NFPA

79

ELECTRICAL STANDARD FOR

METALWORKING MACHINE TOOLS AND PLASTICS MACHINERY 1980

NATIONAL FIRE PROTECTION ASSOCIATION, INC.
470 Atlantic Avenue, Boston, MA 02210

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Electrical Standard for Metalworking Machine Tools and Plastics Machinery

NFPA 79-1980

1980 Edition of NFPA 79

This 1980 edition of NFPA 79 was prepared by the Committee on Metalworking Machine Tools and Plastics Machinery and was adopted by the National Fire Protection Association, Inc. at its 1980 Annual Meeting in Boston, Massachusetts on May 20, 1980. It supersedes the 1977 edition. It was released by the Standards Council on June 11, 1980.

The 1977 edition of this standard was approved by the American National Standards Institute under date of July 18, 1977 and designated ANSI/NFPA 79-1977. The 1980 edition is being submitted for similar approval. The ANSI designation and date of approval will be printed on the front cover of copies of this edition printed after approval has been received.

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, and 1977 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.

NFPA 79 - 1980
ERRATA
Fire News, 1982

Errata

NFPA 79-1980
Electrical Standard for Metal-Working Machine Tools and Plastics Machinery

The Committee on Electrical Metalworking Machining Tools and Plastics Processing Machinery notes the following errors in NFPA 79-1980, Metalworking Machine Tools and Plastics Machinery.

Page	Section/Article	Remarks
32	9-1 paragraphs (f) & (g)	in paragraph (f) change Table 9-1 (F) to Table 9-1 (b) in paragraph (g) change Table 9-1 (f) to Table 9-1 (b)

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Committee on Metalworking Machine Tools and Plastics Machinery

R.H. Butterfield, *Chairman*
Caterpillar Tractor Co.

J. F. Bloodgood, *Secretary*
Giddings and Lewis Electronics
(Alternate to J. B. Deam)

Lucas G. Ananian, General Motors Corp.

B. L. Auger, Huntington Woods, MI
(Rep. International Assn. Electrical Inspectors)

A. T. Bacheler, Westinghouse Electrical Corp.

John B. Deam, National Machine Tool Builders Assn.

Howard Granquist, Waterbury Cos., Inc.

R. J. Kasper, Industrial Risk Insurers

Kenneth W. Long, Underwriters Laboratories Inc.

Sidney W. Nelson, Nelcor, Inc.

Walter C. Painter, Rockwell International
(Rep. Power Tool Institute)

James C. Sharp, International Brotherhood of Electrical Workers

Dale C. Walker, Square D Co.
(Rep. National Electrical Manufacturers Assn.)

D.L. Winsted, Cincinnati Milacron
(Rep. Society of the Plastics Industry)

Alternates

W. F. Born, Westinghouse Electric Corp.
(Alternate to D. C. Walker)

Robert I. Clift, Industrial Risk Insurers
(Alternate R. J. Kasper)

Robert D. Jordan, Minster Machine Co.
(Alternate to J. B. Deam)

Donn C. Lounsbury, Davis-Standard Division of Crompton and Knowles
(Alternate to D. L. Winsted)

J. E. Menzies, General Motors Corp.
(Alternate to D. C. Walker)

L. Stackhouse, Jr., Emerson Electric Co.
(Alternate to W. C. Painter)

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.

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Electrical Standard for
Metalworking Machine Tools and Plastics Machinery

NFPA 79-1980

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 sacrifice deliberately 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 79-1980 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 of 1978 and through combined efforts of NFPA 79 committees and representatives of the Society of the Plastics Industry the scope was broadened to include such machinery in the 1980 edition.

Chapter 1 General

1-1 Purpose.

(a) The purpose of this Electrical Standard is to provide detailed information for the application to machine tools or plastics machinery of electrical apparatus 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.

1-2 Scope.

(a) The provisions of this standard apply to all electrical/electronic equipment, apparatus, systems, and wiring of a machine tool or plastics machinery, operating from a supply voltage of 600 volts or less, and commencing at the place of connection of the supply to the machine tool or plastics machinery electrical equipment.

(b) This standard shall not be considered adequate for machine tools or plastics machinery intended for use in areas defined as hazardous (classified) locations by the *National Electrical Code* (NFPA 70 — 1981).

