ELECTRICAL STANDARDS for. . .

pages 6 to 36

MASS PRODUCTION EQUIPMENT EMP—1—67

(Supersedes JIC Mass Production Electrical Standard — 1957)

JOINT INDUSTRIAL COUNCIL

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Note: Minor editorial changes have been made in this reprinting to bring it up-to-date. However, *no changes* have been made in the standards, themselves, as originally printed in April-May, 1967.

CONTENTS, EMP-1-1967

*A single asterisk indicates a difference in these Standards as compared with the JIC Electrical Standards for General Purpose Machine Tools.
**A double asterisk indicates material which is not included in the JIC Electrical Standards for General Purpose Machine Tools.

E1. General

E1.1 Purpose. The purpose of this Electrical Standard is to provide detailed specifications for the application of electrical systems to mass production industrial equipment which will promote:

(1) Safety to personnel.
(2) Uninterrupted production.
(3) Long life of the equipment.
(4) Ease and low cost of maintenance.

This standard is not intended to limit or inhibit advancement in the art of electrical or mechanical engineering.

E1.2 Scope. The provisions of this standard shall apply to all electrical systems, furnished as part of the mass production industrial equipment, which operate from a supply voltage of 600 volts or less, commencing at the power supply terminals on the disconnecting means.

Exception No. 1: Hazardous Locations. This standard shall not be considered adequate for mass production industrial equipment intended for use in locations designated as hazardous in the National Electrical Code.

*Exception No. 2: Fixed or Portable Tools. This standard is not intended to apply to 115 volt, single phase, portable type equipment, using cord connections, unless such equipment is auxiliary to the mass production industrial equipment.

E1.3 Definitions.

**E1.3.1* Mass Production Industrial Equipment. Mass production industrial equipment is defined as any equipment electrically powered or controlled, used in or necessary for manufacturing processes and assembly equipment.

E1.3.2 Electrical Systems. Electrical systems shall include:

(1) Electrical equipment consisting of motors, solenoid-operated devices, limit switches, pressure switches, control station electrical components and similar contact-making devices, together with the associated wiring.
(2) Electronic equipment together with the associated wiring and devices.
(3) Static control equipment together with the associated wiring and devices.

E1.3.3 Nominal Voltages. All voltages hereinafter will be considered nominal 115 volts, 230 volts and 460 volts. (See Appendix C for definition of nominal voltage.)

E1.4 Additional Codes and Specifications. On any point for which specific provisions are not made in this standard, the provisions of the National Electrical Code (NEC) and state and local codes shall be observed. The National Fire Protection Association (NFPA) Standard 79, included with the National Electrical Code, applies specifically to machine tools. Articles 500 through 540 of the National Electrical Code apply, as applicable, to Hazardous Locations.

E1.5 Specific Standards and Revisions. Whenever a specific standard is mentioned in this standard, it is understood it will be "the latest revision thereof" unless otherwise specified.

E1.6 Deviations. Deviations from this standard shall have the approval of the purchaser in writing. Any waivers granted shall apply only to the order in question and shall not be considered as permanent.

E1.7 Use of "Shall" and "Should". The word "shall" is understood as a requirement; the word "should" as a recommendation.

***E1.8** Conformity to JIC Standards. When the purchaser requires that electrical equipment and the installation of such equipment by the supplier shall conform to this standard and other requirements, it shall be so specified on the purchase inquiry. (See E1.9)

***E1.9** Additional User Requirements. The purchase inquiry shall be accompanied with an Electrical Equipment Data Form and shall be confirmed on the purchase order. (See Appendix F for Sample Electrical Equipment Data Form)

****E1.10** Approvals and Final Drawings. The industrial equipment builder shall submit to the purchaser diagrams and data specified on the Electrical Equipment Data Form.

***E1.10.1* Approvals. Approval shall be obtained before electrical components are installed on the industrial equipment. After preliminary approval any deviations made by the equipment builder shall have the approval of the purchaser in writing before changes are made.

***E1.10.2* Final Drawings. On completion of the industrial equipment and not later than the date of shipment, a complete set of nonfolded tracings or reproducible copies of final diagrams shall be forwarded to the purchaser. The quality of the tracings or reproducible copies shall permit making changes and clearly legible prints. If any field changes are made by the industrial equipment builder, they shall be recorded and a reproducible copy of the changed drawing shall be forwarded to the purchaser or other designated person.

E2. Diagrams, Data, Nameplates and Identification

E2.1 Diagrams, General.

**E2.1.1* Drawing Size. The electrical diagrams, including panel layout, stock list and sequence of operations should be shown on the same sheet. The foundation drawing should be shown on a separate sheet. Multiple sheets shall be cross-referenced. All information shall be clearly legible. Sheet size shall be 24" × 36". (For sample diagrams, see Appendix B.)

**E2.1.2* Diagrams Supplied. Diagrams of the electrical system shall be furnished. The diagrams shall show the equipment serial number, the purchaser's drawing number, purchase order number or similar identification which will indicate the particular equipment to which the diagrams apply. Diagrams shall show all equipment in the electrical system including internal wiring of sub-assemblies. Diagrams of sub-assemblies may be furnished on separate sheets.

