NFPA No.

79

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ELECTRICAL STANDARD FOR

METALWORKING MACHINE TOOLS 1973

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NATIONAL FIRE PROTECTION ASSOCIATION
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Official NFPA Definitions

Adopted Jan. 23, 1964: Revised Dec. 9, 1969. Where variances to these definitions are found, efforts to eliminate such conflicts are in process.

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Electrical Standard for
Metalworking Machine Tools

NFPA No. 79 — 1973

1973 Edition of No. 79

This edition of NFPA No. 79, adopted by the NFPA at its 1973 Annual Meeting in St. Louis, Missouri, supersedes the 1971 edition.

The 1971 edition of this standard was approved by the American National Standards Institute under date of January 25, 1973 and designated ANSI C113.1-1973. The 1973 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.

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*Nonvoting.

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.

Origin and Development of No. 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 when it was officially adopted. In 1965 a revised edition was adopted, reconfirmed in 1969, and in 1970 and 1971 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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Chapter

Electrical Standard for

Metalworking Machine Tools

NFPA No. 79 — 1973

PREFACE

A Metalworking Machine Tool, as covered by this Standard, is defined herein as follows:

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

Other types of electrically powered production and processing equipment are excluded, and their electrical equipment and installations should be judged under the general provisions of the National Electrical Code (NFPA No. 70 — 1971, ANSI C1-1971), rather than this Standard.

In September 1941, the 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 an 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 industrial 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 tool 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.

CHAPTER 100. GENERAL

100-1. Purpose.

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

100-3. Scope.

(a) The provisions of this Standard apply to all electrical/electronic equipment, apparatus, systems, and wiring furnished as a part of an industrial machine tool, commencing at the place of connection of the supply to the machine tool electrical equipment.

(b) The provisions of this Standard apply to electrical equipment for use on circuits which operate from a supply voltage of 600 volts or less.

(c) This Standard shall not be considered adequate for machine tools intended for use in areas defined as hazardous locations by the National Electrical Code (NFPA No. 70 — 1971, ANSI C1-1971).

(d) 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) Tools on which the electrical equipment consists only of a single motor, motor-controller, push button stations and work lights.

(e) The installation of the machine tool is covered by Article 670 of the National Electrical Code (NFPA No. 70 — 1971, ANSI C1-1971).

100-5. Definition of Metalworking Machine Tools. For the purpose of this Standard, a machine tool is defined as follows:

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

100-6. Other Definitions. For purposes of this Standard, definitions of some other terms are given in Appendix A.

100-8. Official Interpretations. The procedure for requesting and processing an Official Interpretation shall be given as in Chapter 110 of NFPA Regulations Governing Technical Committees — 1972, as shown in Appendix C.

100-9. Other Standards. Other organizations having standards which may provide additional information are listed in Appendix B.

100-11. Nominal Voltages. All voltages mentioned in this Standard are nominal.

CHAPTER 110. DIAGRAMS, INSTRUCTIONS, AND NAMEPLATES

110-1. Diagrams. Complete diagrams showing all of the electrical circuits on the machine tool shall be provided.

110-3. Instructions. Information referring to the installation, operation, and maintenance of the equipment shall be furnished.

110-5. Equipment Nameplates.

(a) A permanent nameplate listing supply voltage, phase, frequency, full-load current, ampere rating of largest motor, 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 be not 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 130-3, the machine tool shall be permanently marked "Overcurrent protection provided at machine supply terminals."

110-7. Machine Marking. The machine tool shall be marked with the builder's name, trademark, or other identification symbol.

110-8. Warning Marking. 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.

110-9. Component Marking.

(a) Where electrical equipment is removed from its original enclosure or where equipment is so placed that the manufacturer's identification plate is not readily visible, an additional identification plate shall be permanently attached to the machine tool 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 electrical equipment.

110-11. Device Identification.

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

Exception: Where the size or location of the devices make individual identification impractical, group identification shall be used.

(b) 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 110-13.

110-13. Function Identification. Each control station device (push button, indicating light, selector switch, etc.) shall be identified as to its function by a legend plate.

CHAPTER 120. SUPPLY CIRCUIT DISCONNECTING MEANS

120-1. Type. A manually operated disconnecting means shall be provided for each incoming supply circuit and shall be of the following types: A fusible or nonfusible motor circuit switch, or a circuit breaker, or a circuit interrupter (circuit breaker without trip elements).

