NFPA 79
Electrical Standard for Industrial Machinery

1997 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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Electrical Standard for

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1997 Edition

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 the National Fire Protection Association, Inc., at its Annual Meeting held May 19–22, 1997, in Los Angeles, CA. It was issued by the Standards Council on July 24, 1997, with an effective date of August 15, 1997, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 79 was approved as an American National Standard on August 15, 1997.

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, and 1994 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.

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.

Technical Committee on Electrical Equipment of Industrial Machinery

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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 text of this edition. Since that time, changes in membership may have occurred. A key to classifications is found at the back of this 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.

Contents

Foreword

This edition of NFPA 79 continues to be formatted in accordance with the ANSI style manual (8th edition), which includes the use of the following terms:

— Clause for the term Chapter
— Subclause for the term Section
— Annex for the term Appendix
— Normative references for mandatory references.

Figures and tables have been numbered consecutively starting with 1.

Annexes (appendices) A, B, C, D, E, and F are provided for informational purposes and should not be considered as part of the requirements of this standard.

This standard is intended to apply to electrical equipment used with a wide variety of machines and a group of machines working together in a coordinated manner. Therefore, the requirements and recommendations in this standard may not be relevant in all cases.

The risks associated with the hazards relevant to the electrical equipment should be assessed as part of the overall requirements for risk assessment of the machine. This will determine the acceptable level of risk and necessary protective measures for personnel who can be exposed to these hazards while still maintaining an acceptable level of performance of the machine and its equipment.

Hazards can include but are not limited to the following:

— Failures or faults in the electrical equipment resulting in the possibility of electrical shock or electrical fire.

— Failures or faults in control circuits (or components and devices associated with these circuits) resulting in malfunctioning of the machine.

— Disturbances or disruptions in external power sources as well as failures or faults in the power circuits resulting in the malfunctioning of the machine.

— Electrical interferences (e.g., electromagnetic, electrostatic, radio interference) either from outside the electrical equipment or internally generated.

— Stored energy (either electrical or mechanical).

— Audible noise at levels that cause health problems to personnel.

Safety measures are a combination of the measures incorporated at the design state 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.

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NOTICE: Information on referenced publications can be found in Clause 2 and Annex A.

1 Scope and purpose

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 place of connection of the supply to the electrical equipment of the machine.

NOTE 1: In this standard, the term "electrical" includes both electrical and electronic equipment. Requirements that apply only to electronic equipment shall be so identified.

NOTE 2: The general terms "machine" and "machinery" as used throughout this standard mean industrial machinery.

NOTE 3: See Annex B for examples of industrial machines covered by this standard.

1.1.2 This standard shall not be considered adequate for machines intended for use in areas defined as hazardous (classified) locations by NFPA 70.

1.1.3 This standard is not intended to apply to:

— Fixed or portable tools judged under the requirements of a testing laboratory acceptable to the authority having jurisdiction.

— Machines used in dwelling units.

1.1.4 The size and overcurrent protection of the supply conductors to a machine are covered by NFPA 70, Article 670. The wiring between component machines of an industrial manufacturing system is covered by NFPA 70.

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.

1.1.5 On any point for which specific provisions are not made in this standard (e.g., some requirements for the application of Design E motors), the provisions of NFPA 70 shall be observed.

NOTE: Motor design letter definitions are found in ANSI/NEMA MG.1 and in IEEE 100.

1.2 Purpose

(a) The purpose of this electrical standard is to 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.

(b) This standard is not intended to 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.

2 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements subject to this standard should apply the most recent editions of the normative documents listed below.

ANSI C80.1-1990, *Rigid Steel Conduit-Zinc Coated*

ANSI C84.1-1995, *Electric Power Systems and Equipment-Voltage Ratings (60 Hertz)*

ANSI/IEEE 315-1994, *Graphical Symbols for Electrical and Electronics Diagrams*

IEEE 100-1992, *Standard Dictionary of Electrical and Electronic Terms*

ANSI/NEMA ICS-2: 1993, *Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated Not More than 2000 Volts AC or 750 Volts DC*

ANSI/NFPA 70-1996, *National Electrical Code®*

ANSI/UL 1063-1995, *Standard for Safety Machine-Tool Wires and Cables*

ASTM B 8-1995, *Standard Specification for Concentric-Lay-Stranded Copper Conductors Hard, Medium-Hard, or Soft*

ASTM B 33-1994, *Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes*

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

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

IEC 204-1 (1992-09), *Electrical equipment of industrial machines — Part 1: General requirements*

IEC 417 O: (1996-04), *Graphical symbols for use on equipment. Index, survey, and compilation of the single sheets, Supplement O*

IEC 50-191: (1990-12), *International Electrotechnical Vocabulary. Chapter 191: Dependability and quality of service*

IEC 50-441: (1984-01), *International Electrotechnical Vocabulary. Chapter 441: Switchgear, controlgear, and fuses*

IEC 50-826: (1982-01), *International Electrotechnical Vocabulary. Chapter 826: Electrical installation of buildings*

ISO 3864: 1984, *Safety colours and safety signs*

NEMA FB 1-1993, *Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit and Cable Assemblies*

NOTE: A list of standards that may provide additional information related to electrical equipment of industrial machines is found in Annex A — Bibliography.

3 Definitions

3.1 accessible (as applied to equipment): Admitting close approach: not guarded by locked doors, elevation, or other effective means. (NFPA 70.)

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, chairs, etc. (NFPA 70.)

3.3 actuator: The part of the actuating system to which an external actuating force is applied.

NOTE 1: The actuator may take the form of a handle, knob, push-button, roller, plunger, etc. (IEC 50-441.)

NOTE 2: There are some actuating means that do not require an external actuating force — only an action.

NOTE 3: See also 3.61 — machine actuator.

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. This includes ac and dc voltage modes and frequency mode controls. Belt, chain, or roller shifting controllers are not included.

3.5 alphanumeric: Pertaining to a character set that contains both letters and digits, but usually some other characters such as punctuation marks. (IEEE 100.)

3.6 ambient temperature: The temperature of air or other medium where the equipment is to be used. (IEC 50-826.)

3.7 ampacity: The current in amperes a conductor can carry continuously under the conditions of use without exceeding its temperature rating. (NFPA 70.)

3.8 attachment plug (plug cap) (cap): A device that, by insertion in a receptacle, establishes connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle. (NFPA 70.)

3.9 barrier: A part providing protection against direct contact from any usual direction of access. (IEC 50-826.)

3.10 bonding: The permanent joining of metallic parts to form an electrically conductive path that will assure electrical continuity and the capacity to conduct safely any current likely to be imposed. (NFPA 70.)

3.11 branch circuit: The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s). (NFPA 70.)

3.12 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. (NFPA 70.)

3.13 concurrent: Acting in conjunction; used to describe a situation wherein two or more controls exist in an operated condition at the same time (but not necessarily simultaneously).

3.14 conduit, intermediate metal: A metal raceway of circular cross section with integral or associated couplings, connectors, and fittings approved for the installation of electrical conductors. (NFPA 70.)

3-15 conduit, rigid metal: A raceway specially constructed for the purpose of the pulling in or the withdrawing of wires or cables after the conduit is in place and made of metal pipe of standard weight and thickness permitting the cutting of standard threads. (IEEE 100.)

3.16 conduit, rigid nonmetallic: A type of conduit and fittings of suitable nonmetallic material that is resistant to moisture and chemical atmospheres, flame retardant, resistant to impact and crushing, and resistant to distortion from heat or low temperatures under conditions likely to be encountered in service. (NFPA 70.)

3.17 control circuit: 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. (NFPA 70.)

3.18 control circuit transformer: A voltage transformer utilized to supply a voltage suitable for the operation of control devices. (IEEE 100.)

3.19 control circuit voltage: The voltage provided for the operation of shunt coil magnetic devices.

3.20 control device: Device connected into the control circuit and used for controlling the operation of the machine (e.g., position sensors, manual control switches, relays, magnetically operated valves). (IEC 204-1.)

3.21 controlled stop: The stopping of machine motion by reducing the electrical command signal to 0 once the stop signal has been recognized by the control but retaining power to the machine actuators during the stopping process. (IEC 204-1.)

3.22 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. For the purpose of this standard, a controller is any switch or device normally used to start and stop a motor by making and breaking the motor circuit current. (NFPA 70.)

3.23 device: A unit of an electrical system that is intended to carry but not utilize electric energy. (NFPA 70.)

3.24 digital: Operated by the use of discrete signals to represent data in the form of numbers or other characters. (IEC 204-1.)

3.25 direct contact: Contact of persons with live parts. (IEC 50-826.)

3.26 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. (NFPA 70.)

3.27 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. (NFPA 70.)

3.28 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. (NFPA 70.)

3.29 electric 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. (IEEE 100.)

3.30 electromechanical: Applied to any device in which electrical energy is used to magnetically cause mechanical movement.

3.31 electronic: Of, or pertaining to, devices, circuits, or systems utilizing electron devices. Examples: Electronic control, electronic equipment, electronic instrument, and electronic circuit. (IEEE 100.)

3.32 electronic equipment: That part of the electrical equipment containing circuitry mainly based on electronic devices and components.

3.33 enclosure: A part providing protection of equipment against certain external influences and, in any direction, protection against direct contact. (IEC 50-826.)

3.34 energized: Electrically connected to a source of potential difference. (NFPA 70.)

3.35 equipment: Includes material, fittings, devices, appliances, fixtures, apparatus, and the like used as a part of, or in connection with, an electrical installation. (NFPA 70.)

3.36 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. (NFPA 70.)

3.37 exposed conductive part: A conductive part of electrical equipment that can be touched and that normally is not live, but that can become live under fault conditions. (IEC 50-826.)

3.38 failure [of equipment]: The termination of the ability of an item to perform a required function.

NOTES:

1. After failure, the item has a fault.
2. "Failure" is an event, as distinguished from fault, which is a state.
3. The concept as defined does not apply to items consisting of software only. (IEC 50-191.)

3.39 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.

NOTE: A fault is often the result of a failure of the item itself, but may exist without prior failure. (IEC 50-191.)

3.40 feeder: All circuit conductors between the service equipment or the source of a separately derived system and the final branch-circuit overcurrent device. (NFPA 70.)

3.41 flame retardant: So constructed or treated that it will not support or convey flame. (IEEE 100.)

3.42 grounded: Connected to earth or to some conducting body that serves in place of the earth. (NFPA 70.)

3.43 grounded conductor: A system or circuit conductor that is intentionally grounded. (NFPA 70.)

3.44 grounding conductor: A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes. (NFPA 70.)

3.45 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. (NFPA 70.)

3.46 grounding electrode conductor: The conductor used to connect the grounding electrode to the equipment grounding conductor, to the grounded conductor, or both, of the circuit at the service equipment or at the source of a separately derived system. (NFPA 70.)

3.47 guard: Part of a machine specifically used to provide protection by means of a physical barrier. Depending on its construction, a guard may be called a casing, cover, screen, door, enclosing guard, etc. (IEC 204-1.)

3.48 hazard: A source of possible injury or damage to health. (IEC 204-1.)

3.49 identified (as applied to equipment): Recognizable as suitable for the specific purpose, function, use, environment, application, etc., where described in a particular code requirement.

NOTE: Suitability of equipment for a specific purpose, environment, or application may be determined by a qualified testing laboratory, inspection agency, or other organization concerned with product evaluation. Such identification may include labeling or listing. (NFPA 70.)

3.50 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," etc., of another equipment, one of the equipments specified is to be visible and not more than 50 ft (15.24 m) distant from the other. (NFPA 70.)

3.51 indirect contact: Contact of persons with exposed conductive parts that have become live under fault conditions. (IEC 50-826.)

3.52 industrial 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. It can include associated equipment used to transfer material or tooling (including fixtures), assemble/disassemble, inspect or test, or 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.)

3.53 industrial manufacturing system: A systematic array of one or more industrial machines that are not portable by hand and that includes any associated material handling, manipulating, gauging, measuring, or inspection equipment.

3.54 input:

1. The terminals where current, voltage, power, or driving force may be applied to a circuit or device;

2. The state or sequence of states occurring on a specific input channel;

3. The device or collective set of devices used for bringing data into another device. (IEC 204-1.)

3.55 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.

3.56 interlock (for safeguarding): An arrangement that interconnects guard(s) or device(s) with the control system and/or all or part of the electrical energy distributed to the machine. (IEC 204-1.)

3.57 interrupting rating: The highest current at rated voltage that a device is intended to interrupt under standard test conditions.

NOTE: Equipment intended to break current at other than fault levels may have its interrupting rating implied in other ratings, such as horsepower or locked-rotor current.

3.58 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. (IEEE 100.)

3.59 live parts: Electric conductors, buses, terminals, or components that are uninsulated or exposed and a shock hazard exists. (NFPA 70.)

3.60 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. (IEEE 100.)

3.61 machine actuator: A power mechanism used to effect motion of the machine. (IEC 204-1.)

3.62 motor-circuit switch: A switch intended for use in a motor branch circuit.

NOTE: It is rated in horsepower, and it is capable of interrupting the maximum operating overload current of a motor of the same rating at the rated voltage. (IEEE 100.)

3.63 output:

1. The terminals where current, voltage, power, or driving force may be delivered by a circuit or device;

2. The state or sequence of states occurring on a specific output channel;

3. The device or collective set of devices used for taking data out of another device.

3.64 overcurrent: Any current in excess of the rated current of the equipment or the rated ampacity of the conductor. It may result from overload, short circuit, or ground fault. (NFPA 70.)

3.65 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. (NFPA 70.)

3.66 panel: An element of an electric controller consisting of a slab or plate on which various component parts of the controller are mounted and wired. (IEEE 100.)

3.67 power circuit (wiring): The circuit used for supplying power from the supply network to equipment or components used for the productive operation and to transformers supplying control circuits.

NOTE: A motor is one example of equipment or a component used for productive operation.

3.68 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.

NOTE: The term PES 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.

3.69 qualified person: One familiar with the construction and operation of the equipment and the hazards involved. (NFPA 70.)

3.70 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, surface raceways, wireways, and busways.

3.71 receptacle: A contact device installed at the outlet for the connection of a single attachment plug. (NFPA 70.)

3.72 relay: An electric component designed to interpret input conditions in a prescribed manner and, after specified conditions are met, to respond to cause contact operation or similar abrupt change in associated electric control circuits.

NOTE 1: Inputs are usually electric but may be mechanical, thermal, or other types. Limit switches and similar devices are not relays.

NOTE 2: A relay consists of several units, each responsive to specified inputs, the combination providing the desired performance characteristic.

3.73 risk: A combination of the probability and the degree of possible injury or damage to health in a hazardous situation. (IEC 204-1.)

3.74 safe working procedure: A method of working that reduces risk. (IEC 204-1.)

3.75 safeguard: A guard or protective device used as a safety measure to protect persons from a present or impending hazard. (IEC 204-1.)

3.76 safeguarding: Those safety measures consisting of the use of specific measures called safeguards to protect persons from hazards that cannot reasonably be removed or sufficiently limited by design. (IEC 204-1.)

3.77 safety function (safety measure): A means that eliminates or reduces a hazard. (IEC 204-1.)

