back of hand
	2	12.5 mm diameter	Finger
	3	2.5 mm diameter	Tool
	4	1.0 mm diameter	Wire
	5	Dust protected	Wire
	6	Dusttight	Wire
Second Characteristic Numerals		*Against ingress of water with harmful effects*	
	0	Nonprotected	
	1	Vertically dripping	
	2	Dripping (15° tilted)	
	3	Spraying	
	4	Splashing	
	5	Jetting	
	6	Powerful jetting	
	7	Temporary immersion	
	8	Continuous immersion	
Additional letter (optional)			*Against access to hazardous parts with the following:*
	A		Back of hand
	B		Finger
	C		Tool
	D		Wire
Supplementary letter (optional)		*Supplementary information specific to the following:*	
	H	High-voltage apparatus	
	M	Motion during water test	
	S	Stationary during water test	
	W	Weather conditions	

F.5.3.1 Where more than one supplementary letter is used, the following alphabetic sequence applies:

(1) *IPXXA*. Protected against access with the back of hand
(2) *IPXXB*. Protected against access with finger
(3) *IPXXC*. Protected against access with a tool
(4) *IPXXD*. Protected against access with a wire

These letter designations (A, B, C, D) can be used referencing the protection of live parts while the enclosure is accessed. There is not a comparable NEMA 250 type-rating to this application.

F.5.4 Electrical enclosures that carry only an IP-rating have not been designed to the additional NEMA 250 type-rating requirements. Therefore, a type-rating cannot be assigned to an enclosure that has only been IP-rated because of the exclusion of the additional requirements of the type-rating system.

F.5.5 However, because the IP requirements can be interpreted to be inclusive to the type-rating requirements, a conservative IP-rating can be assigned to a type-rated enclosure as shown in Table F.5.5.

As a practical matter though, many electrical enclosures are tested to both the IP and type requirements and carry both IP-rating and type-rating designations.

Table F.5.5 Assignment of IP-Ratings to Type-Rated Enclosures

A														B
	NEMA Enclosure Type													
IP First Character	**1**	**2**	**3**	**3R**	**3S**	**4**	**4X**	**5**	**6**	**6P**	**12**	**12K**	**13**	**IP Second Character**
IP0_	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_0
IP1_	A	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_1
IP2_		B	AB	B	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_2
IP3_			AB	B	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_3
IP4_			AB	B	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_4
IP5_			AB		AB	AB	AB	A	AB	AB	A	A	A	IP_5
IP6_			A		A	AB	AB		AB	AB				IP_6
									B	B				IP_7
										B				IP_8

Notes:
(1) Type-rated enclosures for hazardous locations and potentially explosive areas have been excluded from the table. The additional and supplementary letters for IP-ratings have also been excluded from the table. *(See NEMA 250, UL 508, and IEC 60529.)*
(2) Table F.5.5 may only be used to assign an IP-rating to a type-rated enclosure, and not to assign a type-rating to an IP-rated enclosure. Table F.5.5 assists in specifying enclosure ratings and may not be used as a definitive guide. For example, if the conditions of installation require an IP 55, Table F.5.5 indicates that a Type 3, 3S, 4, 4X, 6, or 6P enclosure can be utilized. However, if the conditions of installation require a NEMA Type 4, an enclosure that is only IP-rated cannot be used as a substitute.
(3) Although the corresponding NEMA type-ratings meet or exceed the corresponding IP-ratings as indicated in Table F.5.5, IEC does not currently accept these type-ratings without further IEC testing.
Key to Table:
A = The first IP character designation is the protection against access to hazardous parts and solid foreign objects. The respective NEMA Enclosure Type meets the requirements for the IEC 60529 IP first character designation.
B = The IP second character designation is the protection against ingress of water. The respective NEMA Enclosure Type meets the requirements for the IEC 60529 IP second character designation.

Annex G Kilowatt Outputs with Horsepower Equivalents

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

G.1 Preferred Kilowatt Outputs with Horsepower Equivalents. The kilowatt and horsepower values shown in Table G.1 and Table G.2 are not exact conversion values. They give the approximate relationships between countries employing the two different systems of units.

Table G.1 Preferred kW Outputs with hp Equivalents

kW		
Primary Series	**Secondary Series**	**hp (746 W)**
0.06		1/12
0.09		1/8
0.12		1/6
0.18		1/4
0.25		1/3
0.37		1/2
0.55		3/4
0.75		1
1.1		1.5
1.5	1.8	2
2.2		3
3.7	3	5
	4	
5.5		7.5
	6.3	
7.5		10
	10	
11		15
	13	
15		20
	17	
18.5		25
	20	
22		30
	25	
30		40
	33	
37		50
	40	
45		60
	50	
55		75
	63	
75		100
	80	
90		125
	100	
110		150
	125	
132		175
150		200
160		220
185		250
200		270
220		300
250		350
280		375
300		402
315		422
335		449
355		476
375		503
400		536
425		570
450		603
475		637
500		670
530		710
560		750
600		804
630		845
670		898
710		952
750		1005
800		1072
850		1139
900		1206
950		1273
1000		1340

Note: The kW–hp conversions are approximately 1 hp = 720 W, not the stated 746 W or even the rounded off metric units that result in 736 W.
Source: IEC 60072-1, Annex D Tables D.5.1 and D.5.2, Sixth Edition 1991-2, are provided to assist with hp and kW.