(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) Machine tools or plastics machinery used in dwelling units.

(d) The installation of the machine tool or plastics machinery is covered by the *National Electrical Code* (NFPA 70 — 1981).

1-3 Definition of Metalworking Machine Tools or Plastics Machinery. For the purposes of this standard, 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; 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. See Appendix C for such types of plastics machinery.

NOTE: The general term "machine" shall be used throughout this standard to signify machine tool or plastics machinery.

1-4 Other Definitions. For purposes of this standard, definitions of some other terms are given in Appendix A.

1-5 Other Standards. Other organizations having standards which may provide additional information are listed in Appendix B.

1-6 Nominal Voltages. All voltages mentioned in this standard are nominal.

Chapter 2 Diagrams, Instructions, and Nameplates

2-1 Diagrams. Diagrams showing all of the electrical circuits on the machine shall be provided.

2-2 Instructions. Information referring to the installation, operation, and maintenance of the machine shall be furnished.

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

2-4 Machine Nameplate Data.

(a) A permanent nameplate listing supply voltage, phase, frequency, full-load current, ampere rating of largest motor or load, short-circuit interrupting capacity of the machine overcurrent protective device if furnished, and diagram number shall be attached to the control equipment enclosure or machine where plainly visible after installation.

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

Where more than one incoming supply circuit is to be provided, the nameplate shall state the above information for each circuit.

(b) Where overcurrent protection is provided in accordance with Section 4-2, the machine shall be marked "overcurrent protection provided at machine supply terminals."

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

2-6 Warning Marking.

(a) A warning marking shall be provided adjacent to the disconnect operating handle(s) if the disconnect(s) that are interlocked with the enclosure door do not de-energize all exposed live parts when the disconnect(s) are in the "off" position.

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

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 the motor nameplate or the connection diagram plate is not visible, an additional plate shall be provided where it can be easily read.

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

(d) All control panel devices shall be plainly identified with the same designation as shown on the diagrams.

Exception No. 1: Where the size or location of the devices makes individual identification impractical, group identification shall be used.

Exception No. 2: Machines on which the equipment consists only of a single motor, motor-controller, push-button stations, and work lights.

(e) All devices external to the control panel shall be identified by a nameplate with the same designation as shown on the diagrams, 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.

Chapter 3 Supply Circuit Disconnecting Means

3-1 General Requirements. A disconnecting means shall be provided for each incoming supply circuit.

3-2 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 3-3 through 3-10.

(b) An attachment plug in accordance with Section 3-11.

3-3 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 4.

3-4 Position Indication. The disconnecting means shall plainly indicate whether it is in the open or closed position.

3-5 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.

3-6 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.

3-7 Exposed Live Parts. With the disconnecting means open, there shall be no exposed live parts.

3-8 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: 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 B) 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.

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

3-9 Interlocking. Each disconnecting means shall be mechanically or electrically interlocked, or both, with the control enclosure doors.

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 2-6 shall apply.

Exception No. 2: Where an attachment plug is used as the disconnecting means in accordance with Section 3-11.

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 2-6 shall apply.

3-10 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 (1.98 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 "off" position.

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

3-11 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 or motors 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 readily accessible.

Diagram 4-1 Protection of Machine Electrical Circuits

TYPICAL DIAGRAMS–CONSULT TEXT

Line	Reference	Sing. Load	Multi-Load		
A	Supply NFPA 70, Article 670				
B	Disconnecting Means Chapter 3				
C	Overcurrent Protection (When Supplied) Section 4-2				
D	Additional Over-current Protection (As Required) Section 4-3				
E	Control Circuits Conductors-Sec 4-9 Transformer-Sec 4-12 Undervoltage-Sec 4-14				
F	Load Controllers and Power Transformers Sec 4-11, Sec 6-3				
G	Motor Overload Section 4-6				
H	Motors and Resistive Loads Chapter 14 Special Motor Overload Section 4-7				
	All Conductors- Ch 11	FIG I	FIG II	FIG III	FIG IV

Chapter 4 Protection

4-1 Machine Circuits. Diagram 4-1 shows typical circuits which are acceptable for protection of machine motors and controls. Protective interlocks are not shown.