120-3. Rating.

(a) The ampacity of the disconnecting means shall be not less than 115 per cent 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 be not 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 130.

120-5. Position Indication. The disconnecting means shall plainly indicate whether it is in the open or closed position.

120-7. 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.

120-9. 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.

120-11. Explosed Live Parts. With the disconnecting means open, there shall be no exposed live parts.

Exception: As permitted in Section 110-8.

120-13. Mounting.

(a) The disconnecting means shall be mounted within the control enclosure, or adjacent thereto. The disconnecting means shall be mounted at the top of the control panel with no other equipment mounted directly above it.

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

120-15. Interlocking. Each disconnecting means shall be mechanically or electrically interlocked, or both, with the control enclosure doors. 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.

120-17. Operating Handle.

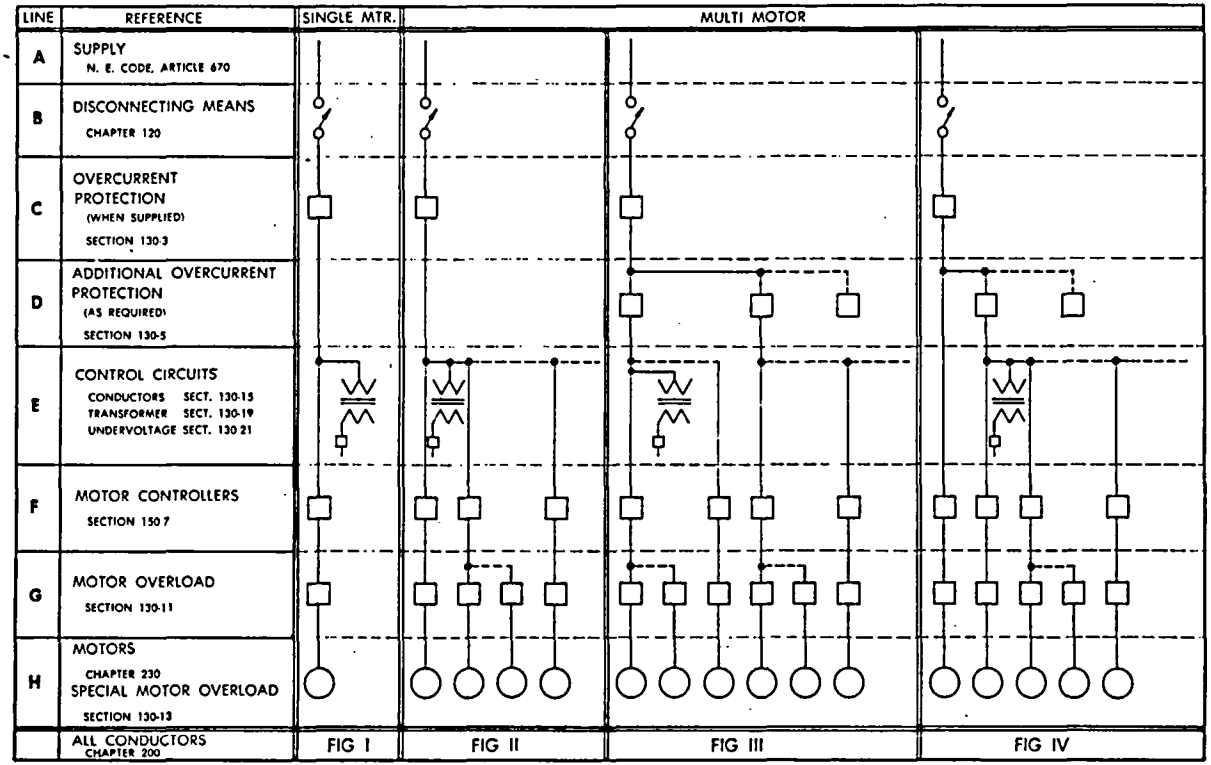
(a) The operating handle of the disconnecting means shall be readily accessible.

(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 feet above the floor.

(c) The operating handle shall be so arranged that it may be locked 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.

DIAGRAM 130-1 — Protection of Machine Tool Electrical Circuits



CHAPTER 130. PROTECTION

130-1. Machine Tool Circuits. Diagram 130-1 shows typical circuits which are acceptable for protection of machine tool motors and controls. Protective interlocks are not shown.