G.2 Preferred Horsepower Outputs with Kilowatt Equivalents. See Table G.2.

Table G.2 Preferred hp Outputs with kW Equivalents

hp (746 W)	kW		hp (746 W)	kW
375	280		710	530
400	298		750	560
425	317		800	597
450	336		850	634
475	354		900	671
500	373		950	709
530	395		1000	746
560	418		1060	791
600	448		1120	836
630	470		1180	880
670	500		1250	930
700*	522		1320	985

*This value is introduced for use in certain countries that prefer rounded off horsepower values.
Note: The kW–hp conversions are approximately 1 hp = 720 W, not the stated 746 W or even the rounded off metric units that result in 736 W.
Source: IEC 60072-1, Annex D Table D.5.1 and Table D.5.2, Sixth Edition 1991-2, are provided to assist with hp and kW.
The notes are to inform the user that additional information is necessary in order to properly exchange motors.

Annex H Cross-Reference Tables

H.1 Table H.1 shows NFPA 79-2002 cross referenced to NFPA 79-1997.

Table H.1 NFPA 79-2002 Cross Referenced to NFPA 79-1997

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
1.0	Administration	1.0	Scope and Purpose
1.1	Scope	1.1	Scope
1.1.1		1.1.1	
1.1.2		1.1.2	
1.2	Purpose	1.2 a	Purpose
1.3	Application	1.1.3	
1.4	Specific Provisions Other Than NFPA 79	1.1.4	
1.5	Specific Provisions Not Made in Relation to NFPA 70	1.1.5	
1.6	State of the Art	1.2 b	Purpose
2.	Referenced Publications	2.0	Normative References
2.1	General	2.0	Normative References
2.2	NFPA Publication	2.0	Normative References
2.3	Other Publications		
2.3.1	ANSI Publications	2.0	Normative References
2.3.2	ASTM Publications	2.0	Normative References
2.3.3	IEC Publications	2.0	Normative References
2.3.4	IEEE Publication	2.0	Normative References
2.3.5	NEMA Publications	2.0	Normative References
2.3.6	UL Publications		
3	Definitions	3.0	Definitions
3.1	General		
3.2	NFPA Official Definitions		
3.3	General Definitions	3.0	Definitions
4	General Operating Conditions	5.0	General Operating Conditions
4.1	General Considerations	5.1	General
4.2	Electrical Components and Devices	5.2	Electrical Components and Devices
4.3	Electrical Supply	5.7	Electrical Supply

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
4.3.1	General	5.7	Electrical Supply
4.3.2	Alternating Current (ac) Supplies	5.7.1	AC Supplies
4.3.2.1	Voltage	5.7.1	AC Supplies
4.3.2.2	Frequency	5.7.1	AC Supplies
4.3.2.3	Harmonics	5.7.1	AC Supplies
4.3.2.4	Voltage Unbalance (in 3-Phase Supplies)	5.7.1	AC Supplies
4.3.2.5	Voltage Impulses	5.7.1	AC Supplies
4.3.2.6	Voltage Interruption	5.7.1	AC Supplies
4.3.2.7	Voltage Dips	5.7.1	AC Supplies
4.3.3	Direct Current (dc) Supplies from Batteries	5.7.2	DC Supplies
4.3.3.1	Voltage	5.7.2	DC Supplies
4.3.3.2	Voltage Interruption	5.7.2	DC Supplies
4.3.4	Direct Current (dc) Supplies from Converting Equipment	5.7.2	DC Supplies
4.3.4.1	Voltage	5.7.2	DC Supplies
4.3.4.2	Voltage Interruption	5.7.2	DC Supplies
4.3.4.3	Ripple (Peak to Peak)	5.7.2	DC Supplies
4.4	Physical Environment and Operating Conditions		
4.4.1	General		
4.4.2	Electromagnetic Compatibility (EMC)		
4.4.3	Ambient Operating Temperature	5.3	Ambient Operating Temperature
4.4.4	Relative Humidity	5.5	Relative Humidity
4.4.5	Altitude	5.4	Altitude
4.4.6	Contaminants		
4.4.7	Nonionizing Radiation		
4.4.8	Vibration, Shock and Bump		
4.5	Transportation and Storage	5.6	Transportation and Storage
4.6	Provisions for Handling		
4.7	Installation and Operating Conditions	5.8	Installation and Operating Conditions

