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NFPA 79 Electrical Standard for Industrial Machinery 1985

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

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The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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Errata

NFPA 79—1985

Electrical Equipment of Industrial Machinery

NFPA 79
Reference: Appendix C

The Technical Committee on Electrical Equipment of Industrial Machinery notes the following error in NFPA 79-1985.

1. Add to Appendix C the following paragraphs C-5 and C-6, inadvertently omitted.

C-5 Thermoset Molding Machines

1. Compression and Transfer Machines
2. Thermoset Compression Machines

C-6 Size Reduction Equipment

1. Granulators
2. Pelletizers
3. Dicers

ERRATA

NFPA 79

Electrical Equipment of Industrial Machines

1985 Edition

The Committee on Electrical Equipment of Industrial Machines notes the following errors in NFPA 79-1985.

1. Add Appexdix "E" to read as follows:

   E. Thermoset Molding Machines

      1. Compression and Transfer Machines

      2. Thermoset Compression Machines

2. Add Appendix "F" to read as follows:

   F. Size Reduction Equipment

      1. Granulators

      2. Pellitizers

      3. Dicers

NFPA 79

Electrical Standard for

Industrial Machinery

1985 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 Fall Meeting held November 12-15, 1984 in San Diego, California. It was issued by the Standards Council on December 7, 1984, with an effective date of December 27, 1984, and supersedes all previous editions.

The 1985 edition of this standard has been approved by the American National Standards Institute.

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 and 1980 revised editions were adopted.

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

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This list represents the membership at the time the Committee was balloted on the text of this edition Since that time, changes in the membership may have occurred.

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

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NFPA 79

Electrical Standard for

Industrial Machinery

1985 Edition

Preface

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, the Electrical Section of the National Fire Protection Association in 1941 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 which 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 in one article the special requirements of this broad field. 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*.

The electrical equipment of a modern machine tool may vary from that found on a single motor machine such as a drill press which performs a simple, repetitive operation to that of the very large, multimotored automatic machines which involve highly complex electrical control systems, including electronic and solid-state devices and equipment. Generally these machines are especially 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 the production of the plant, and their usual 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 a highly skilled operator. 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 (i.e., small drill presses, bench grinders, sanders, etc.) were not appropriately covered. The NFPA 79-1977 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. NFPA 79-1985 reflects this activity and appropriate requirements are now included in the standard.

In 1975, the Society of the Plastics Industry requested to have this standard enlarged in scope so as to include Plastics Machinery. A formal request was received by NFPA in September, 1978 and, through combined efforts of the NFPA 79 committee and representative 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 will 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 reflects the incorporation of the appropriate material from the JIC Electrical (EMP-1-67, EGP-1-67) standards not previously covered.

Chapter 1 General

1-1 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 machinery which will promote safety to life and property.

(b) This standard is a minimum standard and is not intended to limit or inhibit the advancement of the state of the art. Each type of machine has unique requirements which shall be accommodated to provide adequate safety.

1-2 Scope.

(a) The provisions of this standard shall apply to all electrical/electronic equipment, apparatus, or systems supplied as part of industrial machinery as defined in Section 1-3 and operating from a supply voltage of 600 volts or less, and commencing at the place of connection of the supply to the electrical equipment of the machine.

NOTE: The general terms "machines," "machinery," and "industrial machinery," as used throughout this standard, include machine tool(s), plastics machinery or mass production industrial equipment.

(b) This standard shall not be considered adequate for machines intended for use in areas defined as hazardous (classified) locations by NFPA 70-1984, *National Electrical Code*.

(c) This standard is not intended to apply to:

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

2. Machines used in dwelling units.

(d) The installation of a machine and the wiring between component machines of mass production industrial equipment shall be in accordance with NFPA 70-1984, *National Electrical Code*.

1-3 Definitions. For the purposes of this standard, the following definitions shall apply:

(a) A machine tool is defined as a power-driven machine not portable by hand, used to shape or form metal or plastic by cutting, impact, pressure, electrical techniques, or combination of these processes.

(b) Plastics machinery is defined as a power-driven machine not portable by hand, used to shape or form plastic by application of thermal and/or mechanical energy, by cutting, impact, pressure, or a combination of these processes.

NOTE: See Appendix C for such types of plastics machinery.

(c) Mass production industrial equipment is defined as a systematic array of one or more machine tools, plastics machinery, and/or assembly machines which are not portable by hand and which includes any associated material handling, manipulating, gaging, measuring, or inspection equipment.

(d) For purposes of this standard, definitions of some other terms are given in Appendix A.

1-4 Other Standards. On any point for which specific provisions are not made in this standard, the provisions of NFPA 70-1984, *National Electrical Code*, shall be observed. Other organizations having standards which may provide additional information are listed in Appendix B.

NOTE: NFPA 70E, *Electrical Safety Requirements for Employee Workplaces*, contains additional information.

1-5 Nominal Voltages. All voltages mentioned in this standard are nominal.

Chapter 2 Diagrams, Instructions, and Nameplates

2-1 Diagrams.

(a) Diagrams showing all of the electrical circuits on the machine shall be provided. Any electrical symbols not shown in ANSI Y32.2 shall be identified and shown on the diagrams. The symbols and identification of components and devices shall be consistent throughout all documents and on the machine.

(b) A cross-referencing scheme shall be used in conjunction with each relay, solenoid valve, limit switch, pressure switch, etc., so that any contact associated with the device can be readily located on the diagram.

(c) All switch symbols shall be shown on the electrical schematic diagrams with all utilities turned off (electric power, air, water, lubricant, etc.) and the machine and electrical equipment in its normal starting condition.

(d) All directly interconnected conductors shall be designated with the same alphanumeric reference. Conductors shall be identified in accordance with Chapter 14.

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

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

(e) Circuits shall be shown in such a way as to facilitate the understanding of their function as well as maintenance and fault location. Special characteristics relating to the function of the control devices and components which are not evident from their symbolic representation shall be included on the diagram adjacent to the symbol or referenced to a footnote.

(f) An interconnection diagram shall be provided on large systems having a number of separate enclosures and/or control stations. It shall provide full information about the external connections of the entire electrical equipment on the machine.

2-2 Instructions.

(a) 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.

(b) The installation drawing(s) shall provide all information necessary for preliminary machine and control set-up. This includes information on supply cables, particularly if it is 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.

(c) The description of the sequence of operations is only 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 which is necessary for the understanding of the electrical operation in conjunction with the mechanical, hydraulic, and/or pneumatic operation of the machine. When the sequence of operations is programmed 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 schematic diagram(s) shall be included on the block diagram.