3.78 short-time rating: The rating defining the load that can be carried for a short and definitely specified time, with the machine, apparatus, or device being at approximately room temperature at the time the load is applied.

3.79 splashproof (industrial control): So constructed and protected that external splashing will not interfere with successful operation. (IEEE 100.)

3.80 static device: A device that has no moving parts, as associated with electronic and other control or information-handling circuits.

3.81 subpanel: An assembly of electrical devices connected together that forms a simple functional unit in itself.

3.82 switching device: A device designed to make or break the current in one or more electric circuits. (IEC 50-441.)

3.83 tight (suffix): So constructed that the specified material is excluded under specified conditions. (IEEE 100.)

3.84 uncontrolled stop: The stopping of machine motion by removing power to the machine actuators, all brakes or other mechanical stopping devices being activated. (IEC 204-1.)

3.85 undervoltage protection: The effect of a device that operates on the reduction or failure of voltage to cause and maintain the interruption of power.

NOTE: 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.

3.86 ventilated: Provided with a means to permit circulation of air sufficient to remove excess heat, fumes, or vapors. (NFPA 70.)

3.87 wet location: Installations underground or in concrete slabs or masonry in direct contact with the earth, and locations subject to saturation with water or other liquids, such as vehicle washing areas, and locations exposed to weather and unprotected. (NFPA 70.)

3.88 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. (NFPA 70.)

4 Diagrams, instructions, and nameplates

4.1 General

4.1.1 The following shall be included with the electrical drawings where required in 4.2.

— Complete schematic diagram
— Sequence of operations
— Block diagram (where appropriate)
— Equipment layout
— Panel layouts
— Interconnection diagram
— Electronic schematics (where appropriate)
— Parts list
— Instruction and service manuals
— Information for Safety Lockout Procedure (where appropriate).

4.1.2 The following shall be furnished for reference only where appropriate.

— Lubrication diagram
— Pneumatic diagram
— Hydraulic diagram
— Miscellaneous system diagrams (e.g., coolant, refrigerant, etc.).

4.1.3 Where appropriate, a table of contents shall appear prominently on the first sheet and shall refer to all major sections of the electrical drawings.

4.2 Diagrams

4.2.1 Diagrams of the electrical system shall be provided. Any electrical symbols shall be in accordance with IEEE 315. Any electrical symbols not shown in IEEE 315 standards 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.

Pertinent information such as motor horsepower, frame size, and speed shall be listed adjacent to its symbol.

NOTE: See Annex D for examples of electrical diagrams.

4.2.2 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.

4.2.3 The functional description for each device shall be shown.

NOTE: See Annex E for examples of devices and component designations.

4.2.4 Switch symbols shall be shown on the electrical schematic diagrams with all utilities turned off (electric power, air, water, and lubricant), the machine and its electrical equipment in its normal starting condition, and at 68°F (20°C) ambient. Control settings shall be shown on the drawings.

4.2.5 Directly connected conductors shall be uniquely designated with the same alphanumeric reference. Conductors shall be identified in sequential order and in accordance with Clause 16.

Exception No. 1: Conductors of 18 AWG or less used in electronic assemblies shall not be required to be identified by an alphanumeric designation.

Exception No. 2: Where a plug is attached to a multiconductor cable, color coding shall be permitted to be substituted for the alphanumeric designation only at the plug end. Where color-coded multiconductor cable is used to wire identical components (e.g., limit switches), the color shall be consistent throughout. Where color coding is used, it shall be clearly indicated on the electrical diagrams.

4.2.6 Circuits shall be shown in such a way as to facilitate the understanding of their function as well as their maintenance and fault location. Control circuit devices shall be shown between vertical lines that represent control power wiring. The left vertical line shall be the control circuits common and the right line shall be the operating coils common, except where permitted by Clause 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.

4.2.7 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.

4.2.8 Interlock wiring diagrams shall include devices, functions, and conductors in the circuit where used.

4.2.9 Plug/receptacle pin identification shall be shown on the diagram(s).

4.3 Instructions

4.3.1 Information referring to the installation, sequence of operations, explanation of unique terms, list of recommended spare parts, maintenance instructions, and adjustment procedures of the machine electrical equipment shall be furnished.

4.3.2 The installation drawing(s) shall provide information necessary for preliminary machine and control setup. This includes information on supply cables, particularly if they are to be supplied by the end user; the size and purpose of any cable duct, raceway, or wireway that must be supplied by the end user; and the amount of space required to mount and maintain the machine and its electrical equipment.

4.3.3 The description of the sequence of operations is required for electrical equipment comprising several interrelated functions. Where the machine can perform several sequences, the description of operation shall explain each of them and their interrelationship. Information shall be given that is necessary for the understanding of the electrical operation in conjunction with the mechanical, hydraulic, or pneumatic operation of the machine. Where the sequence of operations is program controlled, the information on programming the system for operation, maintenance, and repair shall be provided. A block diagram shall be permitted to be used to facilitate the understanding of the sequence of operations. The block diagram shows the electrical equipment together with its functional interrelationships by the use of symbols or blocks without necessarily showing all interconnections. References to the appropriate electrical diagram(s) shall be included on the block diagram.

4.3.4 The parts list shall itemize recommended electrical spare parts together with the necessary data for ordering replacements.

4.3.5 Maintenance and service instructions shall include:

— Information necessary for calibrating and adjusting components, devices, and subassemblies.

— Operation instructions, including all information necessary to describe initial conditions and operations of the complete system.

— Troubleshooting information and suggestions for locating and replacing faulty components, suggested preventative maintenance schedules, and related data.

4-4 Markings

Nameplates, markings, and identification plates shall be of sufficient durability to withstand the environment involved.

4.5 Warning marking

4.5.1 A warning marking shall be provided adjacent to the disconnect operating handle(s) where the disconnect(s) that is interlocked with the enclosure door does not deenergize all exposed live parts when the disconnect(s) is in the "open (off)" position.

4.5.2 Where an attachment plug is used as the disconnecting means, a warning marking shall be attached to the control enclosure door or cover indicating that power shall be disconnected from the equipment before the enclosure is opened.

4.5.3 Where the disconnecting means is remote from the control enclosure, a warning marking 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.

4.6 Machine marking

The machine shall be marked with the builder's name, trademark, or other identification symbol.

4.7 Machine nameplate data

4.7.1 A permanent nameplate listing the machine serial number, supply voltage, phase, frequency, full-load current, ampere rating of the largest motor or load, short-circuit interrupting capacity of the machine overcurrent protective device where furnished as part of the equipment, and the electrical diagram number(s) or the number of the index to the electrical diagrams (bill of material) shall be attached to the control equipment enclosure or machine where plainly visible after installation. Where more than one incoming supply circuit is to be provided, the nameplate shall state the above information for each circuit.

Exception: 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.

4.7.2 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.

4.7.3 Where overcurrent protection is provided in accordance with 8.2, the machine shall be marked "overcurrent protection provided at machine supply terminals." A separate nameplate shall be permitted to be used for this purpose.

4.8 Equipment marking and identification

4.8.1 Where equipment is removed from its original enclosure or is so placed that the manufacturer's identification plate is not easily read, an additional identification plate shall be attached to the machine or enclosure.

4.8.2 Where a motor nameplate or connection diagram plate is not visible, additional identification shall be provided where it can be easily read.

4.8.3 Nameplates, identification plates, or warning markings shall not be removed from the equipment.

4.8.4 All control panel devices and components shall be plainly identified with the same designation as shown on the 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 section shall not be required to apply to machines on which the equipment consists only of a single motor, motor controller, pushbutton station(s), and worklight(s).

4.8.5 All devices external to the control panel(s) shall be identified by a nameplate with the same designation as shown on the diagram(s) and mounted adjacent to (not on) the device.

Exception: Devices covered by 4.9.

4.8.6 Terminations on multiconductor plugs and receptacles shall be plainly marked. The markings on the plug/receptacles and on drawings shall correspond.

4.8.7 Where group protection as provided for in 8.5.4 is used, information specifying the short-circuit protective device for each group protected motor branch circuit shall be included with the equipment.

4.9 Function identification

Each control station device (pushbutton, indicating light, and selector switch) shall be identified as to its function on or adjacent to the device.

NOTE: Consideration shall be given to the use of IEC symbols for pushbuttons *(see Annex C for examples)*.

4.10 Equipment grounding terminal marking

The equipment grounding terminal shall be identified with the word "GROUND," the letters "GND" or "GRD," the letter "G," or by coloring the terminal GREEN.

NOTE: Some other standards recognize symbols C.1 (IEC 417-5019) and C.2 (IEC 417-5017).

5 General operating conditions

5.1 General

This chapter describes the general requirements and conditions for the operation of the electrical equipment of the machine.

5.2 Electrical components and devices

Electrical components and devices shall be used or installed 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.

5.3 Ambient operating temperature

The electrical equipment shall be capable of operating in an ambient temperature range of 41 to 104°F (5 to 40°C) under no load to full load conditions.

5.4 Altitude

The electrical equipment shall be suitable for operating correctly at altitudes up to 3300 ft (1000 m) above sea level.

5.5 Relative humidity

The electrical equipment shall be capable of operating within a relative humidity range of 20-95 percent (noncondensing).

5.6 Transportation and storage

The electrical equipment shall be designed to withstand storage and transportation temperatures within the range of -13 to +131°F (-25 to 55°C) and up to 149°F (65°C) 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.

5.7 Electrical supply

The electrical equipment shall be designed to operate correctly under full load as well as no load with the conditions of the nominal supply as specified below unless otherwise specified by the user.

5.7.1 AC supplies

Steady state voltage	
Voltage	0.9 ...1.1 of nominal voltage.
Frequency	0.99 ...1.01 of nominal frequency continuously.
	0.98 ...1.02 short time.
	Note: The short time value may be specified by the user.
Harmonics	Harmonic distortion not to exceed 10% of the total rms voltage between live conductors for the sum of the 2nd through 5th harmonic.
	An additional 2% of the total rms voltage between live conductors for the sum of the 6th through 30th harmonic is permissible.
Voltage unbalance (in 3-phase supplies)	Neither the voltage of the negative sequence component nor voltage of the zero sequence component in 3-phase supplies exceeds 2% of the positive sequence component.
Voltage impulses	Not to exceed 1.5 ms in duration with a rise/fall time between 500 ns and 500μs and a peak value of not more than 200% of the rated rms supply voltage value.
Voltage interruption	Supply interrupted or at zero voltage for not more than 3 ms at any random time in the supply cycle. There shall be more than 1 sec between successive interruptions.
Voltage dips	Voltage dips shall not exceed 20% of the peak voltage of the supply for more than 1 cycle. There shall be more than 1 sec between successive dips.

5.7.2 DC supplies

From batteries	
Voltage	0.85 ... 1.15 of nominal voltage.
	0.7 ... 1.2 of nominal voltage in the case of battery-operated vehicles.
Voltage interruption	Not exceeding 5 ms.
From converting equipment	
Voltage	0.9 ... 1.1 of nominal voltage.
Voltage interruption	Not exceeding 20 ms. There shall be more than 1 sec between successive interruptions.
Ripple (peak-to-peak)	Does not exceed 0.05 of nominal voltage.

5.8 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

Clause 5 shall be permitted where acceptable to both the manufacturer and user.

6 Safeguarding of personnel

6.1 General

The electrical equipment shall provide safeguarding of persons against electrical shock both in normal service and in case of fault.

6.2 Safeguarding against electric shock in normal service

6.2.1 Live parts shall either be located inside enclosures as described in Clauses 11 and 12 or be completely covered by insulation that can only be removed by destruction (e.g., interconnecting cables).

6.2.2 Enclosure interlocking as described in 7.9 and 11.8 shall be provided.

6.2.3 Grounding and bonding of the electrical equipment and machine members shall comply with Clause 19 of this standard.

6.3 Protection by the use of PELV (protective extra low voltage)

This measure is intended to protect persons against electric shock from direct contact and indirect contact.

PELV circuits shall satisfy all of the following conditions:

(a) Limitation of maximum nominal voltage to 30 V ac or 60 V dc;

(b) Limitation of maximum current (in case of failure) to 1 A ac or 0.2 A dc;

(c) Limitation to 12.5 in.^{2} (80 cm^2) of any area not protected against direct contact;

(d) Usage only indoors with dry conditions;

(e) The source of supply and live parts of such circuits shall be separated or isolated from circuits with higher voltages;

(f) One side of the circuit or one point of the source of the supply of that circuit shall be connected to the equipment grounding circuit associated with the higher voltages;

(g) Exposed conductive parts associated with such circuits shall be either separated or isolated from higher voltage circuits or connected to the grounding circuit associated with the higher voltages;

(h) Plugs and socket-outlets shall comply with the following:

1.) plugs shall not be able to enter socket-outlets not in accordance with this subclause, and

2.) socket-outlets shall exclude plugs of circuits not in accordance with this subclause.

(i) Where such circuits are used as control circuits, they shall also fulfill the relevant requirements of Clause 7.

6.4 Safeguarding against electrical shock from residual voltages

Where the equipment includes elements that may retain residual voltages after being switched off, the voltage shall be reduced to below 50 volts within 1 min after being disconnected.

6.5 Safeguarding against other hazards

6.5.1 Where hazards are identified for the specific machine on which the electrical equipment is present, provisions for the connection of the appropriate safeguards (e.g., guards and protective devices) shall be made. These safeguards shall function in accordance with the requirements of the specific industrial machine.

6.5.2 Where the industrial machine is used in conjunction with other machines or equipment (e.g., in a manufacturing system/cell), provisions shall be made, where appropriate, to connect external emergency stop devices to the emergency stop circuit *(see 9.6)*. Where appropriate, provisions also shall be made to indicate the status of the emergency stop circuit to other machines and associated equipment.

7 Supply circuit disconnecting means

7.1 General requirements

A disconnecting means shall be provided for each incoming supply circuit.

7.2 Type

7.2.1 The disconnecting means shall be manually operable and shall be a fusible or nonfusible motor circuit switch or a circuit breaker in accordance with 7.3 through 7.10.

7.2.2 An attachment plug shall be permitted in accordance with 7.11.

7.3 Rating

7.3.1 The ampere rating of the disconnecting means shall be not less than 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.

7.3.2 A disconnecting means with short-circuit and ground-fault protection shall have a short-circuit interrupting rating sufficient for the nominal circuit voltage and current that is available at the point of installation.

A disconnecting means provided to break current at levels less than short-circuit (e.g., motor locked-rotor currents) shall have an interrupting rating that is not less than 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 or non-motor loads that can be operated at that time. This sum is the equivalent locked-rotor current from which the minimum size disconnecting means shall be selected *(see NFPA 70, Table 430-151B, for relating locked-rotor currents to horsepower ratings).*

7.3.3 Fusible motor-circuit switches or circuit breakers shall be applied in accordance with Clause 8 of this standard.

7.4 Position indication

The disconnecting means shall plainly indicate whether it is in the open (off) or closed position.

7.5 Supply conductors to be disconnected

Each disconnecting means shall disconnect all ungrounded conductors of a single supply circuit simultaneously. Where there is more than one source, additional individual disconnecting means shall be provided for each supply circuit, so that all supply to the machine may be interrupted.