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
5	Incoming Supply Circuit Conductor Terminations and Devices for Disconnecting and Removing Power	7.0	Supply Circuit Disconnecting Means
5.1	Incoming Supply Circuit Conductor Terminations		
5.1.1			
5.1.2			
5.1.3			
5.1.4			
5.2	Grounding Terminal	19.5	Grounding Terminal
5.3	Supply Disconnecting (Isolating) Means		
5.3.1	General		
5.3.1.1		7.5	Supply Conductors to Be Disconnected
5.3.1.1.1		4.5.2 4.5.3	
5.3.1.1.2		4.7.1 7.5	Supply Connectors to Be Disconnected
5.3.1.2		7.5	Supply Connectors to Be Disconnected
5.3.1.3		7.8.1 7.9.1	
5.3.1.3	Exception	7.8.1 Exception No. 2 11.8 Exception No. 4	Interlocks
5.3.1.4		7.8.1	
5.3.1.5		7.7	Exposed Live Parts
5.3.1.6		7.8.2	
5.3.1.7		7.5	Supply Conductors to Be Disconnected
5.3.2	Type	7.2	Type
5.3.3	Requirements		
5.3.3.1		7.10.3 7.10.4 7.5 7.3.1 7.3.2	Supply Conductors to Be Disconnected
5.3.3.2			

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
5.3.3.3		7.11	Attachment Plug and Receptacle
5.3.3.3.1			
5.3.4	Operating Handle	7.10	Operating Handle
5.3.4.1		7.10.2	
5.3.4.2		7.10.1	
5.3.5	Excepted Circuits		
5.3.5.1		7.9.1 9.1 Exception	Source of Control Power
5.3.5.2			
5.3.5.3			
5.3.5.4		7.9.1	
5.4	Means for Removal of Power for Prevention of Unexpected Start-Up		
5.4.1			
5.4.2			
5.4.3			
5.4.4			
5.5	Devices for Disconnecting (Isolating) Electrical Equipment	7.0	Supply Circuit Disconnecting Means
5.5.1			
5.5.2			
5.5.3			
5.5.4		7.2.1	
5.5.5		7.10.1 7.11	Attachment Plug and Receptacle
6	Protection from Electric Shock	6	Safeguarding of Personnel
6.1	General	6.1	General
6.2	Protection from Electric Shock During Normal Operation	6.2	Safeguarding Against Electrical Shock in Normal Service
6.2.1	Protection by Insulation of Live Parts	6.2.1	
6.2.2	Protection by Enclosures	6.2.2	
6.2.2.1	Direct Contact from Outside an Enclosure		

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
6.2.3	Enclosure Interlocking		
6.2.3.1		7.9.1	
6.2.3.1.1		9.13 11.8	Setup Mode Interlocks Exception No. 2
6.2.3.1.2		7.9.2	
6.2.3.2			
6.2.3.3		7.9.4	
6.3	Protection by the Use of Protective Extra Low Voltage (PELV)	6.3	Protection by the Use of PELV (protective extra low voltage)
6.3.1	General Requirements	6.3	Protection by the Use of PELV (protective extra low voltage)
6.3.2	Sources for PELV	6.3 e	Protection by the Use of PELV (protective extra low voltage)
6.4	Protection Against Residual Voltages	6.4	Safeguarding Against Electrical Shock from Residual Voltages
6.4.1		6.4	Safeguarding Against Electrical Shock from Residual Voltages
6.4.2			
7.0	Protection of Equipment	8.0	Protection
7.1	General		
7.2	Overcurrent Protection	8.2 8.3	Supply Conductor and Machine Overcurrent Protection Branch Circuit Overcurrent Protection
7.2.1	General		
7.2.1.1			
7.2.1.2			
7.2.1.3			
7.2.2	Supply Conductors	8.2	Supply Conductor and Machine Overcurrent Protection
7.2.3	Power Circuits	8.3	Branch Circuit Overcurrent Protection
7.2.4	Control Circuits	8.9.2	Conductor Protection
7.2.4.1	General	8.9.2	Conductor Protection
7.2.4.2	Conductor Protection	8.9.2	Conductor Protection
7.2.4.2.1		8.9.2.1	

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
7.2.4.2.2		8.9.2.2	
7.2.4.2.3		8.9.2.2	Exception No. 1
7.2.4.2.4		8.9.2.2	Exception No. 2
7.2.4.2.5		8.9.2.2	Exception No. 3
7.2.4.2.6		8.9.2.2	Exception No. 4
7.2.5	Receptacle (Socket) Outlets and Their Associated Conductors	14	Accessories and Lighting
7.2.5.1		14.2	Receptacle Internal to the Control Enclosure
7.2.5.2		14.2.3	
7.2.6	Lighting Circuits	8.10	Lighting Branch Circuits
7.2.7	Transformers	8.11 8.12	Power Transformer Control Circuit Transformer
7.2.7.1			
7.2.8	Location of Overcurrent Protective Devices	8.4	Location of Protective Devices
7.2.9	Short-Circuit Interrupting Rating	8.1.2 8.1.3 8.1.4	
7.2.10	Rating and Setting of Overcurrent Protective Devices	8.5.1	
7.2.10.1			
Table 7.2.10.1	Maximum Rating or Setting of Fuse and Circuit Breakers: Motor, Motor Branch Circuit, and Motor Controller	Table 1	Fuse and Circuit Breaker Selection: Motor, Motor Branch Circuit, and Motor Controller
7.2.10.2		8.5.2	
7.2.10.3		8.5.3	
7.2.10.4		8.5.4	
Table 7.2.10.4(2)	Relationship Between Conductor Size and Maximum Rating or Setting of Short-Circuit Protective Device for Power Circuits	Table 2	Relationship Between Conductor Size and Maximum Rating or Short-Circuit Protective Device for Power Circuits
7.2.11	Resistance Heating Branch-Circuit Overcurrent Protection	8.8	Resistance Heating Circuits
7.2.11.1		8.8.1	
7.2.11.2		8.8.2	
7.2.11.3		8.8.3 8.8.4	