(d) The parts listed shall itemize recommended electrical spare parts together with the necessary data for ordering.

(e) Maintenance instructions and adjustment procedures shall include the schedule of preventive maintenance, instructions for replacement of parts, and adjustment procedures expected to be performed by the end user. A device location diagram shall be included for systems having multiple control panels and/or enclosures.

2-3 Markings. Nameplates, markings, and identification plates shall be of sufficient durability to withstand the environment involved.

2-4 Warning Marking.

(a) 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 de-energize all exposed live parts when the disconnect(s) is in the "open (off)" position.

(b) When 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.

2-5 Machine Marking. The machine shall be marked with the builder's name, trademark, or other identification symbol.

2-6 Machine Nameplate Data.

(a) 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.

(b) The full-load current shown on the nameplate shall not be less than the full-load currents for all motors and other equipment which can be in operation at the same time under normal conditions of use. Where unusual loads, duty cycles, etc., require oversized conductors, the required capacity shall be included in the full-load current specified on the nameplate.

(c) Where overcurrent protection is provided in accordance with Section 6-2, the machine shall be marked "overcurrent protection provided at machine supply terminals." A separate nameplate shall be permitted to be used for this purpose.

2-7 Equipment Marking and Identification.

(a) 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.

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

(c) Nameplates, identification plates, or warning markings shall not be removed from the equipment.

(d) 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 need not apply to machines on which the equipment consists only of a single motor, motor-controller, pushbutton station(s), and worklight(s).

(e) 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 Section 2-8.

2-8 Function Identification. Each control station device (pushbutton, indicating light, selector switch, etc.) 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 Appendix D for examples*).

Chapter 3 General Operating Conditions

3-1 General. This chapter describes the general requirements and conditions for the operation of the electrical equipment of the machine.

3-2 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.

3-3 Ambient Operating Temperature. The electrical equipment shall be capable of operating in an ambient temperature range of 5 to 40°C (41 to 104°F).

3-4 Altitude. The electrical equipment shall be suitable for operating correctly at altitudes up to 3300 ft (1000 m) above sea level.

3-5 Relative Humidity. The electrical equipment shall be capable of operating within a relative humidity range of 20-95 percent (non-condensing).

3-6 Transportation and Storage. The electrical equipment shall be designed to withstand storage and transportation temperatures within the range of -25 to 55°C (-13 to + 131°F) and up to 65°C (149°F) for short periods not exceeding 24 hours. Suitable means shall be provided to prevent damage from excessive moisture, vibration, stress, and mechanical shock during shipment.

3-7 Installation and Operating Conditions. The electrical equipment shall be installed and operated in accordance with the manufacturer's instructions.

3-8 Supply Voltage. The electrical equipment shall operate satisfactorily at full-load as well as no-load under the following conditions:

(a) Voltage	90-110 percent of rated voltage.
(b) Frequency	± 2 percent of rated frequency.
(c) Harmonic Distortion	Up to 10 percent of total RMS sum of the 2nd through 5th harmonics. Up to an additional 2 percent RMS sum of the 6th through 30th harmonics.
(d) Radio Frequency Voltages	2 percent RMS above 10KHZ.
(e) Impulse Voltage	200 percent peak voltage up to 1 ms duration with a rise time of 500 *n*s to 500 μs.
(f) Voltage Drop	Reduction of 50 percent of peak voltage for ½ cycle or 20 percent for 1 cycle. More than 1 second between successive reductions.
(g) Micro-interruption	Supply disconnected or at zero voltage for 3 ms at any random time in the cycle. More than 1 second between successive reductions.

Chapter 4 Safeguarding of Personnel

4-1 General. The electrical equipment shall provide safeguarding of persons against electrical shock both in normal service and in case of fault.

4-2 Safeguarding Against Electric Shock in Normal Service.

(a) Live parts shall either be located inside enclosures as described in Chapters 9 and 10 or be completely covered by insulation which can only be removed by destruction (e.g., interconnecting cables).

(b) Enclosure interlocking as described in Sections 5-9 and 9-8 shall be provided.

(c) Grounding and bonding of the electrical equipment and machine members shall comply with Chapter 17.

4-3 Safeguarding Against Electrical Shock by Machine Extra Low Voltage (MELV). Circuits of which not all live parts are protected against direct contact in normal service shall fulfill all of the following conditions:

(a) The highest voltage (with respect to ground) shall not exceed 30VAC (RMS) or 30VDC (with less than 10 percent ripple).

(b) The source of supply and all live parts and conductors of such circuits shall be separated or isolated from circuits with higher voltages by insulation rated for the maximum voltage used in the same part of the electrical equipment.

(c) One side of the circuit or one point of the source of supply of that circuit shall be connected to the grounding circuit associated with the higher voltages used on the machine and its related exposed conductive parts.

(d) Plugs and receptacles used in MELV circuits shall be chosen so as to preclude accidental connection to circuits having higher voltages.

4-4 Safeguarding Against Electrical Shock from Residual Voltages. Where the equipment includes elements which may retain dangerous charges after being switched off, the voltage shall be reduced automatically to below 50 volts within one minute after being disconnected.

Chapter 5 Supply Circuit Disconnecting Means

5-1 General Requirements. A disconnecting means shall be provided for each incoming supply circuit.

5-2 Type.

(a) The disconnecting means shall be manually operable and shall be a fusible or nonfusible motor circuit switch or a circuit breaker in accordance with Sections 5-3 through 5-10.

(b) An attachment plug in accordance with Section 5-11.

5-3 Rating.

(a) The ampacity of the disconnecting means shall not be less than 115 percent of the sum of the full-load currents required for all equipment which may be in operation at the same time under normal conditions of use.

(b) The interrupting capacity of the disconnecting means shall not be less than the sum of the locked-rotor current of the largest motor plus the full-load current of all other connected operating equipment.

(c) Fusible motor-circuit switches or circuit breakers shall be applied in accordance with Chapter 6.

5-4 Position Indication. The disconnecting means shall plainly indicate whether it is in the open (off) or closed position.

5-5 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.

5-6 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.

5-7 Exposed Live Parts. There shall be no exposed live parts with the disconnecting means in the open (off) position.

NOTE: See Exception to Section 7-1.

5-8 Mounting.

(a) 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.

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 Appendix C, Paragraph C-2) where the design configuration of the enclosure may preclude mounting the disconnect as the uppermost component:

a. Live parts shall be guarded against accidental contact.

b. 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 where the motors total 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 within sight of and readily accessible to the operator.

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

5-9 Interlocking.

(a) 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 Section 2-4(a) shall apply.

Exception No. 2: Where an attachment plug is used as the disconnecting means in accordance with Section 5-11.