Exception: Interlocking circuits energized from remote source(s) and identified with yellow wiring in accordance with 16.1.1 shall not be required to be disconnected. The warning requirements of 4.5.1 shall apply.

7.6 Connections to supply lines

Incoming supply line conductors shall terminate at the disconnecting means with no connection to terminal blocks or other devices ahead of the disconnecting means.

7.7 Exposed live parts

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

NOTE: See Exception to 9.1.

7.8 Mounting

7.8.1 The disconnecting means shall be mounted within the control enclosure or adjacent thereto. Where mounted within the control enclosure, the disconnecting means shall be mounted at the top of the control panel with no other equipment mounted directly above it. Wire bending space shall be provided as required by NFPA 70, Section 430-10(b). Space shall be determined by maximum wire size of incoming lines or by maximum capacity of line lugs on the disconnecting means.

Exception No. 1: In plastics extrusion machinery (extruders, film casting machines, film and sheet winding equipment, wire coating machinery, and sheet line and pull roll equipment ONLY — see B.2) where the design configuration of the enclosure may preclude mounting the disconnect as the uppermost component:

— Live parts shall be guarded against accidental contact.

— Barriers shall be placed in all enclosures to isolate the supply circuit conductors and terminals from other internal conductors and components.

Exception No. 2: Machines with a motor(s) totaling two horsepower or less shall be permitted to be connected to a remotely mounted disconnecting means through a flexible cord, cable, or conduit provided the disconnecting means is in sight from, readily accessible to, and no more than 20 ft (6 m) from the machine operator.

7.8.2 Where two or more disconnecting means are provided within the control enclosure for multiple supply circuits, they shall be grouped in one location.

7.9 Interlocking

7.9.1 Each disconnecting means shall be mechanically or electrically interlocked, or both, with the control enclosure doors. Interlocking shall be reactivated automatically when panel 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. The marking requirements of 4.5.1 shall apply.

Exception No. 2: Where an attachment plug is used as the disconnecting means in accordance with 7.11.

Exception No. 3: 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 the storage of information shall not be required to be interlocked with the control enclosure doors. The marking requirements of 4.5.1 shall apply.

Exception No. 4: Where a remotely mounted disconnecting means is permitted as per 7.8.1, Exception No. 2, interlocking shall not be required provided that a tool is required to open the enclosure door and a label is attached to the control enclosure warning of dangerous voltage inside and advising disconnection of the power before opening.

7.9.2 Interlocking shall be provided between the disconnecting means and its associated door to accomplish both of the following:

— To prevent closing of the disconnecting means while the enclosure door is open, unless an interlock is operated by deliberate action.

— To prevent closing of the disconnecting means while the door is in the initial latch position or until the door hardware is fully engaged.

7.9.3 All doors on multiple-door enclosures shall be interlocked simultaneously with the door that is interlocked with the main disconnecting means.

7.9.4 Where there are two or more sources of power to the equipment or where there are two or more independent disconnecting means, power wiring from each disconnecting means shall be run in separate conduit and shall not terminate in or pass through common junction boxes.

7.10 Operating handle

7.10.1 The operating handle of the disconnecting means shall be readily accessible.

7.10.2 The center of the grip of the operating handle of the disconnecting means, when in its highest position, shall be not more than 6 ft 7 in. (2.0 m) 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.

7.10.3 The operating handle shall be capable of being locked only in the open (off) position.

7.10.4 When the control enclosure door is closed, the operating handle shall positively indicate whether the disconnecting means is in the open (off) or closed position.

7.11 Attachment plug and receptacle

An attachment plug and receptacle shall be permitted as a disconnecting means providing all of the following conditions are complied with:

— The motor(s) on the machine shall total two horsepower or less.

— The supply voltage shall not exceed 150 volts to ground.

— DC shall not be used.

— The ampere rating of the attachment plug shall be not less than 115 percent of the sum of the ful-load currents required for all equipment that may be inoperation at the same time under normal conditions of use.

— The attachment plug shall be single voltage rated.

— The attachment plug shall be provided with a grounding pole and so constructed that the groundingpole is made before any current-carrying polesare made and is not broken until all current-carrying poles of the attachment plug have been disconnected. A grounding pole shall not be used as a current-carrying part.

— The attachment plug shall be in sight from the operator's station and readily accessible.

— The marking requirements of 4.5.2 shall apply.

8 Protection

8.1 Machine circuits

8.1.1 Figures 1 and 2 show typical circuits acceptable for the protection of current-carrying and current-consuming electrical machine components. Protective interlocks are not shown.

8.1.2 The main overcurrent protective device in single motor (main SCPD only) circuits or in multiple motor (main SCPD only) circuits *(see Figure 1, line C)* and the branch circuit overcurrent protective devices in multiple motor (main and branch SCPD) applications *(see Figure 1, line D)* shall be selected to protect conductors and components during the occurrence of short circuits or ground faults. All protective devices shall be selected and applied with proper consideration being given to, but not limited to, the following:

(a) System maximum available fault current at the point of application.

(b) Interrupting rating of the protective device.

(c) Voltage rating of the system.

(d) Load and circuit component characteristics.

1.) Normal operating current.

2.) Inrush characteristics.

3.) Thermal withstand capability (I^2t).

4.) Magnetic withstand capability (I_p).

(e) Current-limiting ability of the protective device.

(f) Coordination of protective devices to each other.

8.1.3 Class H fuses, and devices that will accept Class H fuses, shall not be used.

8.1.4 All circuit breakers shall be identified *(see 3.49)* and shall be suitable for the specific location. Circuit breakers used in control circuits not over 125 volts, 30 amperes shall have a minimum interrupting rating of 1,000 amperes. *(See Figures 1 and 2.)*

8.2 Supply conductor and machine overcurrent protection

The overcurrent protection as shown in Line C of Figures 1 and 2 may or may not be furnished as part of the machine. Where furnished as part of the machine, it shall consist of a single circuit breaker or set of fuses, and the machine shall bear the marking required in 4.7.3.

8.3 Branch circuit overcurrent protection

Where required, the branch circuit overcurrent protection shown in Line D of Figures 1 and 2 shall be provided as part of the machine control. Such overcurrent protection (fuse or overcurrent trip unit of a circuit breaker) shall be placed in each ungrounded branch circuit conductor. A circuit breaker shall open all ungrounded conductors of the branch circuit.

8.3.1 Programmable electronic system (PES) 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.

8.3.2 Programmable electronic system (PES) outputs shall be either internally protected or provided with external overcurrent protective devices sized or rated in accordance with the manufacturer's instructions.

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

8.4 Location of protective devices

Overcurrent protective devices shall be located at the point where the conductor to be protected receives its supply.

Exception No. 1: Where all of the following conditions are complied with:

— the conductor has an ampacity of at least one-third ($^1/_3$) that of the conductor from which it is supplied

— the conductor is suitably protected from physical damage

— the conductor is not over 25 ft (7.62 m) long

— the conductor terminates in a single circuit breaker or set of fuses.

Exception No. 2: Where all of the following conditions are complied with:

— the conductor has an ampacity of not less than the sum of the maximum continuous load currents supplied

— the conductor is not over 10 ft (3.05 m) long

— the conductor does not extend beyond the control panel enclosure

— the conductor terminates in a splitter block, circuit breaker, or set of fuses.

8.5 Motor branch circuits

8.5.1 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 1.

Exception: Table 1 shall not apply to Design E motor circuits. The provisions of NFPA 70 shall be observed for Design E motor circuits.

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

— The full-load rating of each motor does not exceed 6 amperes.

— The rating of the branch-circuit short-circuit a ground fault protective device marked on any of the controllers is not exceeded.

— Individual overload protection conforms to 8.6.

8.5.3 Where the branch-circuit and short-circuit and ground-fault protective device is selected not to exceed that allowed by 8.5.1 for the motor of the smallest rating, 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.

8.5.4 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:

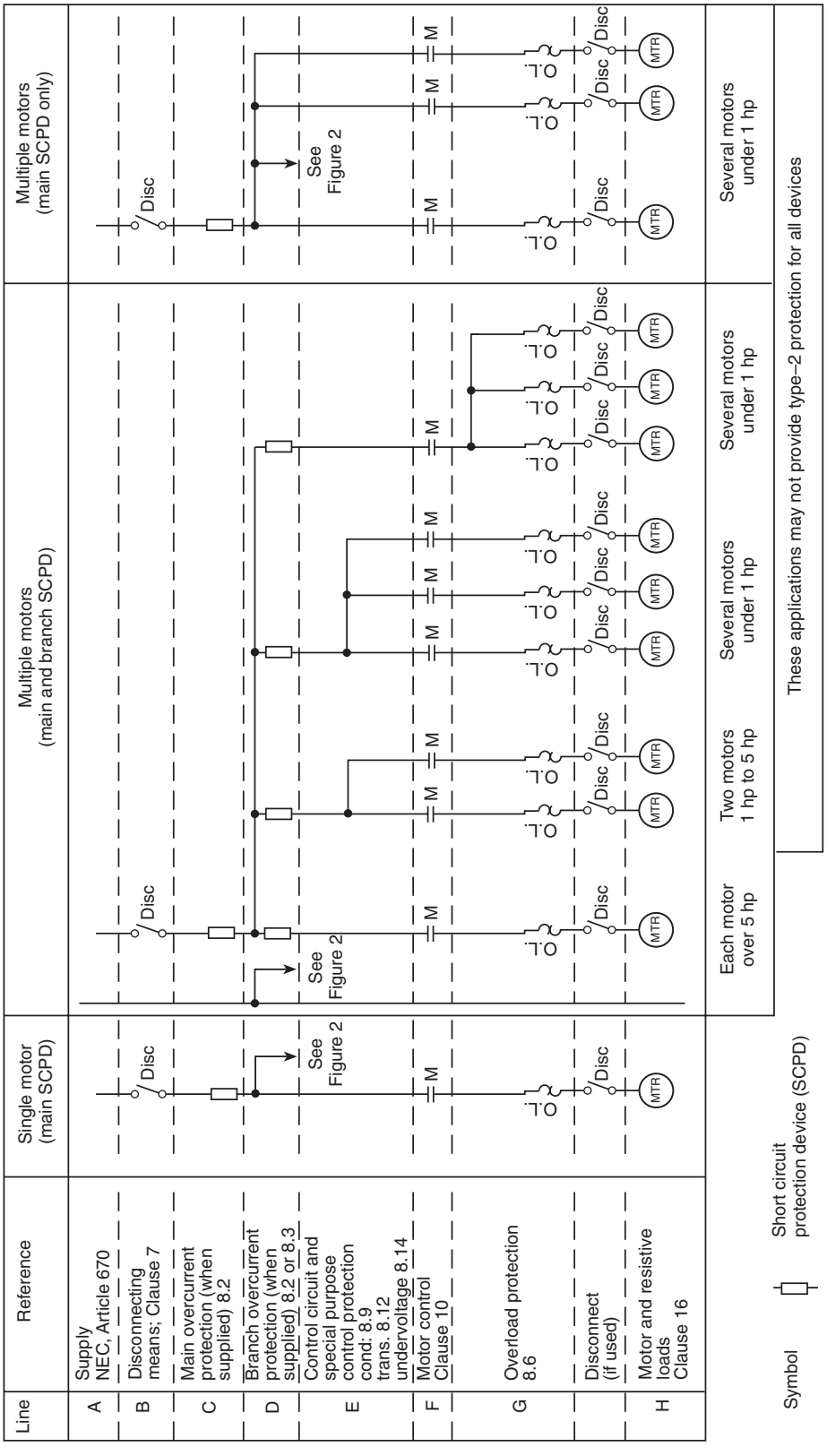

Figure 1 — One line representation of electrical system power distribution

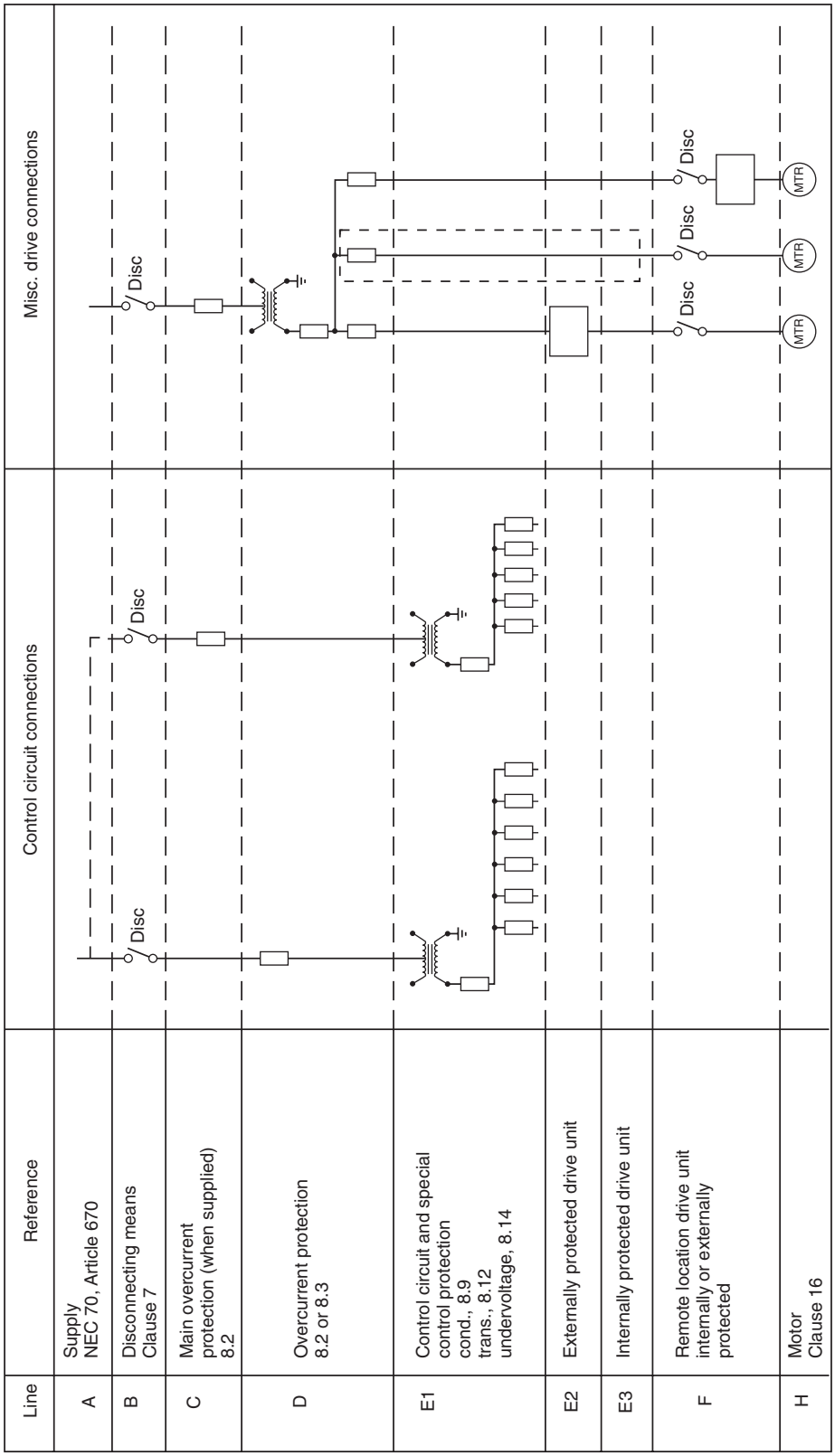

Figure 2 — One line representation of electrical system power protection

Table 1 —– Fuse and circuit breaker selection: motor, motor branch circuit, and motor controller

	Maximum Setting or Rating[1] (Fuse and Circuit Breaker)		
Application	Type[2]		
Fuse class with time delay [3]	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 C/B[5]	800	800	800
Inverse trip C/B6	150	250	250

NOTES (to Table 1):

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

2) Types:

— AC-2: Slip-ring motors starting, switching off, or all light-starting duty motors.