130-3. Supply Conductor and Machine Overcurrent Protection. The overcurrent protection as shown in line C of Diagram 130-1, Figures I through IV inclusive, may or may not be furnished as part of the machine tool. Where furnished as a part of the machine tool it shall consist of a single circuit breaker or set of fuses and the machine shall bear the marking required in Section 110-5.

130-5. Additional Overcurrent Protection. The additional overcurrent protection shown in line D of the Diagram 130-1, 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.

130-7. 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 feet long, and (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, and (2) is not over 10 feet long, and (3) does not extend beyond the control panel enclosure.

130-9. 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 130-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 per cent of the motor full load current for thermal-magnetic

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Table 130-A

Maximum Rating or Setting of Motor Branch Circuit Protective Devices for Various Types of Motors

TYPE OF MOTOR	Per Cent of Full-Load Current		
	Fuse Rating		Thermal-Magnetic Circuit Breaker Rating
	Time Delay or Dual Element	Nontime Delay	
MOTORS MARKED WITH CODE LETTER INDICATING LOCKED-ROTOR KVA			
All A.C. Single-Phase and Polyphase Squirrel-Cage and Synchronous Motors.			
Code Letter A	125	150	150
Code Letter B to E	125	250	200
Code Letter F to V	125	300	250
MOTORS NOT MARKED WITH CODE LETTER INDICATING LOCKED-ROTOR KVA			
Single-Phase, All Types	125	300	250
Squirrel-Cage and Synchronous	125	300	250
High Reactance Squirrel Cage:			
Not more than 30 Amp. Full-Load Current	125	250	250
More than 30 Amp. Full-Load Current	125	200	200
Wound Rotor	125	150	150
Direct Current	125	150	150

trip circuit breakers and nontime delay fuses, and a maximum of 200 per cent for time delay or dual element fuses.

(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 maximum size of a conductor (selected from Table 200-B) connected to a motor controller shall not exceed the values given in Table 130-B.

(2) The rating or setting of the overcurrent protective device shall be as low as practicable, and shall not exceed the values in Table 130-C for the smallest conductor in the circuit.

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

130-11. 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.

(c) The minimum number and location of running overcurrent units shall be determined from Table 130-D.

Table 130-B

Maximum Conductor Size for Given Motor Controller Size*

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

*See ANSI C19.1 — 1959.

Table 130-C

Relationship Between Conductor Size and Overcurrent Protection Rating for Power Circuits

Conductor Size, AWG	Max. Rating of Overcurrent Protective Device, Amp.
14	60
12	80
10	100
8	150
6	200
4	250
3	300
2	350
1	400
0	500
00	600
000	700
0000	800

Table 130-D

Running Overcurrent Units

Kind of Motor	Supply System	Number and Location of Overcurrent Units (such as trip coils, relays, etc.)
1-phase A.C. or D.C.	2-wire, 1-phase A.C. or D.C. ungrounded	1 in either conductor
1-phase A.C. or D.C.	2-wire, 1-phase A.C. or D.C., one conductor grounded	1 in ungrounded conductor
1-phase A.C. or D.C.	3-wire, 1-phase A.C. or D.C., grounded-neutral	1 in either ungrounded conductor
3-phase A.C.	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.

Table 130-E

Relationship Between Conductor Size and Overcurrent Protection Rating for Control Circuits

Conductor Size, AWG	Max. Rating of Overcurrent Protective Device, Amp.
22-30	6
20	10
18	15
16	30
14	45
12	60
10	70

130-13. Special Motor Overload. 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.

130-15. Control Circuit Conductors.

(a) The conductors in the control transformer secondary circuit shall be protected against overloads and short circuits. A branch circuit overcurrent device (fuse or circuit breaker) shall be connected in series with each branch control circuit. Where the circuit is grounded, the protective device shall be located only in the ungrounded side.

(b) The rating or setting of the overcurrent protective device shall be as low as practicable, and shall not exceed the values in Table 130-E for the smallest conductor in the circuit.

130-17. Lighting Branch Circuits. Overcurrent protection for lighting branch circuits shall not exceed 15 amperes.

130-19. Control Circuit Transformer.

(a) The control circuit transformer shall be protected in the secondary circuit against overloads and short circuits by an overcurrent protective device. Where the circuit is grounded, the protective device shall be located only in the ungrounded side.