Exception: On industrial equipment having only one motor and one starter, the diagram normally furnished with the combination starter is satisfactory, provided the diagram shows all of the electrical apparatus on the industrial equipment.

E2.1.3 Symbols and Device Designations.

E2.1.3.1 Standard electrical symbols as shown in Appendix A shall be used for all diagrams. For symbols not shown in Appendix A refer to American National Standard Y32.2. Symbols for logic devices shall be in accordance with NEMA Standard IC-1, Industrial Control.

Exception: Special symbols may be used where there is no standard symbol; such symbols shall be identified and explained both on the diagrams and in instruction manuals.

E2.1.3.2 The symbols for devices shall be identified by a number or number-letter combination, using abbreviations shown in Appendix D. For special abbreviations not listed, refer to NEMA Standard IC-1, Industrial Control.

E2.1.3.3 The following alphabetical designations shall be used for the devices indicated and shall not be used for other identification purposes:

Items	Examples
Relays—General Use	CR, 1CR, 2CR
—Master	CRM
—Automatic	CRA
—Electronically Energized	CRE, 1CRE, 2CRE
—Manual (hand)	CRH
—Latch	CRL, 1CRL, 2CRL
—Unlatch	CRU, 1CRU, 2CRU
Timers	TR, 1TR, 2TR
Overload Relay	OL, 1OL, 2OL
Motor Starters	1M, 2M, etc.
Reversing Motor Starters	1MF (Forward)—1MR (Reverse)

Example: 2M F

Starter Number

Forward

Plugs	1PL, 2PL, etc.

Example: 2PL 6

Plug Number

Pole Number

Solenoids	1SOL, 2SOL, 3SOL
Limit Switches	1LS, 2LS, 3LS
Pressure Switches	1PS, 2PS, 3PS

E2.1.3.4 Special abbreviations not covered by the above paragraphs may be used and shall be identified on the diagrams and in the instruction manual.

E2.1.4 Conductor Identification. Each conductor shall be identified by a number, letter or number-letter combination. Consecutive numbering is preferred. The identification shall be used only once in the electrical system. Each conductor shall have the same identification at all terminals and tie points. All conductors connected to the same terminal or tie point shall have the same identification. Where multiconductor cable is used, a color code may be used to supplement the above identification. Where color-coded multiconductor cable is used for wiring identical components, such as limit switches, the color code used shall be consistent and charted on related diagrams.

E2.1.5 Sub-assembly Terminal Identification. Terminal numbers, letters or number-letter combinations for sub-assemblies or components shall be identified distinctively and associated with the sub-assembly or component.

E2.2 Elementary (Schematic) Diagram.

E2.2.1 An elementary diagram shall be furnished for each electrical system. A logic diagram may be furnished in lieu of or in combination with an elementary diagram.

E2.2.2 The elementary diagram shall be drawn between vertical lines which represent the source of control power. All control devices shall be shown between these lines. Actuating coils of control devices shall be shown on the right-hand side. All contacts shall be shown between the coils and the left vertical line.

Where the internal wiring diagrams of sub-assemblies are furnished on separate sheets, they shall be shown as a rectangle in the elementary diagram with all external points identified and cross-referenced to the separate sheet(s) of the control circuit. Coils and contacts internal to the sub-assemblies shall be shown in the rectangle connected to their terminal points.

Exception No. 1: Where relay and electronic circuits are mixed, diagrams may be drawn between horizontal lines which represent the source of control power.

Exception No. 2: Overload relay contacts may be connected to the right of the coil (common) if the conductors between such contacts and the coils of the magnetic devices do not extend beyond the control enclosure.

E2.2.2.1 Control device symbols should be shown in the order in which the controls are energized and positioned on the diagram for clarity.

*E2.2.2.2 A cross-referencing system shall be used in conjunction with each relay coil so that associated contacts may be readily located on the diagram. Where a relay contact appears on a sheet separate from the one on which the coil is shown, the purpose of the contact shall be described on the same sheet.

E2.2.2.3 Only contacts actually used shall be shown.

E2.2.2.4 Limit, pressure, float, flow, temperature-sensitive and similar switch symbols shall be shown on the elementary diagram with all utilities turned off (electric power, air, gas, oil, water, lubrication, etc.) and with the equipment at its normal starting position.

E2.2.2.5 Contacts of multiple-contact devices (e.g., selector switches) shall be shown on the line of the elementary diagram where they are connected in a circuit. A mechanical connection between the multiple contacts shall be indicated by a dotted line or arrow. This does not apply to control relays, starters or contactors.

E2.2.2.6 Additional charts or diagrams may be used to indicate the position of multiple-contact devices such as drum, cam and selector switches.

E2.2.2.7 The connections between pushbuttons, limit switches and similar items connected in series shall be shown as test points on the diagram as required in E12.4.14.