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
7.2.12	Programmable Electronic System Power Supply Input Overcurrent Protection		
7.2.13	Control Devices		
7.2.14	Common Overcurrent Device		
7.3	Overload Protection of Motors	8.6	Motor Overload
7.3.1	General	8.6.1 8.15	Adjustable Speed Drive System
7.3.1.1	Motors	8.6.4	
7.3.1.2	Adjustable Speed Drives (Electronic Drives)	8.6.4 8.7.1	
7.3.2	Resetting	8.6.2	
7.3.3	Number of Overloads	8.6.3	
Table 7.3.3	Running Overcurrent Units	Table 3	Running Overcurrent Units
7.3.3.1		Table 3	Exception
7.3.3.2		8.7.1	
7.3.3.3		8.7.2	
7.4	Abnormal Temperature Protection		
7.5	Protection Against Supply Interruption or Voltage Reduction and Subsequent Restoration	8.14	Undervoltage Protection
7.5.1	General	8.14.1	
7.5.2	Undervoltage Protection	8.14.3	
7.5.3	Restarting	8.14.2	
7.6	Overspeed Protection	8.16	Motor Overspeed Protection
7.6.1	Motor Overspeed Protection	8.16	Motor Overspeed Protection
7.6.2	Equipment Overspeed Protection	8.16	Motor Overspeed Protection
7.7	(Reserved)		
7.8	Phase Sequence Protection		
7.9	Protection Against Overvoltages Due to Lightning and Switching Surges		
7.9.1			
7.9.2			
7.9.3			

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
7.10	Power Factor Correction Capacitors		
7.10.1	Overcurrent Protection		
7.10.2	Discharge of Stored Energy		
7.10.2.1	Time of Discharge		
7.10.2.2	Means of Discharge		
8	Grounding	19	Ground Circuits and Equipment Grounding
8.1	General		
8.1.1	Applicability	19.1	General
8.1.2	Connections		
8.2	Equipment Grounding (Protective Bonding) Circuit		
8.2.1	Grounding System	19.1 19.5	General Ground Terminal
8.2.1.1	Equipment Grounding	19.3	Equipment Grounding
8.2.1.2	Equipment Grounding Terminal		
8.2.1.2.1		19.5	Ground Terminal
8.2.1.2.2		19.5	Ground Terminal
8.2.1.2.3			
8.2.1.2.4		4.10	Equipment Grounding Terminal Marking
8.2.1.2.5			
8.2.2	Equipment Grounding (Protective) Conductors and Bonding Jumpers		
8.2.2.1		19.2.1	
8.2.2.2		19.2.2	
8.2.2.3		19.2.3	
8.2.3.3.1		19.2.4	
Table 8.2.2.3	Minimum Size of Equipment Grounding Conductors and Bonding Jumpers	Table 14	Size of Grounding Conductors
8.2.3	Continuity of the Equipment Grounding (Protective Bonding) Circuit	19.6	Continuity of the Grounding Circuit
8.2.3.1		19.6.1	
8.2.3.2		19.6.6	
8.2.3.3		19.6.2	

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
8.2.3.4		19.6.3	
8.2.3.5		19.6.5	
8.2.3.6	Doors or Covers		
8.2.3.6.1			
8.2.3.6.2			
8.2.3.7		19.6.4	
8.2.3.8			
8.2.4	Exclusion of Switching Devices	19.4	Exclusion of Switching Devices
8.2.5	Equipment Grounding (Protective) Conductor Connecting Points		
8.2.5.1			
8.2.5.2		4.10	Equipment Grounding Terminal Marking
8.3	Control Circuits	19.7 9.3	Control Circuits Grounding of Control Circuits
8.3.1			
8.4	Lighting Circuits	19.8	Lighting Circuits
8.4.1		19.8.1	
8.4.2		19.8.2	
8.4.3		19.8.3	
9	Control Circuits and Control Functions		
9.1	Control Circuits	9	Control Circuits
9.1.1	Control Circuit Supply		
9.1.1.1			
9.1.1.2			
9.1.1.3			
9.1.1.4		9.1	Source of Control Power
9.1.1.5			
9.1.2	Control Circuit Voltages	9.2	Control Circuit Voltages
9.1.2.1	AC Control Circuit Voltages	9.2.1	
9.1.2.2	DC Control Circuit Voltages	9.2.2	Exception Deleted
9.1.3	Protection		