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 Section 2-4(a) shall apply.

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

1. Prevent closing of the disconnecting means while the enclosure door is open, unless an interlock is operated by deliberate action.

2. Prevent closing of the disconnecting means while the door is in the initial latch position or until the door hardware is fully engaged.

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

(b) 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.

5-10 Operating Handle.

(a) The operating handle of the disconnecting means shall be readily accessible.

(b) The center of the grip of the operating handle of the disconnecting means, when in its highest position, shall not be more than 6½ ft (2 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.

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

(d) 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.

5-11 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:

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

(b) The supply voltage shall not exceed 150 volts to ground.

(c) DC shall not be used.

(d) The ampacity of the attachment plug shall not be less than 115 percent of the sum of the full-load currents required for all equipment which may be in operation at the same time under normal conditions of use.

(e) The attachment plug shall be single voltage rated.

(f) The attachment plug 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.

(g) The attachment plug shall be in sight of the operator's station and readily accessible.

Chapter 6 Protection

6-1 Machine Circuits. Diagram 6-1 shows typical circuits which are acceptable for protection of machine motors, resistive heating loads, and controls. Protective interlocks are not shown.

6-2 Supply Conductor and Machine Overcurrent Protection. The overcurrent protection as shown in line C of Diagram 6-1, Figures I through IV inclusive, 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 Section 2-6(c).

6-3 Additional Overcurrent Protection. The additional overcurrent protection shown in line D of Diagram 6-1, Figures III and IV, 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.

6-4 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:

(1) the conductor has an ampacity of at least one-third (⅓) that of the conductor from which it is supplied

(2) it is suitably protected from physical damage

(3) is not over 25 ft (7.6 m) long

(4) terminates in a single circuit breaker or set of fuses.

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

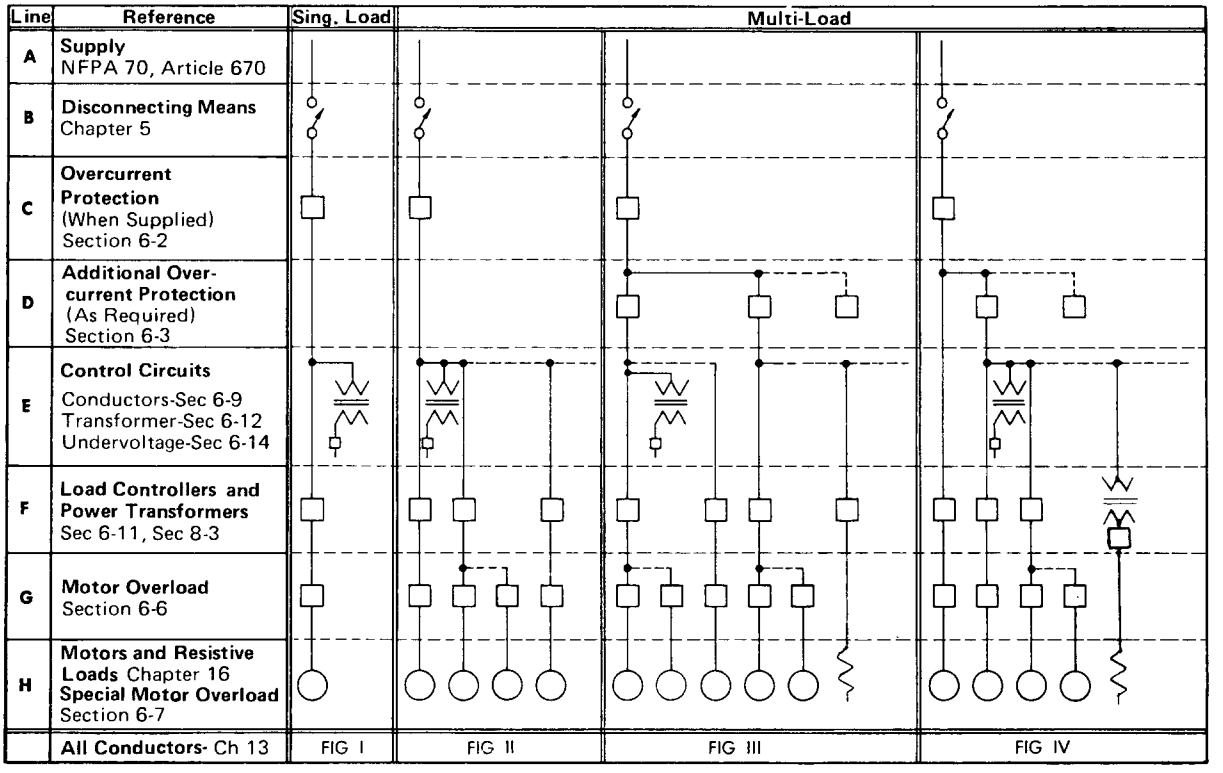
(1) the conductor has an ampacity of not less than the sum of the maximum continuous load currents supplied

(2) is not over 10 feet (3 m) long

(3) does not extend beyond the control panel enclosure.

Diagram 6-1 Protection of Machine Electrical Circuits

TYPICAL DIAGRAMS—CONSULT TEXT



6-5 Motor Branch Circuits.

(a) The overcurrent protective device for a branch-circuit supplying a single motor shall be capable of carrying the starting current of the motor. Overcurrent protection shall be considered as being obtained when the overcurrent device has a rating or setting not exceeding the values given in Table 6-5(a). Where the overcurrent protection specified in the table is not sufficient for the starting current of the motor, it shall be permitted to be increased to a maximum of 400 percent of the motor full-load current for inverse time circuit breakers and non-time delay fuses, a maximum of 225 percent for time delay or dual element fuses, and a maximum of 1300 percent for instantaneous trip breakers.

Exception: Where the values for the branch-circuit, short-circuit and ground-fault protective devices determined by Table 6-5(a) do not correspond to the standard sizes or ratings of fuses, nonadjustable circuit breakers or thermal protective devices, or possible settings of adjustable circuit breakers adequate to carry the load, the next higher size, rating, or setting shall be permitted.