(b) The rating or setting of the overcurrent protective device shall not exceed the values in Table 130-F for the rating of the control transformer.

130-20. Common Overcurrent Device. The use of the same overcurrent device to provide the protection called for in Sections 130-15, 130-17, and 130-19 shall be permitted.

130-21. Undervoltage. Undervoltage protection shall be provided for all equipment which creates an unsafe condition should a motion be initiated upon the return of power after an undervoltage condition.

Table 130-F

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.

CHAPTER 140. CONTROL CIRCUITS

140-1. Source of Control Power. The source of supply for all control circuits shall be taken from the load side of the main disconnecting means.

140-3. Control Circuit Voltages.

(a) Alternating Current (AC) control voltage shall be 115 volts, single phase, obtained from a transformer with an isolated secondary winding, except as follows:

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 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 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 not exceed 250 volts.

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

140-4. Grounding of Control Circuits. Grounded or ungrounded control circuits shall be permitted as provided for in Section 240-1.

140-5. Connection of Control Devices. 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 multi-speed 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 multi-pole 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.

140-7. Interlocking. Where there is more than one electrically controlled or operated device on a machine tool, and where possible damage may be caused by the failure of any one device to function properly, the circuits shall be arranged with interlocks. Where practicable, these interlocks shall interrupt all operations, provided such interruption will not create an unsafe condition.

140-9. Sequencing. Where operation of control devices in improper sequence can cause a malfunction, circuits shall be so interlocked as to ensure proper sequence of operation.

CHAPTER 150. CONTROL COMPONENTS AND EQUIPMENT

150-3. Connections. Convenient means for making conductor connections shall be provided on or adjacent to all control devices mounted in the control enclosure.

150-5. Subpanels. Subpanels with concealed or inaccessible internal wiring or components shall be mounted and wired so as to be removable.

150-7. 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.

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

Table 150-A

Horsepower Ratings for Special Duty Motor Controller Applications*

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

*See ANSI C19.1 — 1959.

(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 150-A.

(d) Several motors may be operated from one motor controller if separate overload protection is provided for each motor, and the horsepower rating of the controller is not exceeded.

CHAPTER 160. CONTROL ENCLOSURES AND COMPARTMENTS

160-1. Type. Enclosures and compartments shall be nonventilated and constructed to exclude such materials as dust, flyings, oil and coolant.

Exception: Equipment normally requiring ventilation shall be permitted to be housed in ventilated enclosures or compartments provided they are so located that the enclosed equipment is capable of operating satisfactorily.

160-2. Nonmetallic Enclosures. Nonmetallic enclosures approved for the purpose shall be permitted. For grounding provisions see Section 240-5.

160-3. 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 tool rests, or to other compartments of the machine tool which are not clean and dry.

160-5. Wall Thickness. The walls of compartments shall be not less than the following: No. 14 MSG gage for sheet steel; 1/8 inch for cast metal; or 3/32 inch for malleable iron.

160-7. Dimensions. The depth of the enclosure or compartment including doors shall be not less than the maximum depth of the enclosed equipment plus the required electrical clearances.

160-9. 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 be not less than that indicated in Section 160-5. The width of doors shall not exceed 36 inches.

160-11. Gaskets. Where gaskets are used they shall be of an oil-resistant material and shall be securely attached to the door or enclosure.

160-13. Interlocks. All door(s) which permit 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 210-1 (a) and a warning marking is attached to the door in accordance with Section 110-8.

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.

CHAPTER 170. LOCATION AND MOUNTING OF CONTROL EQUIPMENT

170-1. 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.

170-3. Control Panels.

(a) All devices mounted on the control panel and connected to supply circuit voltage, or to both supply and control circuit voltages, shall be grouped above or to the side of devices connected only to control voltages.

Exception: Where supply circuit 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.

170-5. 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.

170-7. Clearance in Enclosures.

(a) Enclosures or compartments for mounting control panels shall provide ample room between panel and case for proper 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 inch. Where barriers between metal enclosures or compartments and arcing parts are required, they shall be of flame-retardant insulating materials which will not readily carbonize.

170-9. Machine Mounted Components.