— AC-3: 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. All wye-delta and two-step auto-transformer starting, or all medium starting duty motors.

— AC-4: Squirrel-cage motors; starting, plugging, inching, jogging, or all heavy starting duty motors.

3) 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 shall be permitted to be increased but shall in no case exceed 400 percent of the full-load current.

4) Class RK-5 fuses shall be used only with NEMA rated motor controllers.

Exception: Motor controllers listed for use with RK5 fuses.

5) Magnetic only circuit breakers are limited to single motor applications. These instantaneous trip circuit breakers shall only be used if they are adjustable, if part of a combination controller having motor-running and also short-circuit and ground-fault protection in each conductor, and if the combination is especially identified for use, and it is installed per any instructions included in its listing or labeling. 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 the table 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.

NOTE: IEC 947-4 defines the terms Type 1 and Type 2 coordinated protection as follows:

— Type 1 Protection: Under short-circuit conditions the contactor or starter may not be suitable for further use without repair or replacement.

— Type 2 Protection: Under short-circuit conditions the contactor or starter shall be suitable for further use.

The maximum allowable values in Table 1 do not guarantee Type 2 protection. Type 2 protection is recommended for use in applications where enhanced performance and reliability are required.

(a) Each motor controller and overload device is listed *(see ANSI/NFPA 70, Article 100, Listed)* for group installation with specified short-circuit current ratings.

NOTE: The short-circuit current rating includes:

a) The class and rating of the short-circuit protective device.

b) The maximum nominal application voltage.

c) The maximum available fault current.

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

Table 2 —– Relationship between conductor size and maximum rating or short-circuit protective device for power circuits

	Max. Rating	
Conductor Size AWG	Non-Time-Delay Fuse or Inverse Time Circuit Breaker	Time Delay or Dual Element Fuse
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

8.6 Motor overload

8.6.1 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.

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

Exception: Where there is only a single motor of two horsepower or less on the machine, 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 12 in. (300 mm) or less, and a suitable warning label is attached on or adjacent to the overload reset operator.

8.6.3 The minimum number and location of running overcurrent units shall be determined from Table 3.

Table 3 —– Running-over current units

Kind of Motor	Supply System	Number and Location of Overcurrent 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, grounded-neutral	1 in either ungrounded conductor
3-phase ac	Any 3-phase	*3, one in each phase

**Exception: Unless protected by other approved means.*

NOTE: For 2-phase power supply systems see NFPA 70, Section 430-37.

8.6.4 Motor overload protection shall be provided per NFPA 70, Article 430, Part C.

8.7 Motor overload, special duty

8.7.1 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.

8.7.2 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.

8.8 Resistance heating branch circuits

8.8.1 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.

8.8.2 Electric machines 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.

8.8.3 The supplementary overcurrent protective devices shall be: (1) installed within or on the machinery or provided as a separate assembly; and (2) accessible but shall not be required to be readily accessible; and (3) suitable for branch-circuit protection.

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

8.9 Control circuit conductors

8.9.1 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 this subclause. 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).

8.9.2 Conductor protection

8.9.2.1 Conductors larger than No. 14 shall be protected against overcurrent in accordance with their ampacities. The ampacities for control circuit conductors No. 14 and larger shall be those given in Table 11.

8.9.2.2 Conductors of Nos. 18, 16, and 14 shall be considered as protected by an overcurrent device(s) of not more than 20 amperes rating.

Exception No. 1 for 8.9.2.1 and 8.9.2.2 above: Conductors that do not 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 400 percent of the ampacity of the control circuit conductor for conductors No. 14 and larger, or not more than 25 amperes for No. 18 and 40 amperes for No. 16. The ampacities for conductors No. 14 and larger shall be the values given in Table 11.

Exception No. 2 for 8.9.2.1 and 8.9.2.2 above: Conductors of No. 14 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. The ampacities shall be the values given in Table 11.

Exception No. 3 for 8.9.2.1 and 8.9.2.2 above: 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, provided this protection is in accordance with 8.12 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 protection.

Exception No. 4 for 8.9.2.1 and 8.9.2.2 above: 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 as, for example, the control circuit of a magnetic chuck and the like.

8.10 Lighting branch circuits

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

8.11 Power transformer

As used in this subclause, the word "transformer" shall mean a power transformer or polyphase bank of two or three single-phase power transformers operating as a unit to supply power to loads other than control circuit devices.

8.11.1 Primary

Each 600-volt or less transformer shall be protected by an individual overcurrent device on the primary side rated or set at not more than 125 percent of the rated primary current of the transformer.

Exception No. 1: Where the rated primary current of a transformer is 9 amperes or more and 125 percent of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, the next higher standard rating shall be permitted. Where the rated primary current is less than 9 amperes, an overcurrent device rated or set at not more than 167 percent of the primary current shall be permitted.

Where the rated primary current is less than 2 amperes, an overcurrent device rated or set at not more than 300 percent shall be permitted.

Exception No. 2: An individual overcurrent device shall not be required where the primary circuit overcurrent device provides the protection specified in this subclause.

Exception No. 3: As provided in 8.11.2 below.

8.11.2 Primary and secondary

A transformer that is 600 volts or less, having an overcurrent device on the secondary side rated or set at not more than 125 percent of the rated secondary current of the transformer shall not be required to have an individual overcurrent device on the primary side if the primary feeder overcurrent device is rated or set at a current value not more than 250 percent of the rated primary current of the transformer.

A transformer, 600 volts or less, equipped with coordinated thermal overload protection by the manufacturer and arranged to interrupt the primary current shall not be required to have an individual overcurrent device on the primary side if the primary feeder overcurrent device is rated or set at a current value not more than 6 times the rated current of the transformer for transformers having not more than 6 percent impedance, and not more than 4 times the rated current of the transformer for transformers having more than 6 but not more than 10 percent impedance.

Exception: Where the rated secondary current of a transformer is 9 amperes or more and 125 percent of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, the next higher standard rating shall be permitted.

Where the rated secondary current is less than 9 amperes, an overcurrent device rated or set at not more than 167 percent of the rated secondary current shall be permitted.

8.12 Control circuit transformer

8.12.1 Where a control circuit transformer is provided, the primary shall be protected in accordance with Table 4 and the secondary shall be protected in accordance with Table 5.

Exception No. 1: Where the control circuit transformer is an integral part of the motor controller and is located within the motor controller enclosure, and where an overcurrent device(s) rated or set at not more than 200 percent of the rated secondary current of the transformer is provided in the secondary circuit.

Exception No. 2: Where the transformer supplies a Class 1 power-limited, Class 2, or Class 3 remote-control circuit.

Exception No. 3: Overcurrent protection shall be omitted where the opening of the control circuit would create a hazard as, for example, the control circuit of a magnetic chuck and the like.

Exception No. 4: A single-phase transformer having a 2-wire (single-voltage) secondary shall be considered protected by overcurrent protection on the primary (supply) side of the transformer, provided that this protection does not exceed the value determined by multiplying the rated secondary current by the transformer secondary-to-primary voltage ratio.

Table 4 —– Control transformer overcurrent protection (primary voltage)

Rated Primary (Amperes)	Maximum Rating of Primary Overcurrent Protective Device as a Percent of Transformer Rated Primary Current
Less than 2	300[1]
2 or more	250[2]

[1]500% is permitted for a circuit of a control apparatus or system that carries the electric signals directing the performance of the motor controller, but does not carry the main power current.
[2]400% is permitted where Class CC fuses are used providing that the ampacity of the primary conductors is at least equal to the rating of the primary fuses.

8.12.2 Where the circuit is grounded, the protective device(s) shall be located only in the ungrounded side.

8.12.3 Where multiple overcurrent protective devices are used to protect individual branch circuits, and the sum of the current ratings of these overload protective devices exceeds the current allowed in Table 5, a single overload protective device complying with Table 5 shall be placed in the circuit ahead of the multiple protective devices. The rating or setting of the overcurrent protective device shall not exceed the values in Table 5 for the rating of the control transformer.

8.12.4 Control circuit voltage derived from a power transformer shall be permitted.

Table 5 —– Control transformer overcurrent protection (120 volt secondary)

Control Transformer Size, Volt-Amperes	Maximum Rating, Amperes
50	0.5
100	1.0
150	1.6
200	2.0
250	2.5
300	3.2
500	5
750	8
1000	10
1250	12
1500	15
2000	20
3000	30
5000	50

NOTE: For transformers larger than 5000 volt-amperes, the protective device rating shall be based on 125 percent of the secondary current rating of the transformer.

8.13 Common overcurrent device

The use of the same overcurrent device to provide the protection called for in 8.9, 8.10, 8.11, and 8.12 shall be permitted.

8.14 Undervoltage protection

8.14.1 In cases where a voltage drop below a specified level can cause malfunctioning of the electrical equipment, a minimum voltage device or detector that ensures appropriate protection at a predetermined voltage level shall be provided.

8.14.2 The electrical equipment shall be designed to prevent automatic restart of any machine motion or cycles after power has been restored to required operating levels.

Exception No. 1: Blower motors where moving parts are fully guarded.

Exception No. 2: Coolant pumps.

Exception No. 3: Pumps utilized to maintain the raw materials in a workable condition.

Exception No. 4: Compressor pumpdown circuits.

8.14.3 In an unsupported extrusion system such as blown film, sheet, or pipe, and where the operation of the machine can allow for an interruption of the voltage during a fraction of a second, a delayed no-voltage device shall be permitted. The delayed interruption and the reclosing shall in no way hinder instantaneous interruption by the control and operating devices (e.g., limit switches, relays, and pushbuttons).

8.15 Adjustable-speed drive system

The incoming branch circuit or feeder to power conversion equipment included as part of an adjustable-speed drive system shall be based on the rated input to the power conversion equipment. Where the power conversion equipment provides overload protection for the motor, additional overload protection shall not be required.

8.16 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.

Overspeed protection means include, but are not necessarily limited to, the following:

— A mechanical overspeed device incorporated in the drive to remove armature voltage on motor overspeed.

— An electrical overspeed detector that will remove armature voltage on motor overspeed.

— Field loss detection to remove armature voltage upon the loss of field current.

— 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.

The safe operating speed of the driven equipment may be less than that of the motor. In this case, the user should coordinate with the drive manufacturer to obtain the most suitable means of limiting operation to safe operating speed.

8.17 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.

9 Control circuits

9.1 Source of control power

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

Exception: Power supply 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 main disconnecting means or other power source. The marking requirements of 4.5.1 shall apply.

9.2 Control circuit voltages

9.2.1 Alternating-current (ac) control voltage shall be 120 volts or less, single phase. Where the supply voltage is greater than 120 volts, the control voltage shall be provided from a transformer with an isolated secondary winding.

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: Exposed, grounded control circuits shall be permitted where supplied by a transformer having a primary rating of not more than 120 volts, a secondary rating of not more than 25 volts, and a capacity of not more than 50 volt-amperes.

Exception No. 3: 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.

9.2.2 Direct-current (dc) control voltage shall be 250 volts or less.

Exception: Other voltages shall be permitted, where necessary, for the operation of electronic, precision, static, or similar devices used in the control circuit.

9.3 Grounding of control circuits

Grounded or ungrounded control circuits shall be permitted as provided in 19.7. Ground faults on any control circuit shall not cause unintentional starting or dangerous movements, or prevent stopping of the machine.

9.4 Connection of control devices

9.4.1 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.

9.4.2 Contacts shall not be connected in parallel to increase ampacity.

9.5 Control functions

9.5.1 Start functions

Start functions shall operate by energizing the relevant circuit.

9.5.2 Stop functions

There are three categories of stops as follows:

— Category 0: stopping by immediate removal of power to the machine actuators (i.e., an uncontrolled stop) *(see 3.84)*

— Category 1: a controlled stop *(see 3.21)* with power to the machine actuators available to achieve the stop and then removal of power when the stop is achieved

— Category 2: a controlled stop with power left available to the machine actuators.

Each machine shall be equipped with a Category 0 stop. Category 1 and/or Category 2 stops shall be provided where demanded by the safety and functional requirements of the machine. Category 0 and Category 1 stops shall be operational regardless of operating mode and a Category 0 stop shall take priority. Stop functions shall operate by deenergizing the relevant circuit and shall override related start functions.

9.6 Operation

9.6.1 Start

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 9.15. Suitable interlocks shall be provided to secure correct sequential starting.

On machines requiring the use of more than one control station to initiate a start:

— each control station shall have a separate manually actuated start control device;

— all required conditions for machine operation shall be met;

— all start control devices shall be in the released (off) position before a start may be permitted; and

— all start control devices shall be actuated concurrently.

9.6.2 Stop

The choice of category of stop shall be determined in accordance with the requirements of the application *(see 9.5.2)*.

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.

9.6.3 Emergency stop

In addition to the requirements for stop *(see 9.6.2)*, the emergency stop has the following requirements:

— It shall override all other functions and operations in all modes.

— Power to the machine actuators that can cause a hazardous condition(s) shall be removed as quickly as possble 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).

— Reset shall not initiate a restart.

Where required, provisions to connect additional emergency stop devices shall be provided *(see 13.2 for the requirements of emergency stop devices)*.

The emergency stop shall function as either a Category 0 or a Category 1 stop *(see 9.5.2)*. The choice of category of emergency stop shall be determined in accordance with the requirements of the application.

Where a Category 0 stop is used for the emergency stop function, it shall have only hardwired electromechanical components. In addition, its operation shall not depend on electronic logic (hardware or software) or the transmission of commands over a communications network or link.

Where 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.

9.7 Hold to run circuits

9.7.1 Where used, hold to run circuits [e.g., jog, inch circuit(s)], shall be designed to require continuous actuation of the control device(s) to achieve operation (i.e., machine motion), particularly when a hazardous condition is present.

9.7.2 JOG or INCH circuits shall operate only in the MANUAL mode. The prevention of RUN or AUTOMATIC operation during JOG or INCH shall be accomplished by pushbutton(s) and a separate JOG or INCH selection method. MANUAL reverse shall be considered a JOG operation.

9.8 Operating modes

9.8.1 Each machine shall be permitted to have one or more operating modes (e.g., teach for robots) that are determined by the type of machine and its application.

9.8.2 Where hazardous conditions can arise from mode selection, such operation shall be protected by suitable means (e.g., key operated switch, access code). Mode selection by itself shall not initiate operation. A separate action by the operator shall be required.

9.8.3 Safeguards shall remain effective for all operating modes.

9.9 Feed interlocked with spindle drive

Interlocking shall be provided so that the spindle drive motor controller is activated before the tool is driven into the workpiece.