Table 6-5(a) Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit Ground-Fault Protective Devices

	Percent of Full-Load Current			
Type of Motor	Nontime Delay Fuse	Dual-Element (Time-Delay) Fuse	Instantaneous Trip Breaker	Inverse Time Breaker
Single-phase, all types				
No code letter	300	175	700	250
All ac single-phase and polyphase squirrel-cage and synchronous motors with full-voltage, resistor or reactor starting:				
No code letter	300	175	700	250
Code letter F to V	300	175	700	250
Code letter B to E	250	175	700	200
Code letter A	150	150	700	150
All ac squirrel-cage and synchronous motors with autotransformer starting:				
Not more than 30 amps				
No code letter	250	175	700	200
More than 30 amps				
No code letter	200	175	700	200
Code letter F to V	250	175	700	200
Code letter B to E	200	175	700	200
Code letter A	150	150	700	150
High-reactance squirrel-cage				
Not more than 30 amps				
No code letter	250	175	700	250
More than 30 amps				
No code letter	200	175	700	200
Wound-rotor — No code letter	150	150	700	150
Direct current (constant voltage)				
No more than 50 hp				
No code letter	150	150	250	150
More than 50 hp				
No code letter	150	150	175	150

NOTE: Rating or Setting for Individual Motor Circuit. The motor branch-circuit short-circuit and ground-fault protective device shall be capable of carrying the starting current of the motor. The required protection shall be considered as being obtained where the protective device has a rating or setting not exceeding the values given in the above table.

An instantaneous trip circuit breaker shall be used only if adjustable, if part of a combination controller having motor-running overload and also short-circuit and ground-fault protection in each conductor, and if the combination is especially identified.

(b) Two or more motors and their control equipment shall be permitted to be connected to a single branch-circuit provided the rating or setting of the overcurrent protective device shall be as low as practicable, and shall not exceed the values in Table 6-5(b) for the smallest conductor in the circuit.

Table 6-5(b) Relationship Between Conductor Size and Maximum Rating or Setting of Short-Circuit Protective Device for Power Circuits

Conductor Size AWG	Max. Rating 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

6-6 Motor Overload.

(a) Overload devices shall be provided to protect each motor, motor controller, and branch-circuit conductors against excessive heating due to motor overloads or failure to start.

(b) 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.

(c) The minimum number and location of running overcurrent units shall be determined from Table 6-6(c).

Table 6-6(c) Running Overcurrent 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 the *National Electrical Code*, Section 430-37.

6-7 Motor Overload, Special Duty. Short-time rated motors or high-reversing duty motors which 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.

6-8 Resistance Heating Branch Circuits.

(a) 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.

(b) 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.

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

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

6-9 Control Circuit Conductors.

(a) *General.* A control circuit tapped from the load side of a 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 section. 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).

(b) *Conductor Protection.*

(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 13-1(b).

(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 (1) and (2) above: Conductors which do not extend beyond the enclosure shall be considered as 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 13-1(b).

Exception No. 2 for (1) and (2) above: Conductors of No. 14 and larger which extend beyond the enclosure shall be considered as 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 13-1(b).

Exception No. 3 for (1) and (2) above: Conductors supplied by the secondary side of a single-phase transformer having a 2-wire (single-voltage) secondary shall be considered as protected by overcurrent protection provided on the primary (supply) side of the transformer, provided this protection is in accordance with Section 6-12 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 (1) and (2) above: Conductors of control circuits shall be considered as 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.

6-10 Lighting Branch Circuits. Overcurrent protection for lighting branch-circuits shall not exceed 15 amperes.

6-11 Power Transformer. As used in this section, 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.

(a) *Primary.* Each transformer 600 volts or less 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 section.

Exception No. 3: As provided in (b) below.

(b) *Primary and Secondary.* A transformer, 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 six times the rated current of the transformer for transformers having not more than 6 percent impedance, and not more than four 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.

6-12 Control Circuit Transformer.

(a) Where a control circuit transformer is provided, the transformer shall be protected in accordance with Table 6-12.

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.

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

(c) 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 6-12, a single overload protective device complying with Table 6-12 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 6-12 for the rating of the control transformer.

(d) Control circuit voltage derived from a power transformer shall be permitted.

6-13 Common Overcurrent Device. The use of the same overcurrent device to provide the protection called for in Sections 6-9, 6-10, 6-11, and 6-12 shall be permitted.

6-14 Undervoltage Protection.

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

(b) The electrical equipment shall be so designed as to prevent automatic restart of any machine motion or

Table 6-12 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.

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.

(c) 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 (limit switches, relays, pushbuttons, etc.).

6-15 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 is not required.

6-16 Motor Field or Tachometer Loss. DC motor systems shall be provided with devices to prevent destructive overspeed as a result of field or tachometer loss.

Chapter 7 Control Circuits

7-1 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 Section 2-4(a) shall apply.

7-2 Control Circuit Voltages.

(a) Alternating-current (ac) control voltage shall be 120 volts or less, single phase, obtained 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 when 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 electro-mechanical magnetic device having an inrush current exceeding 20 amperes at 120 volts shall be permitted to be energized at line voltage through relay contacts. The relay coil shall be connected to the control circuit.

(b) 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.

7-3 Grounding of Control Circuits. Grounded or ungrounded control circuits shall be permitted as provided in Section 17-7. Ground faults on any control circuit shall not cause unintentional starting or dangerous movements, or prevent stopping of the machine.

7-4 Connection of Control Devices.

(a) All operating coils of electro-mechanical 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: Electrical interlock contacts on multispeed motor controllers where the wiring to these contacts does not extend beyond the control enclosure.

Exception No. 2: Overload relay contacts where the wiring to these contacts does not extend beyond the control enclosure.

Exception No. 3: Contacts of multipole control circuit switching devices that simultaneously open both sides of the control circuit.

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

Exception No. 5: Solenoid test switching device contacts in ungrounded circuits.

Exception No. 6: 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. 7: "Run" pushbuttons for two-hand operation, such as for presses having ground detection circuits and overcurrent protection in each conductor.

(b) Contacts shall not be connected in parallel to increase ampacity.

7-5 Stop Circuits.

(a) Stop functions shall be initiated through de-energization rather than energization of control devices.

(b) Stop functions shall override their related start functions.

(c) Each machine shall incorporate at least one emergency stop device which, when actuated, shall stop all machine motions without creating other hazards.

Exception: Where an emergency stop device would exactly duplicate the function of the stop device(s), a separate emergency stop device shall not be required.

(d) All machine motions stopped by emergency stop function or other stop functions shall be restartable only by deliberate operator action. The resetting of the emergency stop function or stop function shall not restart any part of the machine.

7-6 Cycle Start.

(a) The start of a cycle or operation shall only be possible where all the safety measures for personnel, the machine, and the work in progress are fulfilled.

(b) Suitable interlocks shall be provided to secure correct sequential starting of cycles and operations. When necessary for set-up purposes, individual functioning shall be permitted provided that the interlocks for the safety of personnel shall still be effective.

7-7 Jog Circuits. Jog circuits, where used, shall be designed to prevent continuous run or automatic operation.

7-8 Mode Selection. Mode selection alone shall not initiate operation. A separate action by the operator shall be required before a machine will restart or cycle:

(a) After mode selection.