E2.2.2.8 The purpose or function of all switches shall be shown either adjacent to the symbols, or in a switch description chart. The chart shall be on the same sheet as the symbol.

*E2.2.2.9 The purpose or function of controls such as relays, starters, contactors, solenoids, sub-assemblies and timers shall be shown on the diagram adjacent to their respective symbols. The number of positions of the solenoid valve shall be shown adjacent to the valve solenoid symbol.

E2.2.2.10 Values of capacitors and resistors shall be shown on the diagram.

E2.2.2.11 Descriptive terms for command and status functions shall be in the present or past tense. For example, Raise Transfer–Transfer Raised; Advance Transfer–Transfer Advanced. Terms such as "Transfer Up" shall not be used.

**E2.2.2.12 Coils of relays and other control devices should be grouped and drawn in the following order:

(1) Sequencing and position indicating relays, etc.
(2) Solenoids for valves.

Within each group, control devices shall be shown in the order of energization.

Exception: Solenoids common to a valve should be grouped together; for example: "Clamp" and "Unclamp."

E2.2.3 Electronic Diagram. Electronic diagrams shall include pertinent data for maintenance purposes as follows:

(1) Voltage and current data necessary for maintenance purposes.
(2) Normal voltages on transformer windings.
(3) Signal input and output voltages.
(4) Potentials applied to tube elements.
(5) Oscilloscope traces, showing wave form and peak-to-peak voltages where meter readings are inadequate.
(6) The type and sensitivity of test instruments to be used and the condition of the circuit.
(7) The instantaneous polarity of each transformer winding in phase sensitive circuits.
(8) The electrical values of capacitors, resistors, inductances and other electronic components.

E2.3 Block and Logic Diagrams.

E2.3.1 Block Diagram. Where the complexity of the control system warrants, a block diagram of control func-

tions shall be furnished. Each block shall be identified and cross-referenced in a manner that the internal circuitry may be found readily on the elementary diagram.

E2.3.2 Logic Diagram. A logic diagram of the electrical system shall be furnished when static control or logic modules are supplied. The diagram need not show power connections.

E2.4 Panel Layout and Interconnection Diagram.

E2.4.1 The panel layout shall show the general physical arrangement of all components on the control panel. Devices may be represented by rectangles or squares and shall be identified with the same marking as used on the elementary diagram. Spare panel space shall be dimensioned. The drawings shall include a layout of the operator's console or pushbutton station, but terminal numbers need not be shown. This layout may be combined on the same drawing with the interconnection diagram or wiring table. (See Sample Diagram in Appendix B.)

E2.4.2 Photographs of electronic chassis and similar complex devices may be furnished in lieu of panel layouts, provided each component is clearly visible and identified.

E2.4.3 An interconnection diagram or wiring table shall be furnished to indicate the interconnecting conductors between all terminals on each terminal block for all panels and chassis comprising the complete electrical system. Each connection shall be identified as shown on the elementary diagram. Blank spaces and spare terminals shall be shown.

E2.4.4 For logic control systems, a panel layout diagram shall (1) consist of an outline of the control panel, and (2) show the general physical arrangement of the panel-mounted devices. Each device may be represented by a square or rectangle. Each device shall have the same identification as on the elementary diagram.

E2.5 Stock List. The stock list shall show quantity, manufacturer's name, type or model and catalog number of each device used; motor horsepower, frame size, type of enclosure, and speed; and any other information necessary to order replacement electrical and electronic items.

E2.6 Sequence of Operation. The sequence of operation shall indicate the progression of operations of all pushbuttons, limit switches, relays, solenoids and other devices as shown and identified on the elementary diagram. Graphical representations, such as bar charts, may be used to supplement written descriptions.

E2.7 Instruction Manuals. On complex equipment, such as numerical control systems, servo controls, electrical variable-speed drives, etc., an instruction manual shall be furnished. The following shall be included:

(1) Information necessary for calibrating and adjusting components, devices and sub-assemblies.
(2) Operation instructions, including all information necessary to describe the operation of the complete system.
(3) Maintenance instructions, including information and suggestions for locating and replacing faulty components, suggested maintenance schedules and related data.
(4) A recommended spare parts list with complete ordering information and suggested quantities.

***E2.8** Electrical Layout. The electrical layout shall consist of an outline of the equipment, not necessarily to scale, showing the control panel enclosure and its dimensions, operator's console and accessory units not attached directly to the equipment, such as hydraulic power units, in their relative locations. The drawing shall also show the location of control devices whose location cannot be readily determined from the elementary and other electrical diagrams, such as limit switches used on indexing mechanisms. All devices shall be identified as shown on the elementary diagram.

E2.9 Foundation Drawing. On equipment requiring conduit in the foundation, the minimum size, purpose and location of the conduit to be used shall be shown on a foundation drawing.

E2.10 Equipment Nameplates.