Diagram 4-1 shows typical circuits which are acceptable for protection of machine motors, resistive heating loads, and controls.

4-2 Supply Conductor and Machine Overcurrent Protection. The overcurrent protection as shown in line C of Diagram 4-1, Figures I through IV inclusive, may or may not be furnished as part of the machine. Where furnished as a 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 2-4(b).

4-3 Additional Overcurrent Protection. The additional overcurrent protection shown in line D of Diagram 4-1, 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.

4-4 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 that of the conductor from which it is supplied, and (2) it is suitably protected from physical damage, and (3) is not over 25 ft (7.62 m) long, and (4) terminates in a single circuit breaker or set of fuses.

Table 4-5(a)1 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 approved for the purpose.

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, and (2) is not over 10 ft (3.05 m) long, and (3) does not extend beyond the control panel enclosure.

4-5 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 4-5(a). Where the overcurrent protection specified in the table is not sufficient for the starting current of the motor, it may 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.

(b) Two or more motors and their control equipment may be connected to a single branch circuit provided all of the following conditions are complied with:

(1) The rating or setting of the overcurrent protective device shall be as low as practicable, and shall not exceed the values in Table 4-5(b)(1) for the smallest conductor in the circuit.

(2) The motor and controller circuits shall be so arranged that a minimum number of branch-circuit overcurrent protective devices are used.

4-6 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. (305 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 4-6(c).

Table 4-5(b)(1) 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
00	600	300
000	700	350
0000	800	400

Table 4-6(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 undergrounded	1 in either conductor
1-phase ac or dc	2-wire, 1-phase ac or dc, one conductor grounded	1 in undergrounded conductor
1-phase ac or dc	3-wire, 1-phase ac or dc, grounded-neutral	1 in either undergrounded 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.

4-7 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.

4-8 Resistance Heating Branch Circuits. 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.

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.

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.

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

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.

4-9 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 11-1(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 11-1(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 11-1(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 4-12 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.

4-10 Lighting Branch Circuits. Overcurrent protection for lighting branch circuits shall not exceed 15 amperes.

4-11 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.

4-12 Control Circuit Transformer.

(a) Where a control circuit transformer is provided, the transformer shall be protected in accordance with Table 4-12.

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 a current ratings of these overload protective devices exceeds the current allowed in Table 4-12, a single overload protective device complying with Table 4-12 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 4-12 for the rating of the control transformer.

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

4-13 Common Overcurrent Device. The use of the same overcurrent device to provide the protection called for in Sections 4-9, 4-10, 4-11, and 4-12 shall be permitted.

Table 4-12 Control Transformer Overcurrent Protection (115 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.

4-14 Undervoltage.

(a) Undervoltage protection shall be provided for all machines on which a motion can be automatically initiated upon the return of power after an undervoltage condition.

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.

(b) 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, push-buttons, etc.).

4-15 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. If the power conversion equipment provides overload protection for the motor, additional overload protection is not required. DC motors shall be provided with devices to prevent destructive overspeed as a result of field or tach loss.

Chapter 5 Control Circuits

5-1 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 2-6 shall apply.

5-2 Control Circuit Voltages.

(a) Alternating-current (ac) control voltage shall be 115 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 115 volts, a seconday 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 115 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.

5-3 Grounding of Control Circuits. Grounded or ungrounded control circuits shall be permitted as provided for in Section 15-1.

5-4 Connection of Control Devices. All operating coils of electromechanical magnetic devices and indicator lamps (or transformer primary windings for indicator lamps) shall be directly connected to the same side of the control circuit. All control circuit contacts shall be connected between the coil and the other side of the control circuit.

Exception No. 1: 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.

5-5 Jog Circuits. Jog circuits, where used, shall be designed to prevent continuous run or automatic operation.

Chapter 6 Control Equipment

6-1 Connections. Means for making conductor connections shall be provided on or adjacent to all control devices mounted in the control enclosure.

6-2 Subpanels. Subpanels with concealed or inaccessible internal wiring or devices shall be mounted and wired so as to be removable.

6-3 Manual and Electro-Mechanical Motor Controllers.