(b) After restoration of control voltage following a power failure or a stop condition.

7-9 Sequence Control by Pressure Switches. Pressure switches alone shall not be used to enable the next predetermined operation.

7-10 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.

7-11 Machinery Door Interlocking. Hinged or sliding doors providing ready access to compartments containing belts, gears, or other moving parts which 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.

7-12 Motor Contactors and Starters. Motor contactors and starters which initiate opposing motion shall be both mechanically and electrically interlocked to prevent simultaneous operation.

7-13 Relays and Solenoids. Relays and solenoids which are mechanically interlocked shall be electrically interlocked.

Chapter 8 Control Equipment

8-1 Connections. Means for making conductor connections shall be provided on or adjacent to all control devices mounted in the control enclosure.

8-2 Subpanels. Subpanels with concealed or inaccessible internal wiring or devices shall be mounted and wired so as to be removable.

8-3 Manual and Electro-Mechanical Motor Controllers.

(a) Each motor controller shall be identified and shall be capable of starting and stopping the motor(s) which 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 ⅛ HP or larger. The motor controller shall be sized in accordance with Table 8-3(a).

Exception: Other sizes shall be permitted provided they are identified as being suitable for the intended use.

NOTE: See definition of Identified in Appendix A.

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

Table 8-3(a)
Horsepower Ratings for Three-Phase, Single-Speed Full Voltage Magnetic Controllers for Nonplugging and Nonjogging Duty

Size of Motor Controller	Service-Limit Current Rating Amperes*	Three-Phase Horsepower at 200 Volts	230 Volts	460/575 Volts
00	11	1½	1½	2
0	21	3	3	5
1	32	7½	7½	10
2	52	10	15	25
3	104	25	30	50
4	156	40	50	100
5	311	75	100	200
6	621	150	200	400
7	932	—	300	600
8	1400		450	900
9	2590	-	800	1600

Reference ANSI/NEMA ICS-2-1978, Table 2-321-1.
*The service-limit current ratings shown in Tables 8-3(a) and 8-3(c) represent the maximum rms current in amperes which the controller may be expected to carry for protracted periods in normal service.

(c) 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 8-3(c).

Exception: Other sizes shall be permitted provided they are identified as being suitable for the intended use.

NOTE: See definition of Identified in Appendix A.

Table 8-3(c)
Horsepower Ratings for Three-Phase, Single-Speed Full Voltage Magnetic Controllers for Special Duty Applications

Size of Controller	Continuous Current Rating* Amperes	Horsepower at 60 Hertz 200 Volts	230 Volts	460 or 575 Volts	Service-limit Current Rating** Amperes
0	18	1½	1½	2	21
1	27	3	3	5	32
2	45	7½	10	15	52
3	90	15	20	30	104
4	135	25	30	60	156
5	270	60	75	150	311
6	540	125	150	300	621
9	2250		800	1600	2590

Reference ANSI/NEMA ICS 2-1978, Table 2-321-3.
NOTE: Refer to ANSI/NEMA ICS 2-1978 for horsepower ratings of single-phase, reduced voltage, or multispeed motor controller application.
*The continuous-current ratings shown in Tables 8-3(a) and 8-3(c) represent the maximum rms current, in amperes, which the controller may be expected to carry continuously without exceeding the temperature rises permitted by Part ICS 1-109 of NEMA Standards Publication No. ICS 1.
**The service-limit current ratings shown in Tables 8-3(a) and 8-3(c) represent the maximum rms current, in amperes, which 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.

(d) 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.

8-4 Marking on Motor Controllers. A controller for a motor rated ⅛ 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.

Chapter 9 Control Enclosures and Compartments

9-1 Type.

(a) Enclosures and compartments shall be nonventilated and constructed to exclude such materials as dust, flyings, oil, and coolant.

Exception: Equipment requiring ventilation shall be permitted to be:

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

2. housed in a separate ventilated enclosure or compartment.

(b) Any ventilating openings shall be designed to prevent the entrance of any deleterious substance normal to the operating environment.

9-2 Nonmetallic Enclosures. Nonmetallic enclosures identified for the purpose shall be permitted. For grounding provisions see Section 17-3.

9-3 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 to other compartments of the machine which are not clean and dry.

9-4 Wall Thickness. The walls of compartments shall not be less than the following: No. 14 MSG gage for sheet steel; ⅛ in. (3.2 mm) for cast metal; or 3/32 in. (2.38 mm) for malleable iron.

9-5 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.

9-6 Doors. All enclosures or compartments shall have hinged doors which 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 Section 9-4. The width of doors shall not exceed 36 in. (910 mm).

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

9-7 Gaskets. Where gaskets are used they shall be of an oil-resistant material and shall be securely attached to the door or enclosure.

9-8 Interlocks. Any door(s) which 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 need not be disconnected provided that the circuit conductors are identified with a yellow colored insulation as described in Section 14-1(a) and a warning marking is attached to the door in accordance with Section 2-4(a).

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 Section 2-4(b).

Exception No. 4: Where the motor(s) are two horsepower or less, an external, non-interlocked disconnecting means shall be permitted provided that the disconnecting means is within sight 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.

9-9 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.

Chapter 10 Location and Mounting of Control Equipment

10-1 General Requirements.

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

(b) Pipe lines, 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.

10-2 Control Panels.

(a) 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.

(b) 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.

(c) Terminal blocks shall be mounted to provide unobstructed access to the terminals and their conductors.

(d) 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.

(e) 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.

10-3 Control Panel Enclosure. The enclosure shall be mounted in such a manner and position as to guard it against oil, dirt, coolant, and dust, and to minimize the possibility of damage from floor trucks or other moving equipment.

10-4 Clearance in Enclosures.

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

(b) Exposed, nonarcing, bare, live parts within an enclosure or compartment shall have an air space between them and the uninsulated walls of the enclosure or compartment, including conduit fittings, of not less than ½ in. (12.7 mm). Where barriers between metal enclosures or compartments and arcing parts are re-

quired, they shall be of flame-retardant, noncarbonizing insulating materials.

10-5 Machine Mounted Control Equipment.

(a) Control equipment such as limit switches, brakes, solenoids, position sensors, etc., shall be mounted rigidly in a reasonably dry and clean location, shall be protected from physical damage, and shall be free from 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, proximity switches, etc. provided with an identified cable need not be provided with provisions for termination of conduit.

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

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

10-6 Rotary Control Devices. Devices such as potentiometers and selector switches having a rotating member shall be mounted so as to prevent rotation of the stationary member. Friction alone is not sufficient.