(a) Control equipment such as limit switches, brakes, solenoids, position sensors, etc., shall be mounted rigidly in a readily accessible and reasonably dry and clean location, and shall be free from possibility of accidental operation by normal movement of machine components or operator. Such equipment shall be mounted with sufficient clearance from surrounding surfaces to make its removal and replacement easy.

(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 shall be accessible and shall not be submerged in oil.

Exception: Where the solenoid is sealed in an individual oil-filled container.

CHAPTER 180. OPERATOR'S CONTROL STATIONS AND EQUIPMENT

180-1. Push Buttons, Selector Switches, Indicating Lights.

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

(b) Emergency push-button operators shall be of the palm or mushroom type.

(c) "Stop" push-button operators shall be red in color, and the red color shall not be used to identify push-button operators having other functions.

180-3. Fixed Stations. Fixed control stations shall be dust-, moisture-, and oiltight.

180-5. Arrangement of Control Station Components. All start push buttons shall be mounted above or to the left of their associated stop buttons.

Exception: Start push buttons in series, such as operating buttons on punch presses.

180-7. Legend Plates. Legend plates shall be so located that they can be easily read by the machine operator.

180-9. Location of Control Stations.

(a) All stations shall be mounted in a reasonably clean and dry location.

(b) Controls shall be within easy reach of the machine operator, and shall be so placed that he does not have to reach past spindles or other moving parts which might cause injury.

(c) Controls shall be free from possibility of accidental operation by normal movement of the machine, operator or work.

180-11. 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 240-7 and 240-9 (c).

CHAPTER 190. ACCESSORIES AND LIGHTING

190-1. 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 provided with gaskets 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.

190-2. Receptacles (Internal to Control Enclosure).

(a) Receptacles internal to control enclosure shall only be provided for test instruments, 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 or a separate isolating transformer.

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

190-3. Control Panel 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 tool disconnecting means.

(2) A grounded 115-volt machine tool control circuit.

(3) The plant lighting circuit.

(c) The conductors to stationary or built-in lights shall be type MTW, and the conductors within the fixtures shall be not smaller than No. 18 AWG.

(d) Flexible cords shall be all thermoplastic Type STO.

(e) Grounding shall comply with the provisions of Section 240-3.

(f) Incandescent lampholders shall be of the medium-base screwshell type and shall be switchless. The fixture shall not incorporate an attachment plug receptacle.

(g) Stroboscopic effects from lights shall be avoided.

CHAPTER 200. CONDUCTORS

200-1. Power and Control.

(a) Conductors (other than those in Section 200-3.) shall conform to one of the following:

(1) Machine tool wire shall be Type MTW of the following construction:

(a) Annealed stranded copper wire with construction for nonflexing and flexing service in accordance with Table 200-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 coolants.

(c) Insulation thickness in accordance with Table 200-A.

Exception No. 1: Wire Nos. 14-10 with 45 mils insulation and wire No. 8 with 60 mils insulation shall be permitted.

Exception No. 2: Where subjected to normal temperatures exceeding the limits for Type MTW, conductors having suitable insulation shall be used.

NOTE: As defined in the National Electrical Code, Type MTW Wire having a nominal thickness indicated in Column A consists of a conductor and PVC insulation. Type MTW Wire in Column B consists of a conductor and PVC insulation having a nominal thickness indicated in Column B, and covered with a nylon jacket.

(d) A durable surface marking of "MTW", and if the conductor stranding is that shown as flexing in Table 200-A, "Flexing" or "Class K."

Exception: Conductors with insulation characteristics equivalent to those given in Paragraphs (b) and (c) above and with strandings other than those specified in Table 200-A shall be permitted on individual devices purchased completely wired (ie, motor starters, etc.).

(2) Multiconductor, all thermoplastic cord, Type STO.

(3) Special multiconductor control cables having individual conductors of a type specified in paragraph (a) (1) of this Section and a jacket suitable for the purpose.

Exception: The marking specified in paragraph (a) (1) (d) of this Section shall be permitted on the outer surface of the jacket.

(b) Conductors shall be not 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 200-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	60	61[a] (37[d])	[c]

[a]) ASTM designation B-8, Class C (1969).
[b]) ASTM designation B-174, Class K (1964).
[c]) Nonflexing construction shall be permitted for flexing service.
[d]) Shall be permitted.

Table 200-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) For electronic, precision, and static control as in Section 200-3.

(c) The current carried by conductors shall not exceed the values given in Table 200-B.