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
9.1.4	Connection of Control Devices	9.4	Connection of Control Devices
9.1.4.1		9.4.1	
9.1.4.2		9.4.2	
9.2	Control Functions	9.5	Control Functions
9.2.1	Start Functions	9.5.1	Start Functions
9.2.2	Stop Functions	9.5.2	Stop Functions
9.2.3	Operating Modes	9.8	Operating Modes
9.2.3.1		9.8.1	
9.2.3.2		9.8.2	
9.2.3.3		9.8.3	
9.2.3.4			
9.2.4	Overriding Safeguards	9.15	Overriding of Safeguards
9.2.5	Operation	9.6	Operation
9.2.5.1	General		
9.2.5.1.1			
9.2.5.1.2			
9.2.5.2	Start	9.6.1	Start
9.2.5.2.1		9.6.1	Start
9.2.5.2.2			
9.2.5.2.3		9.6.1	Start
9.2.5.2.4		9.6.1	Start
9.2.5.3	Stop	9.6.2	Stop
9.2.5.3.1		9.5.2	Stop Functions
9.2.5.3.2		9.5.2	Stop Functions
9.2.5.3.3		9.6.2	Stop
9.2.5.4	Emergency Operations (Emergency Stop, Emergency Switching Off)		
9.2.5.4.1	Emergency Stop		
9.2.5.4.1.1		9.6.3	Emergency Stop
9.2.5.4.1.2		9.6.3	Emergency Stop
9.2.5.4.1.3		9.6.3	Emergency Stop

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
9.2.5.4.1.4		9.6.3	Emergency Stop
9.2.5.4.1.5		9.6.3	Emergency Stop
9.2.5.4.2	Emergency Switching Off		
9.2.5.4.2.1			
9.2.5.4.2.2			
9.2.5.5	Hold-to-Run Controls	9.7	Hold to Run Circuits
9.2.5.5.1		9.7.1	
9.2.5.5.2		9.7.2	
9.2.5.6	Two-Hand Control	9.14	Two Hand Control Circuits
9.2.5.7	Enabling Device		
9.2.5.7.1			
9.2.5.7.2			
9.2.5.7.3			
9.2.6	Combined Start and Stop Controls		
9.2.7	Cableless Control Functions		
9.2.7.1	General		
9.2.7.1.1			
9.2.7.1.2			
9.2.7.1.3			
9.2.7.2	Control Limitation		
9.2.7.2.1			
9.2.7.2.2			
9.2.7.2.3			
9.2.7.3	Stop Function		
9.2.7.3.1			
9.2.7.3.2			
9.2.7.4	Serial Data Communication		
9.2.7.5	Use of More Than One Operator Station		
9.2.7.6	Battery-Powered Operator Control Station		
9.3	Protective Interlocks		

Table H.1 *Continued*

NFPA 79-2002		NFPA 79-1997	
Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
9.3.1	Reclosing or Resetting of an Interlocking Safeguard		
9.3.2	Overtravel Limits	12.6.2	
9.3.3	Operation of Auxiliary Functions		
9.3.3.1			
9.3.3.2			
9.3.4	Interlocks Between Different Operation and for Contrary Motions		
9.3.4.1			
9.3.4.2		9.11 9.12	Motor Contactors and Starters Relays and Solenoids
9.3.4.3			
9.3.4.4			
9.3.5	Reverse Current Braking		
9.3.5.1			
9.3.5.2			
9.3.6	Protective Interlock	9.10	Machinery Door Interlocking
9.4	Control Functions in the Event of Failure		
9.4.1	General Requirements		
9.4.2	Protection Against Unintended Operation Due to Ground (Earth) Faults and Voltage Interruptions		
9.4.2.1	Ground (Earth) Faults	9.3	Grounding of Control Circuits
9.4.2.2	Voltage Interruptions		
9.4.2.2.1		8.14	Undervoltage Protection
9.4.2.2.2		20.2.5	
9.4.3	Control Systems Incorporating Software and Firmware Based Controllers		
10	Operator Interface and Control Devices	13	Operator's Control Station and Equipment
10.1	General		
10.1.1	Applicability		
10.1.2	Location and Mounting		
10.1.2.1	Control Devices		

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Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
10.1.2.2	Hand-Operated Control Devices		
10.1.3	Protection	13.1.1 13.8.1	
10.1.4	Position Sensors		
10.1.4.1		12.6.2	
10.1.4.2			
10.1.5	Portable and Pendant Control Stations	13.8	Pendent Stations
10.1.5.1		13.1.4 13.7.3	
10.1.5.2		13.8.3	
10.1.6	Operator Interface Devices		
10.1.6.1	Location of Operator Interface Devices	13.7	Location of Control Stations
10.1.6.1.1		13.4 13.7.1	
10.1.6.1.2		13.7.2	
10.1.6.1.3		13.1.4 13.7.3	
10.1.6.2	Arrangement of Operator Interface Devices	13.5	Arrangement of Control Station Components
	Exception No. 1		
	Exception No. 2	13.5 13.8.2	Arrangement of Control Station Components
10.1.7	Foot-Operated Switches	13.3 13.3.1	Foot-Operated Switches
	Exception		
10.2	Pushbutton Actuators and Color Graphic Interface Devices	13.1	Pushbuttons, Selector Switches, Indicating Lights
10.2.1	Pushbutton Actuators	13.1.3	
10.2.2	Colors	13.1.2 Table 8	Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons
10.2.2.1	Start or On	13.1.2	
10.2.2.2	Stop or Off		
10.2.2.3	Emergency Stop		
10.2.2.4	Alternate Action		