E2.10.1 Main Nameplate. A permanent non-corrodible nameplate shall be attached to the control enclosure door. This nameplate shall list the following:

(1) Equipment serial number.
(2) Supply voltage, phase and frequency.
(3) Rated KVA or full-load current (see E2.10.1.1).
(4) NEMA interrupting capacity of the circuit breaker (if supplied).
(5) Ampere rating of the largest motor.
(6) Supplier's electrical diagram number.

Exception: Where only a single motor and motor controller are used, the motor nameplate may serve as the electrical equipment nameplate if it is plainly visible.

E2.10.1.1 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 loads, duty cycles, etc., require oversized conductors, the required capacity shall be included in the "full-load current" rating as marked.

E2.10.1.2 Where more than one incoming supply circuit is provided, the nameplate shall state the above information for each circuit.

E2.10.1.3 Where overcurrent protection is provided in accordance with E4.3, Main and Branch Circuit Overcurrent Protection, the nameplate shall be permanently marked "Overcurrent protection provided at equipment supply terminals." A separate nameplate may be used for this purpose.

E2.10.1.4 Where the builder wishes to indicate compliance with this and other standards, it is recommended that the nameplate be marked with a notation similar to the following: "The electrical equipment and wiring on this machine conform to the following standard(s) . . . ."

E2.10.2 Additional Nameplates. Where electrical equipment is removed from the original enclosure, or where equipment is so placed that the manufacturer's nameplate is not readily visible, an additional nameplate shall be permanently attached to the equipment or enclosure. Nameplates shall not be removed from electrical equipment.

E2.11 Device Identification. Control and power devices shall be plainly and permanently identified, using the same identification as shown on the elementary diagram. Identification shall be shown on a plate mounted adjacent to, not on, the device. Control station components shall be identified by function. (See E9.3.2)

Exception No. 1: Where the size or location of the devices make individual identification impractical, such as on electronic assemblies, group identification shall be used.

Exception No. 2: Where panel layouts do not permit mounting identification plates adjacent to components, such as relays, the permanent relay identification shall be placed on the relay where it is plainly visible, and a second identification provided on the top of the panel wireway cover directly below the relay. The wireway covers shall be identified to show their proper location.

****E2.12** Identification Plates.

****E2.12.1*** Plates for devices mounted inside the control enclosure shall be one of the following:

(1) Non-corrodible metal for engraving stock; a minimum of 0.031 inch thick.

(2) Non-corrodible metal for embossing stock; a minimum of 0.012 inch thick.
(3) Laminated phenolic for engraving stock; a minimum of 0.062 inch thick.

Plates shall be held in place with metallic drive screws or the equivalent. Permanent adhesives shall be used for attaching nameplates to wireway covers.

***E2.12.2* Plates for devices mounted external to the control enclosure shall be non-corrodible metal, a minimum of 0.031 inch thick for engraving stock or 0.012 inch thick for embossing stock. Plates shall be held in place with metallic drive screws.

E3. Supply Circuit Disconnecting Means

***E3.1** Scope. This section shall apply to all industrial equipment, including portable and semi-portable equipment except: (1) small bench-type tools powered by a single motor rated less than 1/4 horsepower operating from a 115 volt supply, and (2) welding transformers and their control circuits.

E3.2 Type.

E3.2.1 Where nominal 115 volt, single phase, is the only power supply to the equipment, a fused disconnect switch or circuit breaker of suitable size shall be installed.

E3.2.2 On all other equipment the builder shall furnish, as specified by the purchaser, one of the following disconnecting means:

(1) A fusible or non-fusible motor circuit switch conforming to all requirements, except enclosures, listed in NEMA Standard KS-1, Enclosed Switches, for heavy duty type HD switches, or
(2) A circuit breaker conforming with NEMA Standard AB-1, Molded Case Circuit Breakers, or
(3) A fusible or non-fusible circuit interrupter.

***E3.2.3* When a separately mounted safety switch is specified by the purchaser as auxiliary equipment, it shall be a NEMA heavy duty industrial type, manually-operated, fusible or non-fusible (as specified) and mounted in a NEMA Type 12 enclosure.

E3.3 Rating.

E3.3.1 The ampacity of the disconnecting means shall be not 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.

E3.3.2 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 the other connected operating equipment.

E3.4 Application. The disconnecting means shall be applied in accordance with E4, Protection.

E3.5 Position Indication. The disconnecting means shall plainly indicate whether it is in the open or closed position. (See E3.11.3)

E3.6 Supply Conductors to be Disconnected. The disconnecting means shall disconnect all ungrounded conductors of the supply circuit simultaneously. Where there is more than one supply source, additional individual disconnecting means shall be provided for each supply circuit so that all supply conductors may be interrupted.

E3.7 Supply Line Connection. The incoming supply conductors shall terminate at the disconnecting means with no connection to terminal blocks or other devices ahead of the disconnecting means.

E3.8 Exposed Live Parts. There shall be no exposed live parts when the disconnecting means is in the open position.

E3.9 Mounting.

E3.9.1 The disconnecting means shall be mounted within the control enclosure.