Chapter 11 Operator's Control Stations and Equipment

11-1 Pushbuttons, Selector Switches, Indicating Lights.

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

Exception: Non-oiltight pushbutton and selector switch operators shall be permitted on machines where identified for the environment.

(b) Pushbutton operators, indicating (pilot) light lenses, and illuminated pushbutton lenses shall be color coded in accordance with Table 11-1.

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

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

3. Pushbuttons which 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.

4. Pushbuttons which 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.

5. 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 pendent station need not be colored red.

(c) Emergency pushbutton operators shall be of the palm or mushroom type.

(d) Pushbutton operators used to initiate a stop function shall be of the extended operator or mushroom head types.

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

Exception: Mushroom-type operators shall be permitted to initiate start functions when installed in accordance with Section 11-3.

Table 11-1
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. (use of RED illuminated pushbutton shall not be permitted for emergency stop)
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 which 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

Table 11-1(continued)
Color Coding for Pushbuttons, Indicator (Pilot) Lights, and Illuminated Pushbuttons

Color	Device Type	Typical Function	Examples
	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; Inching or jogging.
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 (/).

11-2 Emergency Stop Controls.

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

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

11-3 Two-Hand Control. Two-hand control, where required, shall:

(a) Be protected against unintentional operation.

(b) Have the pushbutton contacts connected in series and shall be arranged by design and construction or separation, or both, to require the concurrent use of both hands to initiate the machine operation.

(c) Incorporate an anti-repeat feature for machines which would present a hazard if an unintended repeat cycle occurred.

NOTE: See ANSI B11 series standards.

11-4 Foot-Operated Switches.

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

11-5 Control Station Enclosures. All operator control station enclosures shall be dust-, moisture-, and oiltight.

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

11-6 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 pendent stations.

11-7 Legends. A legend shall be provided for each control station component to identify its function and located so that it can be read easily by the equipment operator from the normal work position.

11-8 Location of Control Stations.

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

(b) 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.

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

11-9 Pendent Stations.

(a) Pendent operator control station enclosures shall be oiltight.

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

(c) Pendent pushbutton stations shall be supported by suitable means other than the flexible electrical conduit or multiconductor cable.

(d) Grounding and bonding shall comply with Sections 17-2, 17-3, 17-4, and 17-6.

Chapter 12 Accessories and Lighting

12-1 Attachment Plugs and Receptacles External to the Control Enclosure.

(a) Attachment plugs and receptacles shall be of a locking type to prevent accidental disconnections, and approved for the voltage applied. Where used on 300 volts or over, they shall be skirted and constructed to contain any arc generated when a connection is made or broken.

(b) 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.

(c) 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.

12-2 Receptacles Internal to the Control Enclosure.

(a) Receptacles internal to the control enclosure shall be permitted only for maintenance equipment and shall be of the parallel-blade grounding type rated 125 volts, 15 amperes.

(b) Receptacles shall be supplied from a 120 volt ac source and shall have individual overcurrent protection not to exceed 15 amperes.

(c) The source of power shall be the equipment control transformer, a separate isolating transformer, or the maintenance lighting circuits permitted in Sections 12-3(b)(3) and (b)(5).

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

12-3 Control Panel, Instrument, and Machine Work Lights.

(a) The lighting circuit voltage shall not exceed 150 volts between conductors.

(b) Lights shall be supplied from one of the following sources:

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

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

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

4. Where the motor(s) on the machine total two horsepower or less, it shall be permitted to connect the machine worklight to the plant lighting circuit.

5. 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.

6. 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.

(c) The conductors to stationary lights used as an integral part of the machine shall be Type MTW, and the conductors within the fixtures shall not be smaller than No. 18 AWG.

(d) Flexible cords shall be Type SO, STO, SJO, or SJTO and shall not incorporate in-line switches.

(e) Grounding shall comply with the provisions of Section 17-8.

(f) Lampholders shall be identified and shall not incorporate a switch or receptacle.

(g) Stroboscopic effects from lights shall be avoided.

(h) Reflectors and protectors shall be supported by a bracket and not the lampholder.

Chapter 13 Conductors

13-1 Power and Control.

(a) Conductors (other than those permitted in Section 13-2) shall conform to one of the following:

1. Machine wire shall be Type MTW as specified in Section 13-3.

Exception No. 1: Conductors with insulation characteristics equivalent to those given in Section 13-3(b) and (c) and with strandings other than those specified in Table 13-1(a) shall be permitted on individual devices purchased completely wired (i.e., motor starters, etc.).

Exception No. 2: Where subject to temperatures, environment, voltages, or flexibility exceeding the limits for Type MTW, conductors having suitable characteristics shall be used.

2. Multiconductor flexible cords, Type SO, STO, SJO, or SJTO.

3. Special multiconductor control cables having individual conductors of a type specified in Section 13-3 and an identified jacket.

4. Mineral-insulated metal-sheath cable, Type MI.

Exception: The marking specified in Section 13-3(d) shall be permitted on the outer surface of the jacket.

(b) Conductors shall not be smaller than:

1. Power circuits ..... No. 14

2. Lighting and control circuits on the machine and in raceways ..... No. 16

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

Table 13-1(a)
Single Conductor Construction — Type MTW

Wire Size AWG MCM	Thickness of Insulation in Mils		Minimum Stranding	
	A	B	Nonflexing	Flexing
22	30	15	7[a]	[c]
20	30	15	10[a]	10[b]
18	30	15	16[a]	16[b]
16	30	15	19[a]	26[b]
14	30	15	19[a]	41[b]
12	30	15	19[a]	65[b]
10	30	20	19[a]	104[b]
8	45	30	19[a]	[c]
6	60	30	19[a]	[c]
4-2	60	40	19[a]	[c]
1-4/0	80	50	37[a] (19[d])	[c]
250-500	95	50	61[a] (37[d])	[c]

([a]) ASTM designation B-8, Class C (1977).
([b]) ASTM designation B-174, Class K (1976).
([c]) Nonflexing construction shall be permitted for flexing service.
([d]) Shall be permitted.

3. Control circuits on panels ..... No. 18

4. Electronic, precision, and static control ..... see Section 13-2.

Table 13-1(c) Conductor Ampacity

Conductor Size AWG	Ampacity In Cable or Raceway	Ampacity In Control Enclosure	Conductor Size AWG or MCM	Ampacity In* Cable or Raceway	Ampacity In* Control Enclosure
30		0.5	00	145	225
28		0.8	000	165	260
26		1	0000	195	300
24	2	2	250	215	340
22	3	3	300	240	375
20	5	5	350	260	420
18	7	7	400	280	455
16	10	10	500	320	515
14	15	20	600	355	575
12	20	25	700	385	630
10	30	40	750	400	655
8	40	55	800	410	680
6	55	80	900	435	730
4	70	105	1000	455	780
3	80	120			
2	95	140			
1	110	165			
0	125	195			

*Sizing of conductors in wiring harnesses or wiring channels shall be based on the ampacity for cables.