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10.2.2.5	Abnormal Conditions	Table 8	Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons
10.2.2.6	Hold to Operate		
10.2.2.7	Reset	13.1.2 Table 8	Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons
10.2.3	Legends	13.6	Legends
10.2.3.1			
	Exception		
10.2.3.2		Note on Table 8	Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons
10.3	Indicator Lights and Icons of Color Graphic Interface Devices	13.1 Table 8	Pushbuttons, Selector Switches, Indicator Lights Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons
10.3.1	Modes of Use	Table 8	Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons
10.3.2	Colors	Table 8	Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons
Table 10.3.2	Machine Indicator Lights and Icons	13.1.2 Table 8	Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons
10.3.3	Flashing Lights		
10.4	Illuminated Pushbuttons	13.1.2 Table 8	Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons
10.5	Rotary Control Devices	12.7	Rotary Control Devices
10.6	Start Devices	13.1.4	
10.7	Devices for Stop and Emergency Stop	13.2	Emergency Stop Devices
10.7.1	Location and Operation		
10.7.1.1		13.2.2	
10.7.1.2		13.2.1	
10.7.2	Types		
10.7.2.1			
10.7.2.2		13.2.4	
10.7.2.3			
10.7.3	Restoration of Normal Function After Emergency Stop		

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10.7.4	Emergency Stop Actuators	13.2.3	
	Exception		
10.7.5	Local Operation of the Supply Disconnecting Means to Effect Emergency Stop		
10.7.5.1			
10.7.5.2			
10.8	Devices for Emergency Switching Off		
10.8.1	Location		
10.8.2	Types		
10.8.2.1			
10.8.2.2			
10.8.2.3			
10.8.3	Restoration of Normal Function After Emergency Switching Off		
10.8.4	Actuators		
10.8.4.1			
10.8.4.2			
10.8.5	Local Operation of the Supply Disconnecting Means to Effect Emergency Switching Off		
10.9	Displays		
11	Electronic Equipment	20	Electronic Equipment
11.1	General	20.1	General
11.1.1		20.1	General
11.1.2			
11.1.3			
11.2	Basic Requirements	20.2	Basic Requirements
11.2.1	Equipment Grounding (Equipotential Bonding)		
11.2.1.1		20.3.2	
11.2.1.2		20.3.2	
11.2.2	Subassemblies	20.2.2	

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11.2.3	Electrical Noise and Transient Suppression	20.2.3	
11.2.4	Output Protection	20.2.6 8.3.2	
11.3	Programmable Equipment	20.3	Programmable Electronic Systems
11.3.1	Software Modification	20.3.1	
	Exception	20.3.1 Exception	
11.3.2	Memory Retention and Protection		
11.3.2.1			
11.3.2.2		20.2.5	
11.3.2.3		20.2.4	
11.3.3	Software Verification		
11.3.4	Use in Safety Related Functions		
12	Control Equipment: Location, Mounting and Enclosures	11 12	Control Enclosures and Compartments Location and Mounting of Control Equipment
12.1	General Requirements	12.1	General Requirements
12.1.1		12.1.1 12.4 11.1.1	Control Enclosure
12.1.2		11.2 11.4	Nonmetallic Enclosures Wall Thickness
12.1.3		11.5	Dimensions
12.1.4		11.8	Interlocks
12.2	Location and Mounting		
12.2.1	Accessibility and Maintenance	12.1.1	
12.2.1.1		12.1.1	
12.2.1.2		12.2.3	
12.2.1.3		12.5.2	
12.2.1.4		12.1.1	
12.2.1.5			
12.2.1.5.1			
12.2.1.5.2			
12.2.1.5.3			

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12.2.1.5.4			
	Exception		
12.2.1.6			
12.2.1.7			
12.2.1.8		12.2.4	
12.2.1.9		12.2.7	
12.2.2	Physical Separation or Grouping		
12.2.2.1		11.3	Compartment Location
12.2.2.2		12.1.2	
	Exception No. 1	12.1.2	Exception
	Exception No. 2		
12.2.2.3		12.2.1	
12.2.2.4		12.2.2	
12.2.2.5		12.2.2	Exception
12.2.3	Heating Effects		
12.3	Degrees of Protection		
12.3.1		12.4	Control Enclosure
12.3.2			
	Exception		
12.4	Enclosures, Doors, and Openings		
12.4.1		11.1.1 11.1.2	
12.4.2			
12.4.3			
12.4.4			
12.4.5		11.1.1	
12.4.6		11.6	Doors
12.4.7		11.6	Doors
12.4.8		11.6	Doors
12.4.9		11.11	Print Pocket
12.4.10		11.1.2	