*Exception: Where panel-mounting of an 800 ampere or larger disconnecting means is impractical, the equipment builder shall furnish a circuit breaker in a NEMA Type 12 enclosure for installation by the purchaser.

**E3.9.2* If more than one disconnecting means is provided for multiple supply circuits in a single enclosure, they shall be grouped in one location and mechanically interlocked with the door(s).

E3.9.2.1 When disconnects are mounted in separate enclosures, each supplying power to part of a complete machine or equipment, the following provisions shall be made:

(1) A main disconnecting means shall be furnished to de-energize the entire system, and
(2) The disconnecting means in any of the separate control enclosures shall de-energize all current-carrying components in that enclosure when placed in the "OFF" position.

Exception: Control devices and terminals located in the enclosure but energized from a remote source need not be de-energized if identified by yellow wiring.

**E3.9.3* The disconnecting means shall be mounted at the top of the control panel; no other equipment shall be mounted directly above it. In enclosures with more than three doors, the disconnecting means shall be on the panel at either the extreme right or left.

***3.9.4* On bench-type equipment the combination starter need not be mounted on the equipment.

E3.10 Interlocking.

E3.10.1 Where there are two or more sources of power to the equipment or where there are two or more independent disconnecting means, not mechanically interlocked with each other, power wiring from each disconnecting means shall be run in separate conduit, and shall not terminate in or pass through common junction boxes.

**E3.10.2* When the disconnecting means is mounted within the control enclosure, it shall be interlocked mechanically with the control enclosure door(s). A suitable device, operated by a screwdriver or other common hand tool, shall be provided so that the interlocks may be bypassed and the panel doors opened without disconnecting the power. Interlocking must be reactivated automatically when panel doors are closed. Progressive interlocking, door to door, shall not be used.

***E3.10.3* All doors on multiple-door enclosures shall be interlocked simultaneously with the door which is interlocked with the main line disconnecting means.

Exception No. 1: When the disconnecting means is separately mounted, it shall be mechanically or electrically interlocked with the control enclosure door(s).

Exception No. 2: The interlock requirements of this paragraph do not apply to industrial equipment such as electric power for resistance welders or electric furnaces unless specified by the purchaser. However, it does apply to motor control for such apparatus.

***E3.10.4* Mechanical interlocking shall be provided between the disconnecting means and its associated door to accomplish both of the following:

(1) Prevent closing of the disconnecting means while the enclosure door is open, unless an interlock is operated, and
(2) Prevent closing of the disconnecting means while the door is in the initial latch position or until the door hardware is fully engaged.

E3.11 Operating Handle.

E3.11.1 Location. The operating handle of the disconnecting means shall be readily accessible. The center of the grip, when in its highest position, shall not be more than 6½ feet above the floor and should not be lower than 3 feet above the floor.

***E3.11.1.1 The operating handle shall be mounted on the front of the control compartment or enclosure, not on a door.

E3.11.2 Locking. The operating handle of the disconnecting means shall be so arranged that it may be locked in the "OFF" position. Provision shall be made for a minimum of three locks having shackles 0.375 inch in diameter.

E3.11.3 Position Indication. The operating handle shall plainly indicate at all times whether the disconnecting means is in the open or closed position. (See E3.5)

**E3.11.4* Linkage. Mechanical linkage between the disconnecting means and its operating handle shall be 12 inches or less in length and shall be such that the operating handle is in control of the disconnect at all times.

E4. Protection

E4.1 Scope. This section shall apply to all industrial equipment, except bench-type machines powered by a single motor rated less than ¼ horsepower.

E4.2 General.

E4.2.1 Figure 4-1 shows typical circuits which are acceptable for protection of electrical systems.

**E4.2.2* Fuses for power and control shall be dual element types having a minimum interrupting capacity of 100,000 amperes at rated voltage. Fuses shall meet the performance standards outlined in NEMA Standard FU-1, Low Voltage Fuses. Fuse dimensions shall conform to those listed for NEMA Class H.

Exception: The interrupting capacity requirement does not apply to fuses in the control circuit below the main control circuit protective device(s). Examples are those used for protection of individual solenoids and small subassemblies.

E4.3 Main and Branch Circuit Overcurrent Protection.

E4.3.1 The main overcurrent protection shown in line "C" of Figure 4-1, Typical Diagrams, Columns 1 through 4 inclusive, may or may not be furnished as part of the electrical system as specified in E3.2. Where furnished as part of the system, it shall consist of a single circuit breaker or set of fuses, and the nameplate shall bear the marking required in E2.10.1.3.

E4.3.2 Additional Overcurrent Protection. On a machine with more than one branch circuit, additional overcurrent protection as shown on line "D" of Figure 4-1, Typical Diagrams, Columns 3 and 4, shall be furnished as part of the electrical system. Overcurrent protection, such as fuses or overcurrent trip units of a circuit breaker, shall be placed in each ungrounded branch circuit conductor. Where a circuit breaker is used, it shall open all ungrounded conductors of the branch circuit.