(c) The continuous current carried by conductors shall not exceed the values given in Table 13-1(c).

(d) Motor circuit conductors shall have an ampacity not less than 125 percent of the full-load current rating of the highest rated motor in the group plus the sum of the full-load current ratings of all other connected motors and apparatus in the group which may be in operation at the same time.

(e) 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 highest rated motor plus the sum of the full-load current ratings of all other connected motors and apparatus which may be in operation at the same time.

(f) The maximum size of a conductor [selected from Table 13-1(c)] connected to a motor controller shall not exceed the values given in Table 13-1(f).

Table 13-1(f) 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 2-1978, Table 2, 110-1.

13-2 Electronic, Precision, and Static Control.

(a) Conductors used to connect electronic, precision, static, or similar devices or panels shall be Type MTW in accordance with Table 13-1(a), or shall conform to the following:

1. Conductor insulation shall be identified and adequate for the voltage on that conductor. Where the conductors are run with or adjacent to other conductors, all conductors shall be insulated for the maximum voltage involved.

Exception: Bare conductors (such as resistor and capacitor leads, jumpers between adjacent terminals, etc.) shall be permitted to be used where the method of securing ensures adequate electrical clearance.

2. Conductors shall be of annealed stranded copper.

Exception: Solid conductors Nos. 24-30, within the control enclosure and not subject to flexing, shall be permitted.

3. Printed circuit boards of flame-retardant material shall be permitted in place of conventional conductor assemblies.

4. Shielded cable, single or multiple conductor, shall consist of stranded copper wire not smaller than No. 25 AWG for a single conductor used in sub-assemblies and not smaller than No. 22 AWG for all other uses. The conductor(s) shall have insulation and gage in accordance with (a) and (1) above, a metallic shield, and an oil and moisture resistant covering such as vinyl plastic.

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

(b) Size of conductors.

1. Conductors in raceways shall not be smaller than No. 18.

Exception: In a jacketed, multiconductor cable assembly, No. 24 or larger conductors shall be permitted.

2. Conductors within the control enclosures shall not be smaller than No. 26.

Exception: For short jumpers and special-wiring applications (e.g., solderless wrapped or wire-clip type connection or shielded conductors) conductors not smaller than No. 30 shall be permitted.

(c) The continuous current carried by conductors shall not exceed the values given in Table 13-1(c).

13-3 Machine Wire Type MTW. Type MTW wire shall conform to the following construction:

(a) Annealed stranded copper wire with construction for non-flexing and flexing service in accordance with Table 13-1(a).

Exception: Multiconductor cable stranding for constant flexing shall conform to Table 13-3(a).

(b) Flame-retardant, moisture-, heat-, and oil-resistant thermoplastic insulation suitable for use at maximum operating temperatures of 90°C in dry locations and 60°C where exposed to moisture, oil, or coolant.

(c) Insulation thickness in accordance with Table 13-1(a).

Exception: Wire Nos. 14-10 with 45 mils insulation and Wire No. 8 with 60 mils insulation shall be permitted.

NOTE: As defined in Table 310-13 of the *National Electrical Code*, Type MTW wire having a nominal thickness indicated in Column (A) consists of a conductor and thermoplastic insulation. Type MTW wire in Column (B) consists of a conductor and thermoplastic insulation having a nominal thickness indicated in Column (B) and covered with a nylon or equivalent jacket.

(d) A durable surface marking of "MTW," and where the conductor stranding is that shown as flexing in Table 13-1(a), "Flexing" or "Class K."

Table 13-3(a) Multiconductor Cable Stranding (Constant Flexing Service)

Conductor Size AWG	No. of Strands
18	41
16	65
14	41
12	65
10	105

Chapter 14 Wiring Methods and Practices

14-1 General Requirements.

(a) Conductors shall be identified at each termination to correspond with the identification on the diagrams and shall be color coded as follows:

BLACK — Line, load, and control circuits at line voltage.

RED — AC control circuits, at less than line voltage.

BLUE — DC control circuits.

YELLOW — Interlock control circuits supplied from an external power source.

GREEN (with or without one or more yellow stripes) — Equipment grounding conductor where insulated or covered.

WHITE or NATURAL GRAY — Grounded circuit conductor.

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

Exception No. 2: Where insulation is used that is not available in the colors required.

Exception No. 3: Where multiconductor cable is used.

Exception No. 4: Conductors used to connect electronic, precision, static, or similar devices or panels.

Exception No. 5: Where local conditions require that the control circuit be grounded, it shall be sufficient to use 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.

Exception No. 6: Additional colors shall be permitted to be used to facilitate identification between control panels and devices on the equipment; however, black shall be used for all wiring at line voltage.

(b) 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, and shall be insulated with oil-resistant electrical tape.

(c) Terminals on terminal blocks shall be plainly identified to correspond with markings on the diagrams.

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

(e) 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 that they will not slip off the wire.

(f) Terminal blocks shall be wired and mounted so that 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.

14-2 Panel Wiring.

(a) 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.

(b) Where back connected control panels are used, access doors or swingout panels which swing about a vertical axis shall be provided.

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

14-3 Machine Wiring.

(a) Conductors and their connections external to the control panel enclosure shall be totally enclosed in suitable raceways or enclosures as described in Chapter 15, unless otherwise permitted in this section.

(b) Fittings used with raceways or multiconductor cable shall be liquidtight.

Exception: Liquidtight fittings are not required where flexible metal conduit is permitted by Exception to Section 14-3(d).

(c) Liquidtight flexible metal conduit or multiconductor cable shall be used where necessary to employ flexible connections to pendent pushbutton stations. The weight of pendent stations shall be supported by chains or wire rope external to the flexible conduit or multiconductor cable.

(d) Liquidtight flexible metal 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.

(e) Connections to frequently moving parts shall be made with conductors for flexing service as shown in Table 13-1(a). 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.

(f) 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, proximity switches, etc., provided with an identified cable need not be provided with provisions for termination of conduit.

(g) All conductors of any ac circuit shall be contained in the same raceway.

(h) Conductors connected in ac circuits and conductors connected in dc circuits shall be permitted in the same raceway regardless of voltage, provided they are all insulated for the maximum voltage of any conductor in the raceway.

(i) 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.

(j) 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.

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

(l) Where liquidtight flexible metal conduit is used for flexible applications, fittings shall be identified.