9.10 Machinery door interlocking

Hinged or sliding doors providing ready access to compartments containing belts, gears, or other moving parts that may expose hazardous conditions shall be interlocked through limit switches or other means to prevent operation of the equipment when the doors are not closed. The requirements for machinery door interlocking shall be in accordance with the requirements of the applicable machinery safety standard(s) (e.g., ANSI B-11 series).

9.11 Motor contactors and starters

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

9.12 Relays and solenoids

Relays and solenoids that are mechanically interlocked shall be electrically interlocked.

9.13 Setup mode

Where necessary for setup purposes and when under supervised control, interlocks shall be permitted to be bypassed by qualified personnel provided that other protective interlocks for the safety of personnel shall remain operational.

9.14 Two-hand control circuits

Where used to initiate potentially hazardous motion, two-hand control devices shall be protected against unintentional operation and shall be one of the following types:

Type 1 — This type requires:

— the provision of two control devices requiring concurrent actuation by both hands;

— continuous actuation during the hazardous condition; and

— cessation of machine operation on release of either control device when hazardous conditions are still present.

Type 2 — A type 1 control requiring the release of both control devices before machine operation may be reinitiated.

Type 3 — A type 2 control requiring concurrent actuation of the control devices as follows:

— it shall be necessary to actuate the control devices within a certain time limit of each other (to be specified by the machine supplier);

— where the time limit is exceeded, both control devices shall be released before operation may be initiated.

9.15 Overriding of safeguards

Where it is necessary to temporarily override one or more safeguards, a mode selection device or means capable of being secured in the desired mode shall be provided to prevent automatic operation. In addition, one or more of the following measures shall be provided:

— Initiation of motion by a hold-to-run or other control device.

— A portable control station (e.g., pendant) with an emergency stop device. Where a portable station is used, motion shall only be initiated from that station.

— Limiting motion speed or power.

— Limiting the range of motion.

10 Control equipment

10.1 Connections

Means for making conductor connections shall be provided on or adjacent to all control devices mounted in the control enclosure.

10.2 Subpanels

Subpanels with concealed or inaccessible internal wiring or devices shall be mounted and wired to be removable.

10.3 Manual and electromechanical motor controllers

10.3.1 Each motor controller shall be identified *(see 3.49)* and shall be capable of starting and stopping the motor(s) it controls and, for alternating current motors, shall be capable of interrupting the stalled rotor current of the motor(s) per the manufacturer's listed ratings. Controllers rated in horsepower shall be used for motors rated $\frac{1}{8}$ HP or larger. The motor controller shall be sized in accordance with Table 6.

Exception: Other motor controllers shall be permitted provided they are identified (see 3.49) as suitable for the intended use and protected in accordance with marked ratings.

10.3.2 Alternating current motor controllers shall open all of the supply conductors leading to associated motors.

Table 6 — Ratings for three-phase, single-speed, full-voltage magnetic controllers for nonplugging and nonjogging duty

Size of Controller	Continuous Current Rating[2] (Amperes)	Horsepower [1,4] at 60 Hertz		Horsepower [1,4] at 50 Hertz	Horsepower [1,4] at 60 Hertz	Service-Limit Current Rating[3] (Amperes)
		200 Volts	230 Volts	380 Volts	460 or 575 Volts	
00	9	1 ½	1 ½	1 ½	2	11
0	18	3	3	5	5	21
1	27	7 ½	7 ½	10	10	32
2	45	10	15	25	25	52
3	90	25	30	50	50	104
4	135	40	50	75	100	156
5	270	75	10	15	200	311
6	540	15	20	30	400	621
7	810	—	30	—	600	932
8	1215	—	450	—	900	1400
9	2250	—	800	—	1600	2590

Reference: ANSI/NEMA ICS-2, Table 2-321-1.

NOTE 1: These horsepower ratings are based on locked-rotor current ratings given in ANSI/NEMA ICS-2, Table 2-237-3. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded. (Refer to ANSI/NEMA ICS-2 for horsepower ratings of single-phase, reduced voltage, or multispeed motor controller application.)

NOTE 2: The continuous-current ratings represent the maximum rms current, in amperes, that the controller may be expected to carry continuously without exceeding the temperature rises permitted by ANSI/NEMA ICS-1, Part 109 Part ICS 1-109.

NOTE 3: The service-limit current ratings represent the maximum rms current, in amperes, the controller may be expected to carry for protracted periods in normal service. At service-limit current ratings, temperature rises may exceed those obtained by testing the controller at its continuous current rating. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

NOTE 4: Refer to ANSI/NEMA ICS-2 for horsepower ratings of single-phase, reduced voltage, or multispeed motor controller application.

Table 7 — Ratings for three-phase, single-speed, full-voltage magnetic controllers for plug-stop, plug-reverse, or jogging duty

Size of Controller	Continuous Current Rating[2] (Amperes)	Horsepower[1,4] at 60 Hertz		Horsepower[1,4] at 50 Hertz	Horsepower[1,4] at 60 Hertz	Service-Limit Current Rating[3] (Amperes)
		200 Volts	230 Volts	380 Volts	460 or 575 Volts	
0	18	1½	1½	1½	2	21
1	27	3	3	5	5	32
2	45	7½	10	15	15	52
3	90	15	20	30	30	104
4	135	25	30	50	60	156
5	270	60	75	125	150	311
6	540	125	150	250	300	621

Reference: ANSI/NEMA ICS-2, Table 2-321-3.
NOTE 1: These horsepower ratings are based on locked-rotor current ratings given in ANSI/NEMA ICS-2, Table 2-237-3. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded. (Refer to ANSI/NEMA ICS-2 for horsepower ratings of single-phase, reduced voltage, or multispeed motor controller application.)
NOTE 2: The continuous-current ratings represent the maximum rms current, in amperes, the controller may be expected to carry continuously without exceeding the temperature rises permitted by ANSI/NEMA ICS-1, Part 109 Part ICS 1-109.
NOTE 3: The service-limit current ratings represent the maximum rms current, in amperes, the controller may be expected to carry for protracted periods in normal service. At service-limit current ratings, temperature rises may exceed those obtained by testing the controller at its continuous current ratings. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.
NOTE 4: Refer to ANSI/NEMA ICS-2 for horsepower ratings of single-phase, reduced voltage, or multispeed motor controller application.

10.3.3 Where machine operation requires a motor controller to repeatedly open high motor current, such as in plug-stop, plug-reverse, or jogging (inching) duty, requiring continuous operation with more than five openings per minute, the controller shall be derated in accordance with Table 7.

Exception: Other motor controllers shall be permitted provided they are identified (see 3.49) as suitable for the intended use and protected in accordance with marked ratings.

10.3.4 Several motors shall be permitted to be operated from one motor controller where separate overload protection is provided for each motor, and the horsepower rating of the controller is not exceeded.

10.4 Marking on motor controllers

A controller for a motor rated $^1/_8$ horsepower or more shall be marked with the voltage, phase, horsepower rating, and such other data as may be needed to properly indicate the motor for which it is suitable.

11 Control enclosures and compartments

11.1 Type

11.1.1 Enclosures and compartments shall be nonventilated with construction and sealing suitable for the intended environment.

Exception: Equipment requiring ventilation shall be permitted to be:

— housed in a separate ventilated portion of the enclosure or compartment, or

— housed in a separate ventilated enclosure or compartment.

11.1.2 Ventilated enclosures and compartments shall be constructed to prevent the entrance of any deleterious substance normal to the operating environment and shall prevent the escape of sparks or burning material.

11.2 Nonmetallic enclosures

Nonmetallic enclosures identified *(see 3.49)* for the purpose shall be permitted. For grounding provisions, see subclause 19.3.

11.3 Compartment location

Compartments for built-in control shall be completely isolated from coolant and oil reservoirs. The compartment shall be readily accessible and completely enclosed; it 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.

11.4 Wall thickness

The walls of compartments shall be not less than the following: .0625 in. (1.5 mm) for sheet steel; $^1/_8$ in. (3.2 mm) for cast metal; or $^3/_{32}$ in. (2.38 mm) for malleable iron.

11.5 Dimensions

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.

11.6 Doors

Enclosures or compartments shall have one or more hinged doors that shall swing about a vertical axis and shall be held closed with captive fasteners or vault-type hardware. The thickness of metallic doors shall not be less than that indicated in 11.4. The width of doors shall not exceed 40 in. (1016 mm).

Exception: Where the motor(s) on the machine totals two horsepower or less, covers held on with captive screw-type fasteners shall be permitted.

11.7 Gaskets

Where gaskets are used, they shall be of an oil-resistant material and shall be securely attached to the door or enclosure.

11.8 Interlocks

Any door(s) that permits access to live parts operating at 50 volts or more shall be so interlocked that the door(s) cannot be opened unless all power is disconnected.

Exception No. 1: External interlocking circuits operating at less than 150 volts shall not be required to be disconnected provided that the circuit conductors are identified with a yellow-colored insulation as described in 16.1.3 and a warning marking is attached to the door in accordance with 4.5.1.

Exception No. 2: It shall be permitted to provide means for qualified persons to gain access without removing power. The interlocking shall be reactivated automatically when the door(s) is closed.

Exception No. 3: Where an attachment plug is used as the disconnecting means and a warning marking is attached to the door in accordance with 4.5.2.

Exception No. 4: Where the motor(s) on the machine totals two horsepower or less, an external, noninterlocked disconnecting means shall be permitted provided that the disconnecting means is in sight from and readily accessible, the control enclosure door or cover is marked with a warning indicating that the power shall be removed by the disconnecting means before the enclosure is opened, and further provided that a tool is required to open the enclosure.

11.9 Interior finish

The interior of control enclosures and exposed surfaces of panels mounted therein shall be finished in a light color.

Exception: An enclosed motor controller for a single motor.

11.10 Warning mark

Enclosures that do not clearly show that they contain electrical devices shall be marked with a black lightning flash on a yellow background within a black triangle, shaped in accordance with the graphical symbol 5036 of IEC 417M, the whole in accordance with symbol 13 of ISO 3864, as shown in Figure 3.

Figure 3 — Warning sign on enclosures

It is permitted to omit this warning sign on:

— an enclosure equipped with a supply disconnecting device;

— an operator-machine interface or control station;

— a single device with its own enclosure (e.g., position sensor).

The warning sign shall be plainly visible on the enclosure door or cover.

11.11 Print pocket

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 multidoor enclosures shall have at least one print pocket.

12 Location and mounting of control equipment

12.1 General requirements

12.1.1 Control equipment shall be mounted and located so that it will not interfere with machine adjustments or maintenance.

12.1.2 Pipelines, tubing, or devices for handling air, gases, or liquids shall not be located in enclosures or compartments containing electrical control equipment.

Exception: Equipment for cooling electronic devices.

12.2 Control panels

12.2.1 All devices mounted on the control panel and connected to supply voltage, or to both supply and control voltages, shall be grouped separately from devices connected only to control voltages.

Exception: Where supply voltage is 150 volts or less.

12.2.2 Terminal blocks for power circuits shall be grouped separately from control circuits.

Exception: Grouped power terminals shall be permitted to be mounted adjacent to grouped control terminals.

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

12.2.4 The stationary part of each multiconductor control cable plug/receptacle shall be mounted to provide unobstructed access.

12.2.5 The panel shall not be set to such depth from the door frame or other projecting portion of machine as to interfere with inspection and servicing.

12.2.6 Starters, contactors, and other control devices shall be front mounted on a rigid metal panel. Equipment shall be mounted so that any component can be replaced without removing the panel. No components shall be mounted behind door pillars unless adequate space is provided for replacement and servicing.

12.2.7 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.

12.3 Subpanels and electronic subassemblies

Subpanels and electronic subassemblies mounted on the control panel or on other supporting means, e.g., rack or shelf, shall be mounted so that adequate space is provided for replacement and servicing.

12.4 Control enclosure

The enclosure shall be mounted in a manner and position to guard it against oil, dirt, coolant, and dust, and to minimize the possibility of damage from floor trucks or other moving equipment.

12.5 Clearance in enclosures and compartments

12.5.1 Enclosures or compartments for mounting control panels shall provide adequate space between panel and case for wiring and maintenance.

12.5.2 Exposed, nonarcing, bare, live parts within an enclosure or compartment, including conduit fittings, shall have an air space between them and the uninsulated walls of the enclo-

sure or compartment of not less than ½ in. (12.7 mm). Where barriers between metal enclosures or compartments and arcing parts are required, they shall be of flame-retardant, noncarbonizing insulating materials.

12.6 Machine-mounted control equipment

12.6.1 Control equipment, such as limit switches, brakes, solenoids, and position sensors, shall be mounted rigidly in a reasonably dry and clean location, shall be protected from physical damage, and shall be free from the possibility of accidental operation by normal machine movements or by the operator. Such equipment shall be mounted with sufficient clearance from surrounding surfaces to make its removal and replacement easy and shall have a suitable enclosure for the termination of conduit as well as provisions for making electrical connections.

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

Exception No. 2: Prewired devices, such as limit switches and proximity switches, provided with an identified (see 3.49) cable shall not be required to 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 shall drain away from the electrical component enclosure.

12.7 Rotary control devices

Devices such as potentiometers and selector switches having a rotating member shall be mounted to prevent rotation of the stationary member. Friction alone shall not be considered sufficient.

13 Operator's control stations and equipment

13.1 Pushbuttons, selector switches, indicating lights

13.1.1 All pushbutton and selector switch operators, indicating (pilot) lights, and illuminated pushbuttons shall be of the oiltight type.

Exception: Machines identified (see 3.49) for the environment.

13.1.2 Pushbutton operators, indicating (pilot) light lenses, and illuminated pushbutton lenses shall be color coded in accordance with Table 8.

— The color RED shall be used for Stop, Emergency Stop, or Off operators only.

— The preferred color of Start or On operators is GREEN, except that BLACK, WHITE, or GRAY shall be permitted.

— Pushbuttons that, when pressed, act alternately as Start and Stop or On and Off shall be BLACK, WHITE, or GRAY. RED or GREEN shall not be used.

— 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.

— 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.

Exception: Stop function operators of the wobble-stick or rod-operated types in the bottom of a pendant station shall not be required to be colored red.

13.1.3 Pushbutton operators used to initiate a stop function shall be of the extended operator or mushroom-head types.

13.1.4 Pushbutton operators used to initiate a start function or movement of machine elements (e.g., slides, spindles, and carriers) shall be constructed or mounted to minimize inadvertent operation.

Exception: Mushroom-head type operators shall be permitted to initiate start functions where installed in accordance with 9.15.

13.2 Emergency stop devices

13.2.1 Emergency stop pushbuttons shall be located at each operator control station and at other operating stations where emergency shutdown shall be required.

13.2.2 Stop and emergency stop pushbuttons shall be continuously operable from all control and operating stations where located.

13.2.3 Actuators of emergency stop devices shall be colored RED. The background immediately around the device actuator shall be colored YELLOW. The actuator of a pushbutton-operated device shall be of the palm or mushroom-head type.

13.2.4 The emergency stop actuator shall be either a momentary or self-latching type.

13.3 Foot-operated switches

13.3.1 Foot-operated switches shall be protected to prevent accidental actuation by falling or moving objects and from unintended operation by accidental stepping onto the switch.