E4.3.3 Overcurrent protective devices shall be located at the point where the conductor to be protected receives its supply except as follows:

Exception No. 1: Where all of the following conditions are complied with: the conductor (1) has an ampacity of at least one-third that of the conductor from which it is supplied, (2) is suitably protected from physical damage, (3) is not over 25 feet long, and (4) terminates in a single circuit breaker or set of fuses.

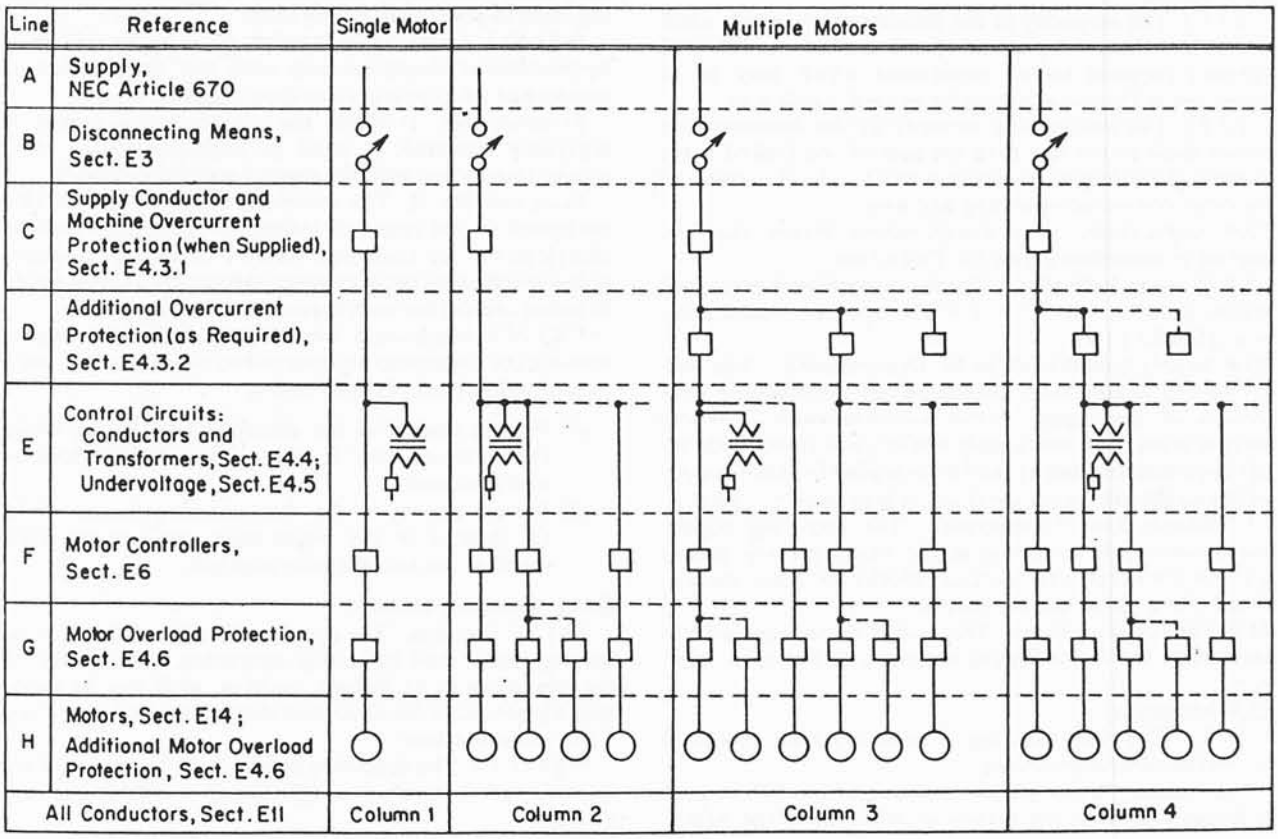
Exception No. 2: Where all of the following conditions are complied with: the conductor (1) has an ampacity of not less than the sum of the maximum continuous load currents, (2) is not over 10 feet long, and (3) does not extend beyond the control panel enclosure.

E4.3.4 Selecting Overcurrent Devices. If the calculated value for overcurrent (short circuit) devices does not correspond to standard ratings or sizes, the next larger size or rating may be used.

E4.3.5 Individual Motor Overcurrent Protection.

E4.3.5.1 The overcurrent protective (short circuit) 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 obtained when the overcurrent device has a rating or setting not

Figure 4-1. Typical diagrams, electrical system protection.



exceeding that shown in Table 4-1.

*E4.3.5.2 Where the overcurrent protection specified in Table 4-1 is not sufficient for the starting current of the motor, it may be increased to a maximum of 200 percent of the motor full-load current for dual element fuses and 400 percent for circuit breakers.

E4.3.6 Several Motors on One Branch Circuit. Two or more motors and their control equipment may be connected to a single branch circuit provided all of the following requirements are complied with:

(1) The maximum size of conductors connected to a motor controller shall be in accordance with Table 4-2,

(2) The rating or setting of the overcurrent protective device shall be as low as practicable and shall not exceed the values shown in Table 4-3 for the smallest conductor in the circuit, and

(3) Motor and control circuits shall be arranged so that a minimum number of branch-circuit overcurrent protective devices are required.