(a) Each motor controller shall be capable of starting and stopping the motor or motors which it controls, and for alternating current motors shall be capable of interrupting the stalled rotor current of the motor or motors.

A controller rated in horsepower shall be used for a ⅛-horsepower or larger motor.

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

Table 6-3(c) Horsepower Ratings for Special Duty Motor Controller Applications*

Size of Motor Controller	Three-Phase Horsepower at		
	200 Volts	230 Volts	460/575 Volts
0	1½	1½	2
1	3	3	5
2	7½	10	15
3	15	20	30
4	25	30	60
5	60	75	150
6	125	150	300

*See ANSI/NEMA ICS 2-1978, Table 2, 321-3.

(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 6-3(c).

(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.

6-4 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 7 Control Enclosures and Compartments

7-1 Type. 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:

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

b. housed in a separate ventilated enclosure or compartment.

7-2. Nonmetallic Enclosures. Nonmetallic enclosures approved for the purpose shall be permitted. For grounding provisions see Section 15-3.

7-3 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.

7-4 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.

7-5 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.

7-6 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 7-4. The width of doors shall not exceed 36 in. (914 mm).

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

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

7-8 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 12-1 (a) and a warning marking is attached to the door in accordance with Section 2-6(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 2-6.

Chapter 8 Location and Mounting of Control Equipment

8-1 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.

8-2 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) The panel shall not be set to such depth from door frame or other projecting portion of machine as to interfere with inspection and servicing.

8-3. 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.

8-4 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 required, they shall be of flame-retardant insulating materials.

8-5 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, 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.

Exception: A solenoid sealed in an individual oil-filled container shall be permitted.

(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.

Chapter 9 Operator's Control Stations and Equipment

9-1 Pushbuttons, Selector Switches, Indicating Lights.

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

Exception: Non-oiltight pushbutton and selector switch operators shall be permitted on machines where the motor or motors total two horsepower or less.

(b) Pushbutton operators shall be color coded in accordance with Table 9-1(a).

Exception: "Stop" function operators of the wobblestick 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 9-3.

(f) Indicating (pilot) light lenses shall be color coded in accordance with Table 9-1(f).

(g) Illuminated operator lenses shall be color coded in accordance with Tables 9-1(a) and 9-1(f), as applicable.

9-2 Emergency Stop Controls.

(a) All machines shall incorporate one or more emergency stop controls which, upon momentary operation, shall stop all machine motions and, when actuated, shall not create other hazards.

Exception: Where emergency stop controls would exactly duplicate the stop function, a separate emergency stop shall not be required.

(b) All machine motions stopped by the emergency stop or stops shall be restartable only by deliberate action by the operator.

(c) Emergency stop controls shall be located at each operator control station and at other operating stations where emergency shutdown may be needed.

(d) Stop controls shall be continuously operable from all operating stations.

Table 9-1(a) Pushbutton Color Code

Color	Typical Function	Example
Red	Stop, Emergency Stop, Off	Stop of one or more motors; master stop; emergency stop.
Yellow	Return, Emergency Return	Return of machine elements to safe positon.
Green or Black	Start, On	Start of a cycle or a partial sequence; inching, jogging; start of one or more motors.
White, Gray or Light Blue	Any function not covered by the above colors	

Table 9-1(b) Indicating (Pilot) Light Lens Color Code

Color	Typical Function	Example
Red	Danger, Abnormal Condition, Fault Condition	Faults in air, water, lubricating or filtering systems; excess pressure or temperature; indication that a protective device has stopped the machine (because of an overload, overtravel or other failure).
Amber or Yellow	Attention, Caution, Marginal Condition	Automatic cycle running; some value (current, temperature) is approaching its permissible limit; ground-fault indication.
Green	Machine Ready	Machine ready for operation; all necessary auxiliaries functioning, units in starting position and hydraulic pressure or output voltage of a motor-generator in the specified range, etc.; cycle completed and machine ready to be restarted.
White or Clear	Normal Condition	Normal pressure of air, water, lubrication.
Blue	Any significant function not covered by the above colors	

9-3 Two-Hand Control. Two-hand control, where used, 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 presses, press brakes, and shears.

9-4 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.

(b) The switch actuating pedal shall have a nonslip contact area.