14-4 Wire Connectors and Connections.

(a) Pressure connectors shall be used to connect conductors to devices with lug-type terminals which 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 which can be removed for bench service [see Section 14-4(b)].

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.

(b) Soldered connections shall conform to the following:

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

2. 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.

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

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

5. Insulation shall not be damaged by soldering.

6. Components which may be damaged by heat shall be suitably shielded from heat during soldering.

Chapter 15 Raceways, Junction and Pull Boxes

15-1 General Requirements.

(a) 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.

(b) Drain holes of ¼ 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 Chapter 17 for acceptable means of equipment grounding.

15-2 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 and/or cables used.

15-3 Rigid Metal Conduit and Fittings.

(a) Rigid metal conduit and fittings shall be of galvanized steel, meeting the requirements of ANSI Standards C80.1-1977, *Specification for Rigid Steel Conduit, Zinc Coated*, and ANSI/NEMA FB 1-1977 (Rev. Dec. 1980), *Fittings and Supports for Conduit and Cable Assemblies*, or of a corrosion-resistant material suitable for the conditions. Dissimilar metals in contact which would cause galvanic action shall not be used. Conduit shall be protected against corrosion except at the threaded joints.

(b) Conduit smaller than ½ in. electrical trade size shall not be used.

(c) Conduit shall be securely held in place and supported at each end.

(d) Fittings shall be threaded unless structural difficulties prevent assembly. When threadless fittings must be used, conduit shall be securely fastened to the equipment.

(e) Running threads shall not be used.

(f) 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 as to afford 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.

(g) Conduit bends shall be so made that the conduit will not be injured, and that the internal diameter of the conduit will not be effectively reduced. The radius of the curve of any field bend shall not be less than shown in Table 15-3(g).

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

15-4 Intermediate Metal Conduit. Intermediate metal (steel) conduit shall be permitted and shall be installed in conformance with the provisions of Sections 15-3(b) through (h).

Table 15-3(g)
Minimum Radius of Conduit Bends

Size of Conduit (In.)	Radius of Bend Done by Hand (In.)[1]	Radius of Bend Done by Machine (In.)[2]
½	4	4
¾	5	4½
1	6	5¼
1¼	8	7¼
1½	10	8¼
2	12	9½
2½	15	10½
3	18	13
3½	21	15
4	24	16
4½	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.

15-5 Liquidtight Flexible Metal Conduit and Fittings.

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

(b) Fittings shall be of metal and shall be designed for use with liquidtight flexible metal conduit.

(c) Liquidtight flexible metal conduit smaller than ⅜ in. electrical trade size shall not be used.

(d) Liquidtight flexible metal conduit shall be permitted to be of the extra flexible construction.

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

15-6 Liquidtight Flexible Nonmetallic Conduit and Fittings.

(a) Liquidtight flexible nonmetallic conduit is a raceway of circular cross section having a smooth inner surface with integral reinforcement within the conduit wall. This conduit is oil- and water-resistant and flame-resistant which, with fittings, is approved for the installation of electrical conductors. Conduit that has been recognized as having suitable physical characteristics are:

1. Those having a smooth seamless inner core and a cover bonded together and having one or more reinforcement layers between the core and cover; or

2. Those having a smooth inner surface and a reinforcement imbedded in the conduit wall.

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

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

(d) Fittings shall be suitable for use with liquidtight flexible nonmetallic conduit.

(e) Liquidtight flexible nonmetallic conduit smaller than ⅜ in. trade size shall not be used.

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

15-7 Flexible Metal (Nonliquidtight) Conduit and Fittings.

(a) Flexible metal conduit shall consist of flexible metal tubing or woven wire armor.

(b) Fittings shall be of metal and shall be designed for use with flexible metal conduit.

(c) Flexible metal conduit smaller than ⅜ in. electrical trade size shall not be permitted.

Exception: Thermocouples and other sensors.

15-8 Wireways.

(a) Exterior wireways shall be permitted where rigidly supported and clear of all moving or contaminating portions of the machine.

(b) Metal thickness shall not be less than No. 14 MSG.

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

(d) Where wireway is furnished in sections, the joints between sections shall fit tightly, but need not be gasketed.

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

15-9 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 so arranged that they will not be subject to physical damage.

15-10 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.

15-11 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.

Chapter 16 Motors and Motor Compartments

16-1 Each motor and its associated couplings, belts, and chains shall be mounted where they are accessible for maintenance and not subject to damage.

16-2 Mounting Arrangement.

(a) The motor mounting arrangement shall be such that all motor hold-down bolts can be removed and re-

placed and terminal boxes reached. Unless bearings are permanently sealed, provision shall be made for lubricating the bearings. The motor nameplate shall indicate where permanently sealed bearings are used.

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

(c) All motor-driven couplings, belts, and chains shall be easily replaceable.

(d) Pulley hubs on belted drives shall not extend beyond the end of the motor shaft.

16-3 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.

16-4 Motor Compartments. Motor compartments shall be clean and 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.

16-5 Marking on Motors. Motors shall be marked in accordance with Section 430-7 of NFPA 70-1984, *National Electrical Code*.

Chapter 17 Grounded Circuits and Equipment Grounding

17-1 General. This chapter applies to grounded circuits and the protective or grounding circuit of the equipment. The grounding circuit consists of conductors and/or structural parts of the electrical equipment and machine which are all electrically connected or bonded together at a common point.

17-2 Grounding Conductors.

(a) Conductors used for grounding and bonding purposes shall be copper. Stipulations on stranding and flexing as outlined in this standard shall apply. [See Section 13-3 and 14-3(f).]

(b) Grounding conductors shall be insulated, covered, or bare and shall be protected against physical damage. Insulated or covered grounding conductors shall be identified with a continuous green color with or without one or more yellow stripes.

(c) The minimum size of the grounding conductor shall be as shown in Table 17-2(c). Column "A" indicates maximum rating or setting of the overcurrent device in the circuit ahead of the equipment.

(d) It is 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.

Table 17-2(c)
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 pendent equipment.

17-3 Equipment Grounding. The machine and all exposed, non-current carrying conductive parts, material, and equipment including metal mounting panels which are likely to become energized and are mounted in nonmetallic enclosures shall be effectively grounded.

17-4 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.

17-5 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 is used as the disconnecting means, Section 5-11(f) shall apply.

17-6 Continuity of the Grounding Circuit.

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

(b) 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.

(c) 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.

(d) Portable, pendent, 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.

(e) For circuits that cannot be classified as MELV (*see Section 4-3*) and are connected to devices attached to lids, doors, cover plates, etc., which do not meet the re-