E4.3.7 Lighting Branch Circuits. Overcurrent protection for lighting branch circuits shall not exceed 15 amperes.

E4.4 Control-Circuit Overcurrent Protection.

***E4.4.1** The control conductors shall be protected against steady overloads and short circuits. An overcurrent device shall be connected in series with each ungrounded leg of all branch control circuits. Solenoids and control shall be considered separate branch circuits. The overcurrent devices shall be rated at not more than 125 percent of the current rating of the transformer and shall interrupt short circuits without damage to the transformer or conductors.

E4.4.2 The rating of overcurrent protective devices in the control circuit shall be as low as practicable and shall not exceed the values given in Table 4-4 for the smallest conductor in the circuit. In Tables 4-4 and 4-5, the smaller of the computed overload ratings shall be used.

E4.4.3 The transformer for the control circuit shall be protected in the secondary circuit against overloads and short circuits with overcurrent devices selected in accordance with Table 4-5.

***E4.4.4** Solenoids mounted external to the control panel and having an inrush current exceeding 150 percent of the sealed value shall be individually protected by an indicating-type overcurrent protective device rated approximately 130 percent of the sealed solenoid current. Where a fuse is used, it shall be a dual element type. The

***Table 4-1—Motor Overcurrent Protective Device Rating**

Type of Motor	Percent of Full-Load Current: Dual Element Fuse, Maximum Rating	Percent of Full-Load Current: Thermal Magnetic Circuit Breaker, Maximum Rating or Setting
Motors Marked with Code Letter Indicating Locked-Rotor KVA		
All AC Single Phase and Polyphase Squirrel Cage and Synchronous Motors.		
Code Letter A	125	150
Code Letter B to E	125	200
Code Letter F to V	125	250
Motors Not Marked with Code Letter Indicating Locked-Rotor KVA		
Single Phase, All Types	125	250
Squirrel Cage and Synchronous	125	250
High Reactance Squirrel Cage:		
Not more than 30 amperes Full-load Current	125	250
More than 30 amperes Full-load Current	125	200
Wound Rotor	125	150
Direct Current	125	150

For motors not included in the table refer to National Electrical Code, Article 430, Table 430-146.

If the calculated value for overcurrent (short circuit) devices do not correspond to standard ratings or sizes, the next larger size or rating may be used.

***Table 4-2—Maximum Conductor Size for NEMA Motor Controllers (Starters)†**

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

†See ANS C19.1, Industrial Control Apparatus.

***Table 4-3—Power Conductor Overcurrent Protection**

Conductor Size, AWG	Maximum Circuit Breaker Rating, Amperes	Maximum Dual Element Fuse Rating, Amperes
14	60	30
12	80	40
10	100	50
8	150	80
6	200	100
4	250	125
3	300	150
2	350	175
1	400	200
0	500	250
00	600	300
000	700	350
0000	800	400

***Table 4-4—Control Conductor Overcurrent Protection**

Conductor Size, AWG	Maximum Rating, Amperes
22	3½
20	6¼
18	8
16	10
14	15
12	20
10	30
8	40
6	60
4	70
3	80
2	100
1	110
0	125
00	150
000	175
0000	200

***Table 4-5—Control Transformer Overcurrent Protection (115 Volt Secondary)**

Control Transformer Size, Volt-Amperes	Maximum Rating, Amperes
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

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.

device shall be connected between the solenoid and the control relay contact.

E4.5 Undervoltage Protection. Undervoltage protection shall be provided for all equipment which may initiate a motion upon return of power after an undervoltage condition.

E4.6 Motor Overload Protection.

E4.6.1 Each motor and related conductors shall be protected against running overload by the use of a separate overload device responsive to motor current. Embedded thermal sensing devices may be used in addition to the current responsive devices.

Exception: Short-time rated motors or high reversing duty motors which cannot be adequately protected by external overload devices shall be protected by a thermal overload device mounted in the motor.

E4.6.2 The minimum allowable number and location of overload devices shall be as shown in Table 4-6.

E4.6.3 The rating of the current sensing overload device shall be based on the motor full-load current, except that, if the rating does not match a standard manufactured size, the next larger standard size shall be used, taking into consideration the service factor, ambient temperature of both the motor and its controller and type of motor enclosure.

E4.6.4 Embedded thermal sensing overload devices shall be sensitive to the temperature of the motor or to both temperature and current. In addition, motors shall be protected against stalled conditions by the use of a separate protective device which is responsive to motor current.

E4.6.5 Resetting of the motor overload device shall not restart the motor.

***E4.6.6* Standard NEMA Design B motors used on special duty cycle applications, such as high reversing duty, shall be protected by overload devices specifically selected for the application.

E5. Control Circuits

E5.1 Source of Control Supply. The source of supply for control circuits shall be taken from the load side of the main disconnecting means.

E5.2 Control Voltage.