13.4 Control station enclosures

All operator control station enclosures shall be dusttight, moisturetight, and oiltight.

Exception: Non-oiltight control station enclosures shall be permitted on machines where suitable for the environment.

13.5 Arrangement of control station components

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.

13.6 Legends

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

Table 8 — Color coding for pushbuttons, indicator (pilot) lights, and illuminated pushbuttons

Color	Device Type	Typical Function	Examples
RED	Pushbutton	Emergency Stop, Stop, Off	Emergency Stop button, Master Stop button, Stop of one or more motors.
	Pilot Light	Danger or alarm, abnormal condition requiring immediate attention	Indication that a protective device has stopped the machine, e.g., overload.
	Illuminated Pushbutton		Machine stalled because of overload, etc. (The color RED for the emergency stop actuator shall not depend on the illumination of its light.)
YELLOW (AMBER)	Pushbutton	Return, Emergency Return, Intervention — suppress abnormal conditions	Return of machine elements to safe position, override other functions previously selected. Avoid unwanted changes.
	Pilot Light	Attention, caution/ marginal condition. Change or impending change of conditions	Automatic cycle or motors running; some value (pressure, temperature) is approaching its permissible limit. Ground fault indication. Overload that is permitted for a limited time.
	Illuminated Pushbutton	Attention or caution/Start of an operation intended to avoid dangerous conditions	Some value (pressure, temperature) is approaching its permissible limit; pressing button to override other functions previously selected.
GREEN	Pushbutton	Start-On	General or machine start; start of cycle or partial sequence; start of one or more motors; start of auxiliary sequence; energize control circuits.
	Pilot Light	Machine ready; Safety	Indication of safe condition or authorization to proceed. Machine ready for operation with all conditions normal or cycle complete and machine ready to be restarted.
	Illuminated Pushbutton	Machine or unit ready for operation/ Start or On	Start or On after authorization by light; start of one or more motors for auxiliary functions; start or energization of machine elements.
BLACK	Pushbutton	No specific function assigned	Shall be permitted to be used for any function except for buttons with the sole function of Stop or Off.
WHITE or CLEAR	Pushbutton	Any function not covered by the above	Control of auxiliary functions not directly related to the working cycles.
	Pilot Light	Normal Condition Confirmation	Normal pressure, temperature.
	Illuminated Pushbutton	Confirmation that a circuit has been energized or function or movement of the machine has been started/Start-On, or any preselection of a function	Energizing of auxiliary function or circuit not related to the working cycle; start or preselection of direction of feed motion or speeds.
BLUE or GRAY	Pushbutton, Pilot Light, or Illuminated Pushbutton	Any function not covered by the above colors	

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

13.7 Location of control stations

13.7.1 All stations shall be mounted in locations that will minimize exposure to oil, coolant, and other contaminants.

13.7.2 Controls shall be within normal reach of the machine operator and shall be so placed that the operator does not have to reach past spindles or other moving parts.

13.7.3 Controls shall be located so that unintentional operation by normal movement of the machine, operator, or work will be unlikely.

13.8 Pendant stations

13.8.1 Pendant operator control station enclosures shall be oiltight.

13.8.2 A wobble stick or rod operator at the bottom of the station shall be permitted for Emergency Stop controls.

13.8.3 Pendant pushbutton stations shall be supported by suitable means other than the flexible electrical conduit or multiconductor cable.

13.8.4 Grounding and bonding shall comply with 19.2, 19.3, 19.4, and 19.6.

14 Accessories and lighting

14.1 Attachment plugs and receptacles external to the control enclosure

14.1.1 Attachment plug and receptacles shall be listed *(see NFPA 70, Article 100, Listed)* for the applied voltage and shall be of the locking type where rated greater than 20 amps. Where used on 300 volts or more, they shall be skirted and constructed to contain any arc generated when a connection is made or broken.

14.1.2 Attachment plugs and receptacles shall be provided with a grounding pole and so constructed that the grounding pole is made before any current-carrying poles are made, and is not broken until all current-carrying poles of the attachment plug have been disconnected. A grounding pole shall not be used as a current-carrying part.

14.1.3 Attachment plugs and receptacles shall be designed to prevent the entrance of oil or moisture when in the operating position. Means shall be provided to cover the receptacle when the plug is removed.

Exception: Where temperatures require the use of high-temperature attachment plugs and receptacles.

14.2 Receptacles internal to the control enclosure

14.2.1 Receptacles internal to the control enclosure shall be permitted only for the following:

— Maintenance equipment.

— AC power distribution within the enclosure to electronic assemblies designed and approved for cord-and-plug connection.

14.2.2 Receptacles shall be of the parallel-blade grounding-type rated 125 volts, 15 amperes.

14.2.3 Receptacles shall be supplied from a 120-volt ac source and shall have overcurrent protection not exceeding 15 amperes.

14.2.4 Receptacles for maintenance equipment shall be separate from receptacles for other purposes and shall have individual overcurrent protection not exceeding 15 amperes.

14.2.5 The source of power shall be the equipment control transformer, a separate isolating transformer, or, in the case of receptacles for maintenance equipment only, one of the maintenance lighting circuits permitted in 14.3.2 items c and e.

14.2.6 The receptacles shall not be accessible when the equipment doors or covers are in the closed position.

14.3 Control panel, instrument, and machine work lights

14.3.1 The lighting circuit voltage shall not exceed 150 volts between conductors.

14.3.2 Lights shall be supplied from one of the following sources:

(a) A separate isolating transformer connected to the load side of the machine disconnecting means. Overcurrent protection shall be provided in the secondary circuit.

(b) A grounded 120-volt machine control circuit with separate overcurrent protection for the lighting circuit.

(c) The plant lighting circuit shall be permitted for the supply of a maintenance lighting circuit in control enclosures only.

(d) Where the motor(s) on the machine totals two horsepower or less, it shall be permitted to connect the machine work light to the plant lighting circuit.

(e) A separate isolating transformer connected to the line side of the machine disconnecting means shall be permitted for the supply of a maintenance lighting circuit in control enclosures only.

(f) The line side of the main disconnecting means where a separate primary disconnecting means, isolating transformer, and secondary overcurrent protection are furnished in an enclosure and mounted within the control enclosure, adjacent to the main disconnecting means.

14.3.3 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 No. 18 AWG.

14.3.4 Flexible cords shall be Type SO, STO, STOW, or SJO, SJOW, SJTO and shall not incorporate in-line switches.

14.3.5 Grounding shall comply with the provisions of subclause 19.8.

14.3.6 Machine work lights shall not contain switches or receptacles where exposed to liquids or condensing mists unless identified *(see 3.49)* for the purpose.

14.3.7 Stroboscopic effects from lights shall be avoided.

14.3.8 Reflectors and protectors shall be supported by a bracket and not the lampholder.

15 Conductors

15.1 General

15.1.1 These requirements cover thermoplastic Type MTW, THHN, THW, and THWN 600-V wires and cables as specified in NFPA 70; UL 1063, *Machine-Tool Wires and Cables*; and ASTM Standards B 8, *Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*; B 33, *Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes*; B 174, *Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors*; and B 286, *Standard Specification for Copper Conductors for Use in Hookup Wire for Electronic Equipment*. The insulation and the finished wires and cables shall be suitably flame retardant and shall have temperature limits and characteristics as listed below:

— MTW — Moisture-, Heat-, and Oil-Resistant Thermoplastic

60°C (140°F) Wet Locations

90°C (194°F) Dry Locations

— THHN — Heat-Resistant Thermoplastic

(194°F) Dry Locations

— THW — Moisture- and Heat-Resistant Thermoplastic

75°C (167°F) Dry and Wet Locations

— THWN — Moisture- and Heat-Resistant Thermoplastic

75°C (167°F) Dry and Wet Locations

15.1.2 Multiconductor flexible cords, Type SO, STO, STOW or SJO, SJOW, SJTO shall be permitted.

15.1.3 Mineral-insulated (metal-sheathed) cable, Type MI, shall be permitted. Temperature range — 85°C (185°F) Dry and Wet Locations.

15.1.4 Conductors smaller than 18 AWG used to connect electronic programmable control I/O, and static control, shall be listed.

15.2 Conductors

15.2.1 Conductors of AWG sizes 22 through 4/0 and kcmil sizes 250 through 1000 shall be only of stranded soft-annealed copper. Conductor cross-sectional area, dc resistance, and stranding is listed in Table 9 shown on the following page.

Exception No. 1: Conductors with insulation characteristics consistent with the provisions of this clause but with stranding other than that specified in Table 9 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 clause shall have suitable characteristics.

15.2.2 Where constant flexing service is required, conductor stranding shall conform to Table 9.

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

15.2.4 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.

15.2.5 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. The conductors shall be in accordance with Tables 9 and 10 and shall have a metallic shield and an oil- and moisture-resistant outer covering such as vinyl plastic.

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

Table 9 — Single conductor characteristics

Size (AWG/ kcmil)	Cross-sectional Area — Nominal(CM/mm²)	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	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)	(\)	(–)

(B, C, K) ASTM Class designation B and C per ASTM B8, Class designation K per ASTM B 174.
(‘) A class designation has not been assigned to this conductor but is designated as size 22-7 in ASTM B286 and is composed of strands 10 mils in diameter (No. 30 AWG)
(\) Nonflexing construction shall be permitted for flexing service * Per ASTM Class designation B 174, Table 3.
(–) Constant flexing cables are not constructed in these sizes.

15.3 Conductor sizing
Conductors shall not be smaller than:

(a) Power circuits . . . . . No. 14

(b) Lighting and control circuits on the machine and in raceways . . . . . No. 16

Exception: In a jacketed, multiconductor cable assembly, No. 18 shall be permitted.

(c) Control circuits within control enclosures or operator stations . . . . . No. 18

(d) Electronic programmable control I/O, and static control:

1) Conductors in raceways . . . . . No. 24

Exception: In a jacketed, multiconductor cable assembly, No. 30 or larger shall be permitted.

2) Conductors within control enclosures . . . . . No. 26

Exception: For jumpers and special wiring applications (e.g., solderless wrap or wire-clip type connections or shielded conductors), conductors No. 30 or larger shall be permitted.

15.4 Wire insulation

15.4.1 Where "thermoplastic" or "PVC" appears in this standard, the intention is to designate a synthesized compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride or vinyl acetate. Every wire requiring insulation and intended for use as a single conductor or in a cable shall be insulated for its entire length with properly compounded homogeneous PVC material.

15.4.2 The color of the insulation shall be solid, or it shall have one or more stripes of different colors.

15.4.3 The average and the minimum thickness of the insulation in constructions A and B shall be in accordance with Table 10.

15.4.4 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 10.

15.4.5 Wire insulation shall be identified *(see 3.49)* and adequate for the voltage on that conductor. Where the conductors are run with or adjacent to other conductors, all conductors shall have insulation rated for the maximum voltage involved.

Exception: Bare conductors such as capacitor or resistor leads and jumpers between terminals shall be permitted where the method of securing provides electrical clearance.

15.5 Conductor ampacity

15.5.1 The continuous current carried by conductors shall not exceed the values given in Table 11.

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

15.5.3 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 that may be in operation at the same time.

Table 10 — Single conductor insulation thickness of insulation in mils* [average/minimum (jacket)]

Wire Size	A	B
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 MCM	95/86	60/54(8)
550–1000	110/99	70/63(9)

* UL 1063 Table 1.1 *NEC* Construction A-No outer covering B-Nylon covering

15.5.4 The maximum size of a conductor selected from Table 11 and connected to a motor controller shall not exceed the values given in Table 12.

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

15.6 Wire markings

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

Exception: Sizes smaller than Number 18 shall be permitted to be marked on the reel or on the smallest unit of the shipping carton.

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

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

16 Wiring methods and practices

16.1 General requirements.

16.1.1 Conductors shall be identified at each termination to correspond with the identification on the diagrams. Conductors shall be color-coded in accordance with 16.1.2 and 16.1.3.

Table 11 — Conductor ampacity based on copper conductors with 60°C and 75°C insulation in an ambient temperature of 30°C

Conductor Size AWG	Ampacity In Cable or Raceway		Control Enclosure
	60°C	75°C	60°C†
30	—	0.5	0.5
28	—	0.8	0.8
26	—	1	1
24	2	2	2
22	3	3	3
20	5	5	5
18	7	7	7
16	10	10	10
14	15	15	20
12	20	20	25
10	30	30	40
8	40	50	60
6	55	65	80
4	70	85	105
3	85	100	120
2	95	115	140
1	110	130	165
0	125	150	195
2/0	145	175	225
3/0	165	200	260
4/0	195	230	300
250	215	255	340
300	240	285	375
350	260	310	420
400	280	335	455
500	320	380	515
600	355	420	575
700	385	460	630
750	400	475	655
800	410	490	680
900	435	520	730
1000	455	545	780

†Sizing of conductors in wiring harnesses or wiring channels shall be based on the ampacity for cables.
NOTE 1: Wire types listed in 15.1 shall be permitted to be used at the ampacities as listed in this table.
NOTE 2: For ambient temperatures other than 30°C, see NFPA 70, Table 310-16, correction factors.
NOTE 3: The sources for the ampacities in this table are Table 310-16 and 310-17 of NFPA 70.

Table 12 — Maximum conductor size for given motor controller size*

Motor Controller Size	Maximum Conductor Size AWG or MCM
00	14
0	10
1	8
2	4
3	0
4	000
5	500

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

16.1.2 The color GREEN (with or without one or more YELLOW stripes) shall be used to identify the equipment grounding conductor where insulated or covered.

NOTE: The international and European standards require the use of the bicolor GREEN-AND-YELLOW for this purpose. *(See IEC 204-1 for specific requirements.)*

Exception No. 1: 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. 2: For grounded control circuits, a GREEN (with or without one or more YELLOW stripes) or a bare conductor from the transformer terminal to a grounding terminal on the control panel may be used.

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

— BLACK: Ungrounded line, load, and control conductors at line voltage.

— RED: Ungrounded ac control conductors, at less than line voltage.

— BLUE: Ungrounded dc control conductors.

— YELLOW: Ungrounded control circuit conductors that may remain energized when the main disconnecting means is in the OFF position. These conductors shall be YELLOW throughout the entire circuit, including wiring in the control panel and the external field wiring.

NOTE: The international and European standards require the use of the color ORANGE for this purpose. *(See IEC 204-1 for specific requirements.)*

— WHITE or NATURAL GRAY: Grounded circuit conductor.

— WHITE WITH BLUE STRIPE: Grounded (current-carrying) dc circuit conductors.

NOTE: The international and European standards require the use of the color LIGHT BLUE for the neutral conductor. *(See IEC 204-1 for specific requirements.)*

— WHITE WITH YELLOW STRIPE: Grounded (current=carrying) ac control circuit conductors that remain energized when the disconnecting means is in the OFF position. For additional circuits powered from different sources that remain energized when the main disconnecting means is in the OFF position, striping colors other than GREEN, YELLOW or BLUE shall be used for the unique identification of the grounded 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.

16.1.4 Conductors and cables shall be run without splices from terminal to terminal.

Exception: 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.