9-5 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 the motor or motors total two horsepower or less.

9-6 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.

9-7 Legend Plates. Legend plates shall be so located that they can be easily read by the machine operator.

9-8 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 he 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.

(d) Pendent operator control stations shall comply with grounding and bonding requirements of Sections 15-3 and 15-4.

9-9 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) Grounding and bonding shall comply with Sections 15-3 and 15-4.

Chapter 10 Accessories and Lighting

10-1 Attachment Plugs and Receptacles (External to 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) They shall be designed to prevent entrance of oil or moisture when in operating position, and 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.

10-2 Receptacles (Internal to Control Enclosure).

(a) Receptacles internal to 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 115 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 Section 10-3(b) (3) and (b) (5).

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

10-3 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.

(2) A grounded 115-volt machine control 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 or motors 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.

(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 15-2.

(f) Lampholders shall be approved for the purpose and shall not incorporate a switch or receptacle.

(g) Stroboscopic effects from lights shall be avoided.

Chapter 11 Conductors

11-1 Power and Control.

(a) Conductors (other than those permitted in Section 11-2) shall conform to one of the following:

(1) Machine wire shall be Type MTW as specified in Section 11-3.

Exception No. 1: Conductors with insulation characteristics equivalent to those given in Section 11-3(b) and (c) and with strandings other than those specified in Table 11-1(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 11-3 and a jacket suitable for the purpose.

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

Exception: The marking specified in Section 11-3(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 11-1(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	[c]
20	30	15	10	10[b]
18	30	15	16	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]
1-0000	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.

Table 11-1(b) Conductor Ampacity

Conductor Size AWG	Ampacity In		Conductor Size AWG or MCM	Ampacity In	
	Cable or Raceway	Control Enclosure		Cable or Raceway	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			

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

(4) Electronic, precision, and static control . . . . see Section 11-2.

(c) The continuous current carried by conductors shall not exceed the values given in Table 11-1(b).

(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 11-1(b)] connected to a motor controller shall not exceed the values given in Table 11-1(f).

11-2 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 11-1(a), or shall conform to the following:

(1) Conductor insulation shall be suitable for the purpose 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.

(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.

(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 (for example, solderless wrapped or wire-clip type connections 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 11-1(b).

11-3 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 11-1(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 11-1(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 11-1(a), "Flexing" or "Class K."

Table 11-1(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.

Chapter 12 Wiring Methods and Practices

12-1 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.

(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.

12-2 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.

12-3 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 13, 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 (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.

(e) Connections to frequently moving parts shall be made with conductors for flexing service as shown in Table 11-1(a). Flexible cable and conduit shall have vertical connections and shall be installed to avoid excessive flexing and straining.

Exception No. 1: Where subjected to temperatures exceeding the limits for liquidtight flexible metal conduit, flexible metal conduit shall be permitted.

Exception No. 2: 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.

(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.

Chapter 13 Raceways, Junction and Pull Boxes

NOTE: Raceways and junction boxes are provided for mechanical protection only. See Chapter 15 for acceptable means of equipment grounding.

13-1 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. (6.35 mm) shall be permitted in raceways, junction boxes, and pull boxes subject to accumulations of oil or moisture.

13-2 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.

13-3 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 and C80.4—1963 (R1974), or of a corrosion-resistant material suitable for the conditions.

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

(c) Fittings shall be threaded unless structural difficulties prevent assembly.

(d) Running threads shall not be used.

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

(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) Bends of conduit 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 the inner edge of any field bend shall not be less than shown in Table 13-3(g).

Table 13-3(g) Minimum Radii of Conduit Bends

Size of Conduit, In.	Minimum Radius of Conduit Bends, In.
½	4
¾	4½
1	5¾
1¼	7¼
1½	8¼
2	9½
2½	10½
3	13
3½	15
4	16
4½	20
5	24
6	30

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

13-4 Intermediate Metal Conduit. Intermediate metal (steel) conduit shall be permitted and shall be installed in conformance with the provisions of Section 13-3(b) through (h).

13-5 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 ½ in. electrical trade size shall not be used.

Exception: Liquidtight flexible metal conduit of ⅜ in. nominal trade size shall be permitted in lengths not in excess of 72 in. (1.83 m).

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