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12.4.11			
12.4.12			
12.4.13			
12.5	Spaces Around Control Cabinets and Compartments		
12.5.1	Working Space		
12.5.1.1			
Table 12.5.1.1	Working Space Depth		
12.5.1.2			
12.5.1.3			
12.5.2	Access		
12.5.2.1			
12.5.2.2			
12.5.3			
12.6	Machine-Mounted Control Equipment	12.6	Machine-Mounted Control Equipment
12.6.1		12.6.1	
12.6.2		12.6.2	
12.6.3		12.6.3	
13	Conductors, Cables, and Flexible Cords	15	Conductors
13.1	General Requirements	15.1	General
13.1.1	General		
13.1.2	Wire Insulation	15.4	Wire Insulation
	Exception No. 1		
	Exception No. 2	15.4.5	Exception
	Exception No. 3		
13.1.3	Type MI Cable		
13.1.4	Conductors and Static Control	15.1.4	
13.2	Conductors	15	Conductors
13.2.1	Conductor Material		
	Exception No. 1		
	Exception No. 2		

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13.2.2	Stranded Conductors	15.2.1	
	Exception No. 1	15.2.1	
	Exception No. 2	15.2.1	
Table 13.2.2	Single Conductor Characteristic	Table 9	Single Conductor Characteristic
13.2.3	Constant Flexing	15.2.2	
13.2.4	Solid Conductors	15.2.3	
13.2.5	Printed Wire Assemblies	15.2.4	
13.2.6	Shielded Conductors	15.2.5	
13.2.7	Special Cables and Conductors		
13.2.7.1			
13.2.7.2		15.2.6	
13.3	Insulation	15.4	Wire Insulation
13.3.1		15.1.1	
13.3.2		15.4.3	
Table 13.3.2	Thickness of Single Conductor	Table 10	Single Conductor Insulation Thickness of Insulation in Mils [average/minimum (jacket)]
13.3.3		15.4.4	
13.4	Wire Markings	15.6	Wire Markings
13.4.1		15.6.1	
13.4.1	Exception	15.6.1	Exception
13.4.2		15.6.2	
13.4.3		15.6.3	
13.4.4		15.4.5	
13.5	Conductor Ampacity	15.5.1	
13.5.1			
Table 13.5.1	Conductor Ampacity Based on Copper Conductors with 60°C and 75°C Insulation in an Ambient Temperature of 30°C	Table 11	Conductor Ampacity Based on Copper Conductors with 60°C and 75°C Insulation in an Ambient Temperature of 30°C
13.5.2			
13.5.3		15.5.2	
13.5.4		15.5.3	

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13.5.5		Table 11	Conductor Ampacity Based on Copper Conductors with 60°C Insulation in an Ambient Temperature of 30°C
Table 13.5.5(a)	Correction Factors		
Table 13.5.5(b)	Adjustment Factors for More Than Three Current-Carrying Conductors in a Raceway or Cable		
13.5.6		15.5.4	
13.5.6	Exception	15.5.4	Exception
Table 13.5.6	Maximum Conductor Size for Given Motor Controller Size	Table 12	Maximum Conductor Size for Given Motor Controller Size
13.5.7	Conductor/Terminal Compatibility		
13.6	Conductor Sizing	15.3	Conductor Sizing
13.6.1		15.3	Conductor Sizing
13.6.1.1		15.3(a)	
13.6.1.1(1)			
13.6.1.1(2)			
13.6.1.1(3)			
13.6.1.2			
13.6.1.2(1)			
13.6.1.2(2)			
13.6.1.2(3)			
13.6.2		15.3(b)	Text and Exception
13.6.3		15.3(c)	
13.6.4		15.3(d)	
13.6.4		15.3(d)	
13.6.4(1)		15.3(d)1	
13.6.4(2)		15.3(d)2	
13.6.5	Shielded Conductors	15.2.5	
13.7	Conductors and Cables Used for Flexing Applications		
13.7.1	General		
13.7.1.1		16.3.5	

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13.7.1.2			
13.7.2	Mechanical Rating		
13.7.3	Current Carrying Capacity of Cables Wound or Drums		
Table 13.7.3	Derating Factors for Cables Wound on Drums		
13.8	Flexible Cords	15.1.2	
13.8.1			
13.8.2	Ampacity of Flexible Cords		
Table 13.8.2	Allowable Ampacity for Flexible Cords and Cables (Based on Ambient Temperature of 30°C)		
13.8.3			
14	Wiring Practices	16 17	Wiring Methods and Practices Raceways, Junction Boxes, and Pull Boxes
14.1	Connections and Routing	16.4	Wiring Connector and Connections
14.1.1	General Requirements	16.1	General Requirements
14.1.1.1		16.1.9	
14.1.1.2			
14.1.1.3		16.1.8	
14.1.1.4			
14.1.1.5		16.4.1 16.4.2	Exception No. 1
14.1.1.6		16.1.5	
14.1.1.7		16.3.11	
14.1.1.8		16.4.1	
14.1.1.9		16.1.6	
14.1.1.10		16.1.7	
14.1.1.11		16.1.8	
14.1.2	Conductor and Cable Runs		
14.1.2.1		16.1.4	
14.1.2.1	Exception No. 1	16.1.4	Exception
14.1.2.1	Exception No. 2		