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

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

16.1.7 Identification tags shall be made of oil-resistant material. Where wrap-type adhesive strips are used, they shall be of a length not less than twice the circumference of the wire. Sleeve-type tags shall be applied so they will not slip off the wire.

16.1.8 Terminal blocks shall be wired and mounted so the internal and external wiring does not cross over the terminals. Not more than two conductors shall be terminated at each terminal connection.

Exception: More than two conductors shall be permitted where the terminal is identified (see 3.49).

16.1.9 Connection of conductors to terminal parts shall ensure a thoroughly good connection.

16.2 Panel wiring

16.2.1 Panel conductors shall be supported where necessary to keep them in place. Wiring channels shall be permitted where made of a flame-retardant insulating material.

16.2.2 Where back-connected control panels are used, access doors or swingout panels that swing about a vertical axis shall be provided.

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

16.3 Machine wiring

16.3.1 Conductors and their connections external to the control panel enclosure shall be totally enclosed in suitable raceways or enclosures as described in Clause 17, unless otherwise permitted in this subclause.

16.3.2 Fittings used with raceways or multiconductor cable shall be liquidtight.

Exception: Liquidtight fittings shall not be required where flexible metal conduit is permitted by the Exception to 16.3.4.

16.3.3 Liquidtight flexible conduit or multiconductor cable shall be used where necessary to employ flexible connections to pendant pushbutton stations. The weight of pendant stations shall be supported by chains or wire rope external to the flexible conduit or multiconductor cable.

16.3.4 Liquidtight flexible conduit or multiconductor cable shall be used for connections involving small or infrequent movements. They shall also be permitted to complete the connection to normally stationary motors, limit switches, and other externally mounted devices.

Exception: Where subjected to temperatures exceeding the limits for liquidtight flexible metal conduit, flexible metal conduit shall be permitted.

16.3.5 Connections to frequently moving parts shall be made with conductors for flexing service as shown in Table 9. Flexible cable and conduit shall have vertical connections and shall be installed to avoid excessive flexing and straining.

Exception: Horizontal connections shall be permitted where the flexible cable or conduit is adequately supported.

16.3.6 Where flexible conduit or cable is adjacent to moving parts, the construction and the supporting means shall prevent damage to the flexible conduit or cable under all conditions of operation.

Exception: Prewired devices such as limit switches and proximity switches provided with an identified (see 3.49) cable shall not be required to be equipped with provisions for termination of conduit.

16.3.7 All conductors of any ac circuit shall be contained in the same raceway.

16.3.8 Functionally associated circuit conductors including power, control, remote I/O, 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.

16.3.9 Connection through a polarized grounding-type attachment plug and receptacle shall be permitted where equipment is removable. The male plug shall be connected to the load circuit.

16.3.10 Where construction is such that wiring must be disconnected for shipment, terminal blocks in an accessible enclosure or attachment plugs and receptacles shall be provided at the sectional points.

16.3.11 The installation of flexible conduit and cable shall be such that liquids will drain away from the fittings.

16.3.12 Where liquidtight flexible metal conduit is used for flexible applications, fittings shall be identified *(see 3.49)*.

16.4 Wire connectors and connections

16.4.1 Pressure connectors shall be used to connect conductors to devices with lug-type terminals that are not equipped with saddle straps or equivalent means of retaining conductor strands.

Exception No. 1: Solder connections shall be permitted to be used within the protective shell of a plug or receptacle and for internal connections of a subassembly that can be removed for bench service (see 16.4.2).

Exception No. 2: Wire-wrapped connections shall be permitted to be used where circumstances permit and where applied by use of a tool specifically recommended for the purpose.

16.4.2 Soldered connections shall conform to the following:

— For manually soldered connections, rosin shall be used as flux.

— Where printed circuit boards or other component assemblies are dip or wave soldered, special fluxes shall be permitted to be used following techniques developed specifically for these methods of fabrication.

— All parts shall be pretinned before soldering unless the part is specifically plated to ensure a good solder joint (e.g., MS-type connectors having gold-plated contacts).

— Each soldered connection shall be made with the least amount of solder that will assure a secure, high-conductivity connection.

— Insulation shall not be damaged by soldering.

— Components that may be damaged by heat shall be suitably shielded from heat during soldering.

16.5 Wiring between machines

Interconnection wiring between machines shall be supported and protected in accordance with the appropriate requirements of NFPA 70 for the wiring methods used.

17 Raceways, junction boxes, and pull boxes

17.1 General requirements

17.1.1 All sharp edges, flash, burrs, rough surfaces, or threads with which the insulation of the conductors may come in contact shall be removed from raceways and fittings. Where necessary, additional protection consisting of a flame-retardant, oil-resistant insulating material shall be provided to protect conductor insulation.

17.1.2 Drain holes of 1/4 in. (6.4 mm) shall be permitted in raceways, junction boxes, and pull boxes subject to accumulations of oil or moisture.

NOTE: Raceways and junction boxes are provided for mechanical protection only. See Clause 19 for acceptable means of equipment grounding.

17.2 Percent fill of raceways

The combined cross-sectional area of all conductors and cables shall not exceed 50 percent of the interior cross-sectional area of the raceway. The fill provisions shall be based on the actual dimensions of the conductors or cables used.

17.3 Rigid metal conduit and fittings

17.3.1 Rigid metal conduit and fittings shall be of galvanized steel, meeting the requirements of ANSI C80.1, *Rigid Steel Conduit-Zinc Coated*; and NEMA FB 1, *Fittings, Cast Metal Boxes and Conduit Bodies for Conduit and Cable Assemblies*; or of a corrosion-resistant material suitable for the conditions. Dissimilar metals in contact that would cause galvanic action shall not be used. Conduit shall be protected against corrosion except at the threaded joints.

Exception: Threads at joints shall be permitted to be coated with an identified (see 3.49) electrically conductive compound.

17.3.2 Conduit smaller than 1/2 in. electrical trade size shall not be used.

17.3.3 Conduit shall be securely held in place and supported at each end.

17.3.4 Fittings shall be threaded unless structural difficulties prevent assembly. Where threadless fittings must be used, conduit shall be securely fastened to the equipment.

17.3.5 Running threads shall not be used.

17.3.6 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 affords equivalent protection. Where conduit bushings are constructed wholly 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.

17.3.7 Conduit bends shall be so made that the conduit will not be injured and the internal diameter of the conduit will not be effectively reduced. The radius of the curve of any field bend shall be not less than shown in Table 13.

Table 13 — Minimum Radius of Conduit Bends

Size of Conduit (in.)	Radius of Bend Doneby Hand (in.)[1]	Radius of Bend Doneby Machine (in.)[2]
1/2	4	4
3/4	5	4 1/2
1	6	5 1/4
1 1/4	8	7 1/4
1 1/2	10	8 1/4
2	12	9 1/2
2 1/2	15	10 1/2
3	18	13
3 1/2	21	15
4	24	16
4 1/2	27	20
5	30	24
6	36	30

For SI units: (Radius) 1 in. = 25.4 mm.
NOTE 1: For field bends done by hand, the radius is measured to the inner edge of the bend.
NOTE 2: For a single-operation (one-shot) bending machine designed for the purpose, the radius is measured to the center line of the conduit.

17.3.8 A run of conduit shall contain not more than the equivalent of four quarter bends (360 degrees, total).

17.4 Intermediate metal conduit

Intermediate metal (steel) conduit shall be permitted and shall be installed in conformance with the provisions of 17.3.2 through 17.3.8.

17.5 Electrical metallic tubing

Electrical metallic (steel) tubing shall be permitted and shall be installed in conformance with the provisions of 17.3.2 through 17.3.8.

17.6 Schedule 80 rigid nonmetallic conduit

17.6.1 Rigid nonmetallic conduit Schedule 80 and fittings shall be listed *(see NFPA 70, Article 100, Listed)*.

17.6.2 Conduit smaller than 1/2 in. electrical trade size shall not be used.

17.6.3 Conduit shall be securely held in place and supported as follows:

Conduit Size (In.)	Maximum Spacing Between Supports (Ft)
1/2–1	3
1 1/4–2	5
2 1/2–3	6
3 1/2–5	7
6	8

In addition, conduit shall be securely fastened within 3 ft (914 mm) of each box, enclosure, or other conduit termination.

17.6.4 Expansion fittings shall be installed to compensate for thermal expansion and contraction. (Table 10, Chapter 9, NFPA 70.)

17.6.5 Where a conduit enters a box or fitting, a bushing or adaptor shall be provided to protect the wire from abrasion

unless the design of the box or fitting is such as to provide equivalent protection.

17.6.6 Conduit bends shall be so made that the conduit will not be injured and the internal diameter of the conduit will not be effectively reduced. The radius of the curve of any field bend shall be not less than shown in Table 13.

17.6.7 A run of conduit shall contain not more than the equivalent of four quarter bends (360 degrees, total).

17.6.8 All joints between lengths of conduit, and between conduit and couplings, fittings, and boxes, shall be made with fittings designed for the purpose.

17.7 Liquidtight flexible metal conduit and fittings

17.7.1 Liquidtight flexible metal conduit shall consist of an oil-resistant, liquidtight jacket or lining in combination with flexible metal reinforcing tubing.

17.7.2 Fittings shall be of metal and shall be designed for use with liquidtight flexible metal conduit.

17.7.3 Liquidtight flexible metal conduit smaller than $^3/_8$ in. electrical trade size shall not be used.

17.7.4 Liquidtight flexible metal conduit shall be permitted to be of the extra flexible construction.

17.7.5 Flexible conduit shall be installed in such a manner that liquids will tend to run off the surface instead of draining toward the fittings.

17.8 Liquidtight flexible nonmetallic conduit and fittings

17.8.1 Liquidtight flexible nonmetallic conduit is a raceway of circular cross section of various types:

— A smooth, seamless inner core and cover bonded together and having one or more reinforcement layers between the core and cover.

— A smoother inner surface with integral reinforcement within the conduit wall.

— A corrugated internal and external surface with or without integral reinforcement within the conduit wall.

This conduit is oil-, water-, and flame-resistant and, with fittings, is approved for the installation of electrical conductors.

17.8.2 The conduit shall be resistant to kinking and shall have physical characteristics comparable to the jacket of multiconductor cable.

17.8.3 The conduit shall be suitable for use at temperatures of 176°F (80°C) in air and 140°F (60°C) in the presence of water, oil, or coolant.

17.8.4 Fittings shall be identified *(see 3.49)* for their intended use.

17.8.5 Liquidtight flexible nonmetallic conduit smaller than $^3/_8$ in. trade size shall not be used.

17.8.6 Flexible conduit shall be installed in such a manner that liquids will tend to run off the surface instead of draining toward the fittings.

17.9 Flexible metal (nonliquidtight) conduit and fittings

17.9.1 Flexible metal conduit shall consist of flexible metal tubing or woven wire armor.

17.9.2 Fittings shall be of metal and shall be designed for use with flexible metal conduit.

17.9.3 Flexible metal conduit smaller than $^3/_8$ in. electrical trade size shall not be permitted.

Exception: Thermocouples and other sensors.

17.10 Wireways

17.10.1 Exterior wireways shall be permitted where rigidly supported and clear of all moving or contaminating portions of the machine. Nonmetallic wireways shall be identified *(see 3.49)*.

17.10.2 Metal thickness shall be not less than No. 14 MSG.

17.10.3 Covers shall be shaped to overlap the sides; gaskets shall be permitted. Covers shall be attached to wireways by hinges or chains or other suitable fastening means and held closed by means of captive screws or other suitable fasteners. On horizontal wireways, the cover shall not be on the bottom.

17.10.4 Where wireway is furnished in sections, the joints between sections shall fit tightly but shall not be required to be gasketed.

17.10.5 Only openings required for wiring or drainage shall be provided. Wireways shall not have unused knockouts.

17.11 Machine compartments and raceways

Compartments or raceways within the column or base of a machine shall be permitted to enclose conductors, provided the compartment or raceway is isolated from coolant and oil reservoirs and is entirely enclosed. Conductors run in enclosed compartments and raceways shall be secured and arranged so they will not be subject to physical damage.

17.12 Junction and pull boxes

Junction and pull boxes shall not have unused knockout or openings and shall be constructed to exclude such materials as dust, flyings, oil, and coolant.

17.13 Motor terminal boxes

Motor terminal boxes shall enclose only connections to the motor and motor-mounted devices, such as brakes, temperature sensors, plugging switches, or tachometer generators.

18 Motors and motor compartments

18.1 Access

Each motor and its associated couplings, belts, and chains shall be mounted where they are accessible for maintenance and not subject to damage.

18.2 Mounting arrangement

18.2.1 The motor mounting arrangement shall be such that all motor hold-down bolts can be removed and replaced and terminal boxes can be reached. Unless bearings are permanently sealed, provision shall be made for lubricating the bearings.

18.2.2 Sufficient air circulation shall be provided so that the motor will not exceed its rated temperature rise at rated operating conditions.

18.2.3 All motor-driven couplings, belts, and chains shall be easily replaceable.

18.2.4 Pulley hubs on belted drives shall not extend beyond the end of the motor shaft.

18.3 Direction arrow

Where reverse rotation can produce an unsafe condition, a direction arrow shall be installed. The arrow shall be adjacent to the motor and plainly visible.

18.4 Motor compartments

Motor compartments shall be clean, dry, and adequately vented directly to the exterior of the machine. There shall be no opening between the motor compartment and any other compartment that does not meet the motor compartment requirements. Where a conduit or pipe is run into the motor compartment from another compartment not meeting the motor compartment requirements, any clearance around the conduit or pipe shall be sealed.

18.5 Marking on motors

Motors shall be marked in accordance with Section 430-7 of NFPA 70.

19 Grounded circuits and equipment grounding

19.1 General

This clause applies to grounded circuits and the protective or grounding circuit of the equipment. The grounding circuit consists of conductors, structural parts of the electrical equipment and machine, or both, that are all electrically connected or bonded together at a common point.

19.2 Grounding conductors

19.2.1 Conductors used for grounding and bonding purposes shall be copper. Stipulations on stranding and flexing as outlined in this standard shall apply. *(See 15.3 and 16.3.6).*

19.2.2 Grounding conductors shall be insulated, covered, or bare and shall be protected against physical damage.

19.2.3 The minimum size of the grounding conductor shall be as shown in Table 14. Column "A" indicates maximum rating or setting of the overcurrent device in the circuit ahead of the equipment.

19.2.4 It shall be permissible to use machine members or structural parts of the electrical equipment in the 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.

19.3 Equipment grounding

The machine and all exposed, noncurrent-carrying conductive parts, material, and equipment, including metal mounting panels that are likely to become energized and are mounted in nonmetallic enclosures, shall be effectively grounded.

19.4 Exclusion of switching devices

The grounding circuit shall not contain any switches or overcurrent protective devices. Links or plugs in the grounding circuit shall be permitted if properly labeled or interlocked with the control circuits.

19.5 Grounding terminal

The entire grounding circuit or network shall be interconnected such that a single point for an external connection will be conductively connected to all grounded parts. A terminal suitable for connecting an external grounding conductor shall be provided at this point.

Exception: Where an attachment plug and receptacle are used as the disconnecting means, 7.11 shall apply.