(d) Motor circuit conductors shall have an ampacity not less than 125 per cent 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.

200-3. 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 200-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 No. 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 be not smaller than No. 18.

Exception. In a jacketed, multi-conductor cable assembly, No. 24 or larger conductors shall be permitted.

(2) Conductors within the control enclosures shall be not 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 current carried by conductors shall not exceed the values given in Table 200-B.

CHAPTER 210. WIRING METHODS AND PRACTICES

210-1. General Requirements.

(a) Conductors shall be identified at each termination by marking with a number to correspond with 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 — 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 white conductor from the transformer terminal to the grounding terminal on the machine frame.

(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 marked to correspond with the markings on the diagrams.

(d) It is recommended that electrical connections be made with pressure connectors (e.g., crimped lug or pin, etc.), or screw or bolt connections where the wire is retained (e.g., saddle, cup washer, etc.).

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

210-3. 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.

210-5. 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 220, unless otherwise permitted in this Section.

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

(c) Liquidtight flexible metal conduit or multiconductor cable shall be used where necessary to employ flexible connections to pendent push-button 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 and fittings shall be used for connections involving small or infrequent movements. They shall also be used to complete the connection to normally stationary motors, limit switches, and other externally mounted devices. The conduit length shall be no longer than necessary, but shall not exceed 5 feet.

(e) Connections to continuously moving parts shall be made with conductors for flexing service as shown in Table 200-A in liquidtight flexible metallic or nonmetallic conduit or multiconductor cable. Flexible cable and conduit shall have vertical connections and shall have sufficient slack to avoid sharp flexing and straining.

Exception: Horizontal connections shall be permitted if 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 220. RACEWAYS, JUNCTION AND PULL BOXES

NOTE: Raceways and junction boxes are provided for mechanical protection only. See Chapter 240 for acceptable means of equipment grounding.

220-1. 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 inch shall be permitted in raceways, junction boxes and pull boxes subject to accumulations of oil or moisture.

220-3. Per Cent Fill of Raceways. The combined cross-sectional area of all conductors and cables shall not exceed 50 per cent 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.

220-5. Rigid Metal Conduit and Fittings.

(a) Rigid metal conduit and fittings shall be of galvanized steel, meeting the requirements of ANSI Standards C80.1 — 1966 and C80.4 — 1963, or of a corrosion-resistant material suitable for the conditions.

(b) Conduit smaller than ½ inch, 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 sheet metal box or enclosure, a bushing 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 rigid 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 220-A.

Table 220-A
Minimum Radii of Conduit Bends

Size of Conduit, Inches	Minimum Radius of Conduit Bends, Inches
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 4 quarter bends (360 degrees, total).

220-7. 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 inch, electrical trade size, shall not be used.

220-9. Liquidtight Flexible Nonmetallic Conduit and Fittings.

(a) Liquidtight flexible nonmetallic conduit shall consist of a

water- and oil-resistant and flame-retardant material. It shall be constructed of a seamless liner and cover, bonded together with one or more layers of flexible, braided, reinforcing cords.

(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) The conduit shall have nominal dimensions as near as shown in Table 220-B.

Table 220-B
Liquidtight Flexible Nonmetallic Conduit Dimensions

Trade Size, Inches	Nominal Inside Diameter, Inches	Nominal Wall Thickness, Inches
½	0.622	0.140
¾	0.824	0.140
1	1.049	0.175
1¼	1.380	0.185
1½	1.610	0.200

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

(f) Liquidtight flexible nonmetallic conduit smaller than ½ inch trade size shall not be used.

220-11. Wireways.

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

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

(c) Covers shall be gasketed and shaped to overlap sides. Covers shall be attached to wireway by hinges or chains and held closed by means of captive screws or other suitable fasteners. On horizontal wireways the cover shall be on the top.

(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.

220-13. Machine Compartments and Raceways. Compartments or raceways within the column or base of a machine tool 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.

220-15. Junction and Pull Boxes. Junction boxes shall not have unused knockouts and shall be provided with gasketed covers.

220-17. Motor Terminal Boxes. Motor terminal boxes shall not be used as junction boxes for wiring to solenoid valves, limit switches, etc. The connection of terminals for motor mounted devices such as brakes, thermostats, plugging switches, or tachometer generators, may be connected in the motor terminal box.