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14.1.2.2			
14.1.2.3			
14.1.2.4			
14.1.3	Conductors of Different Circuits	16.3.8	
14.1.3	Exception		
14.1.4	Cables		
14.1.4.1			
14.1.4.2			
14.1.4.3			
14.1.4.4			
14.1.4.5			
14.1.4.6			
14.1.4.7			
14.1.4.8			
14.1.4.9			
14.1.4.10			
14.1.5	Cord		
14.1.5.1			
14.1.5.2			
14.1.5.3			
14.1.5.4		16.3.3	
14.1.5.5		16.3.4	
14.1.5.6		16.3.5	
14.2	Identification of Conductors		
14.2.1	General Requirements	16.1	General Requirements
14.2.1.1		16.1.1	
14.2.1.2			
14.2.2	Identification of the Equipment Grounding (Protective) Conductor		
14.2.2.1		16.1.2	
14.2.2.1	Exception No. 1		

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Chapter/Section	**Chapter/Section Title**	**Clause/Section**	**Clause/Section Title**
14.2.2.1	Exception No. 2	16.1.2	Exception No. 1
14.2.2.1	Exception No. 3	16.1.2	Exception No. 2
14.2.2.2			
14.2.3	Identification of the Grounded Circuit Conductor		
14.2.3.1		16.1.3	
14.2.3.2		16.1.3	
14.2.3.3			
14.2.4	Identification by Color for Other Conductors		
14.2.4.1		16.1.3	
14.2.4.1	Exception No. 1	16.1.3	Exception No. 1
14.2.4.1	Exception No. 2	16.1.3	Exception No. 2
14.2.4.2			
14.2.4.2	Exception		
14.2.4.3		16.1.3	
14.2.4.3	Exception No. 1	16.1.3	Exception No. 1
14.2.4.3	Exception No. 2	16.1.3	Exception No. 2
14.2.4.3	Exception No. 3	16.1.3	Exception No. 3
14.2.4.3	Exception No. 4		
14.3	Wiring Inside Enclosures	16.2	Panel Wiring
14.3.1		16.2.1	
14.3.2		16.2.2	
14.3.3			
14.3.4			
14.3.5		16.2.3	
14.3.6			
14.3.7			
14.4	Wiring Outside Enclosures	16.3	Machine Wiring
14.4.1	General Requirements		
14.4.2	External Raceways (Ducts)		

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14.4.2.1		16.3.7	
14.4.2.2		16.3.1	
14.4.2.2	Exception	16.3.5 16.3.6	Exception
14.4.2.3		16.3.2 16.3.12	
14.4.2.4		16.3.3	
14.4.2.5		16.3.4 16.3.6	Exception
14.4.3	Connection to Moving Elements of the Machine		
14.4.3.1		16.3.5	
14.4.3.2		16.3.5	
14.4.3.3			
14.4.3.4			
14.4.3.5		16.3.6	
14.4.3.6	Cable Handling System		
14.4.3.6.1			
14.4.3.6.2			
14.4.3.6.3			
14.4.3.6.3	Exception		
Table 14.4.3.6.3	Minimum Permitted Bending Radii for the Forced Guiding of Flexible Cables		
14.4.3.7			
14.4.3.8		16.3.6	
14.4.4	Interconnection of Devices on the Machine		
14.4.5	Attachment Plug and Receptacle (Plug/Socket) Combinations	14.1	Attachment Plugs and Receptacles External to the Control Enclosure
14.4.5.1		16.3.9	
14.4.5.2		14.1.1	
14.4.5.3		14.1.2	
14.4.5.3	Exception		
14.4.5.4			

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14.4.5.5			
14.4.5.6			
14.4.5.7		14.1.3	
14.4.6	Dismantling for Shipment	16.3.10	
14.5	Raceways (Ducts), Support Systems (Cable Supports), Connection Boxes, and Other Boxes	17	Raceways, Junction Boxes, and Pull Boxes
14.5.1	General Requirements	17.1	General Requirements
14.5.1.1		16.3.4	Exception
14.5.1.2		17.1.1	
14.5.1.3		17.1.2	
14.5.1.4			
14.5.2	Percentage Fills of Raceways (Ducts)	17.2	Percent Fill of Raceways
14.5.3	Rigid Conduit and Fittings	17.3	Rigid Metal Conduit and Fittings
14.5.3.1	General Requirements		
14.5.3.1.1		17.3.2 17.4 17.5 17.6.2	Intermediate Metal Conduit Electrical Metallic Tubing
14.5.3.1.2			
14.5.3.1.3		17.3.6 17.4 17.5 17.6.5	Intermediate Metal Conduit Electrical Metallic Tubing
14.5.3.1.3	Exception	17.3.6 17.6.5	Exception
14.5.3.1.4		17.3.7 17.4 17.5 17.6.6	Intermediate Metal Conduit Electrical Metallic tubing
Table 14.5.3.1.4	Minimum Radii of Conduit Bends	Table 13	Minimum Radius of Conduit Bends
14.5.3.1.5		17.3.8 17.4 17.5 17.6.7	Intermediate Metal Conduit Electrical Metallic Tubing
14.5.3.2	Metal Type Nonflexible Conduit		
14.5.3.2.1	General Requirements		