Table 14 — Size of grounding conductors

Column "A," Amperes	Copper Conductor Size, AWG
10	16* or 18*
15	14, 16*, or 18*
20	12, 14*, 16*, or 18*
30	10
40	10
60	10
100	8
200	6
300	4
400	3
500	2
600	1
800	0
1000	2/0
1200	3/0
1600	4/0

*Permitted only in multiconductor cable where connected to portable or pendant equipment.

19.6 Continuity of the grounding circuit

19.6.1 The continuity of the grounding circuit shall be ensured by effective connections through conductors or structural members.

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

19.6.3 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.

19.6.4 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.

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

19.6.6 When a part is removed, the continuity of the grounding circuit for the remaining parts shall remain intact.

19.7 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. For color coding of conductors, see 16.1.1.

Exception No. 1: Exposed control circuits as permitted by 9.2.1, Exception No. 2, 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.

19.8 Lighting circuits

19.8.1 One conductor of all machine lighting and maintenance lighting circuits shall be grounded. The grounded conductor(s) shall be identified with a white or natural gray insulation.

19.8.2 Where the lighting circuit is supplied by a separate isolation transformer, the grounding shall occur at the transformer. Where the equipment maintenance lighting circuit is supplied directly from the plant lighting circuit, the grounding shall occur at the grounding terminal.

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

20 Electronic equipment

20.1 General

The clause applies to all types of electronic equipment including programmable electronic systems, subassemblies, printed circuit boards, electronic components, and other miscellaneous solid state equipment.

20.2 Basic requirements

20.2.1 The provisions of Clause 5 apply to electronic equipment.

20.2.2 Subassemblies shall be readily removable for inspection or replacement.

20.2.3 Transient suppression and isolation shall be provided where this equipment generates transient or electrical noise that can affect the operation of the equipment.

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

20.2.5 Loss of memory contents shall prohibit the initiation of any hazardous conditions whose operation is dependent on memory contents.

20.2.6 Outputs controlled by programmable electronic systems shall be protected from overload and short circuit conditions *(see 20.3.2 for grounding requirements).*

20.3 Programmable electronic systems

20.3.1 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 reasons of safety, the manufacturer or supplier shall be permitted to retain the right not to allow the user to alter the program.

20.3.2 All input/output racks (remote or local), processor racks, and power supplies shall be electrically bonded together and connected to the grounding circuit *(see 19.2)* in accordance with the manufacturer's specifications. Where specified by the manufacturer, components and subassemblies shall be effectively bonded to the grounding circuit in accordance with the manufacturer's recommendations.

Annex A (informative)
Bibliography

The following documents or portions thereof are referenced within this standard for informational purposes only and thus should not be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

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ANSI/NEMA ICS-2: 1993, *Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated Not More than 2000 Volts AC or 750 Volts DC*

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Annex B (informative)

Examples of industrial machines covered by NFPA 79

B.1 Machine tools

1) Metal cutting
2) Metal forming

B.2 Plastics machinery

1) Injection molding machines
2) Extrusion machinery
3) Blow molding machines
4) Specialized processing machines
5) Thermoset molding machines
6) Size reduction equipment

B.3 Wood machinery

1) Woodworking machinery
2) Laminating machinery
3) Sawmill machines

B.4 Assembly machines

B.5 Material handling machines

1) Industrial robots
2) Transfer machines

B.6 Inspection/testing machines

1) Coordinate measuring machines
2) In-process gaging machines

Annex C (informative)

Graphical symbols (IEC 417, Supplement 0)

C.1 Equipment grounding terminal

(Symbol No. 5019)

C.2 Grounded terminal

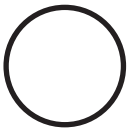
(Symbol No. 5017)

C.3 Start or On

(Symbol No. 5007)

C.4 Stop or Off

(Symbol No. 5008)

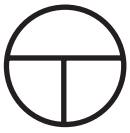


C.5 Alternatively act as Start and Stop or On and Off

(Symbol No. 5010)

C.6 Movement when pressed and Stop Movement when released (jogging)

(Symbol No. 5011)



Annex D (informative)
Sample electrical diagrams

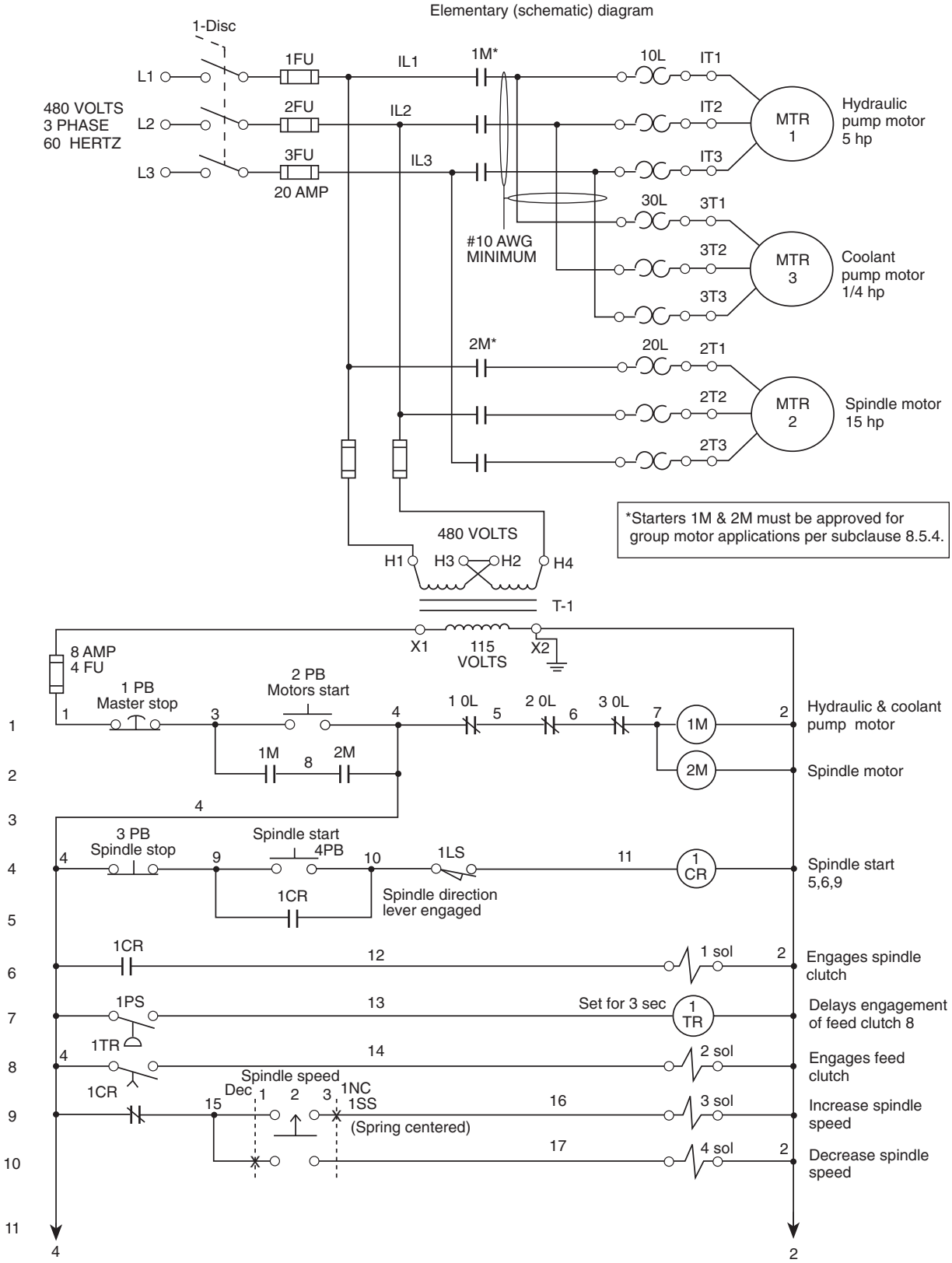
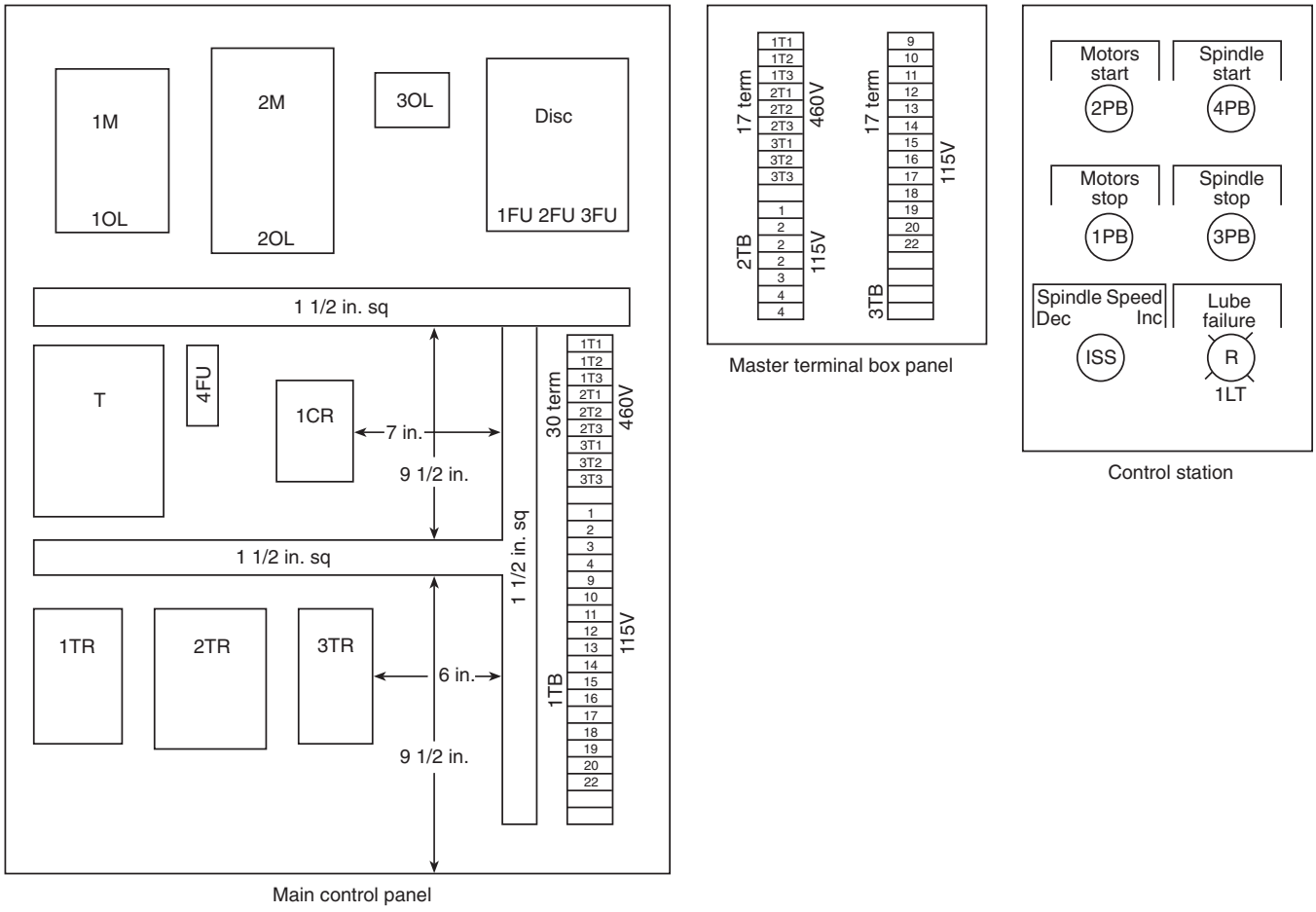


Figure D.1

Panels and control station layout

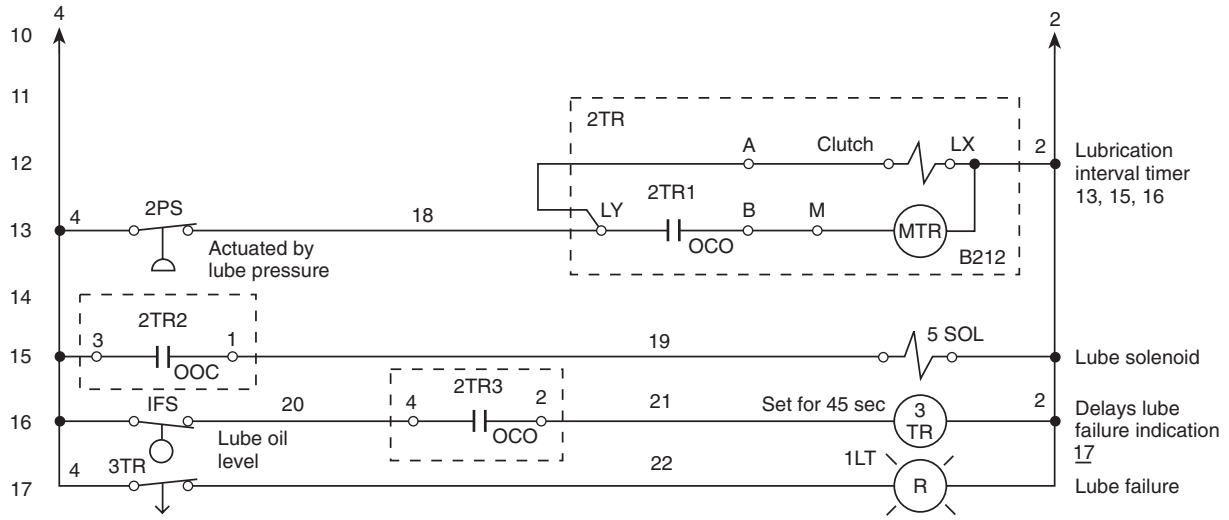


Main control panel

Master terminal box panel

Control station

Figure D.2



Sequence of operation

A. Machine operation: press "MOTORS START" pushbutton "ZPB." Motors start.
B. Select spindle speed by turning selector switch "ISS to "INC," energizing "3 SOL," to increase or to "DEC," energizing "4 SOL," to decrease setting.
C. With correct spindle direction selected, limit switch "1LS" is actuated. Press, 'SPINDLE START" pushbutton "4PB," energizing relay "1CR," which energizes "1 SOL." Spindle starts and pressure switch "1PS" is actuated. "1PS" energizes "1TR" and after a time delay "2 SOL" 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 "2TR-1" closes and energizes timer motor "MTR," starting lube timing period.
   3. Contact "2TR-3" closes and energizes timer "3TR."
G. Timer "2TR" times out.
   1. Contact "2TR-1" opens, deenergizing timer motor "MTR."
   2. Contact "2TR-2" closes, energizing "5 SOL."
   3. Contact "2TR-3" opens, deenergizing timer "3TR."
   4. Lubrication pressure actuates pressure switch "2PS," deenergizing and resetting timer "2TR." Contacts "2TR-1," 2TR-2," and "2TR-3" open.
   5. Contact "2TR-2" opening, deenergizes "5 SOL."
H. Reduced lubrication pressure deactuates pressure switch "2PS" and sequence repeats.

Switch operation

1LS (4) Actuated by spindle direction lever engaged
1PS (11) Operated when spindle clutch engaged
2PS (13) Operated by normal lube pressure
1FS (16) 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 22
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.3