E5.2.1 AC control voltage shall be nominal 115 volts, single phase, obtained from a transformer with an isolated secondary winding, except as follows:

*Exception No. 1: Other voltages may be used, where necessary, for the operation of electronic, static or similar devices used in the control circuit. These special voltages shall be obtained from separate two-winding transformers.

Exception No. 2: Exposed, grounded control circuits may be used when supplied from an isolating 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.

**A complete description of the circuit and the reason for its application must be presented to and permission obtained from the purchaser in writing before such circuit is used.

Exception No. 3: Any magnetic device having an inrush current exceeding 20 amperes at 115 volts may be energized directly from the line through contacts of a contactor or relay rated for line voltage. The coil of the contactor or relay shall be fed from the 115 volt control circuit.

Exception No. 4: Control voltages less than 115 volts may be used where components rated for 60 cycles are applied to a lower frequency (e.g., a coil rated at 115 volts, 60 cycles, may be applied to 95 volts, 50 cycles).

E5.2.2 DC control voltage shall not exceed 250 volts.

Exception: Other voltages may be used, where necessary, for the operation of electronic devices used in the electrical system.

E5.3 Connection of Control Devices.

E5.3.1 Indicator lamps, or transformer primary windings for indicator lamps, and operating coils of control devices shall be connected to the same side of the control circuit. Contacts shall be connected in the other side of the control circuit.

Exception No. 1: Overload relay contacts may be connected to the right of the coil (common) if the conductors between such contacts and coils of the magnetic devices do not extend beyond the control enclosure.

Exception No. 2: Where relay and electronic circuits are mixed, control contacts in the electronic circuit may be connected as required.

E5.3.2 Contacts shall not be connected in parallel to increase ampacity.

**E5.3.3* Relays used for selecting "Manual" or "Automatic" circuits shall be energized through pushbuttons located at the operator's main control station. The circuit shall be protected from undervoltage and return to the "Neutral" mode upon power failure, thus requiring the operator to select the "Manual" or "Automatic" mode.

E5.3.4 Separately mounted solenoid or magnetic brakes may be connected directly across motor terminal leads.

***E5.3.5* Solenoids shall be relay controlled with separate normally-open contacts of the same relay connected in each lead of the solenoid. Not more than two contacts shall control any solenoid. (See Sample Elementary Diagram, Appendix B).

Exception: Where a grounded control circuit is specified, a single normally-open contact shall be connected in the ungrounded lead of the solenoid.

E5.4 Circuit Design and Interlocking.

**E5.4.1* Where improper sequencing may create a hazard or cause damage to the equipment or work in process, protective interlocks shall be provided. These interlocks shall give protection against both:

(1) Failure of one or more devices to function properly, and
(2) Improper sequencing in manual or automatic operation.

For setup purposes, manual means, preferably by pushbuttons, shall be provided to perform individual functions. Direct operation of solenoid valves with rods or tools is not considered "manual means."

**E5.4.2* Where applicable, the requirements of E5.4.2.1 through E5.4.2.19 inclusive shall be provided.

E5.4.2.1 Opposing Motions Interlocked. Starters, relays, contactors and solenoids which are mechanically interlocked shall also be electrically interlocked to pre-

Table 4-6—Number and Location of Overcurrent Devices

Type of Motor	Supply System	Number and Location
1-phase AC or DC	2-wire, 1-phase AC or DC, ungrounded	1 in either conductor
1-phase AC or DC	2-wire, 1-phase AC or DC, one conductor grounded	1 in ungrounded conductor
1-phase AC or DC	3-wire, 1-phase AC or DC, grounded neutral	1 in either ungrounded conductor
3-phase AC	3-wire, 3-phase AC, ungrounded	2 in any 2 conductors
3-phase AC	3-wire, 3-phase AC, one conductor grounded	2 in ungrounded conductors
3-phase AC	3-wire, 3-phase AC, grounded neutral	2 in any 2 conductors
3-phase AC	4-wire, 3-phase AC, grounded neutral or ungrounded	2 in any 2 conductors except the neutral

For 2-phase power supply systems refer to National Electrical Code, Section 430-37.

vent simultaneous energization.

E5.4.2.2 Plugging Circuits. Plugging switches or zero speed switches, used to control the application or removal of power, in order that moving parts may be slowed down, stopped, or reversed, shall be provided with features incorporated in the control circuit to (1) prevent the reapplication of power after the completion of the plugging operation, and (2) prevent the application of power through any manual movement of the plugging switch shaft or of the motor or equipment. Timing relays are not permitted for plugging motors used for tapping at the end of the forward stroke.

E5.4.2.3 "Stop" by De-energization. "Stop" functions shall be initiated through de-energization rather than energization of control devices where possible.

E5.4.2.4 Movement Initiation by Limit Switches. Control circuits shall be designed so that when the equipment is in its "home" or "end of cycle" position, movement of any part of the equipment can be initiated by limit switches only if all of the following conditions are met:

(1) The control is set for automatic operation,
(2) The control is of the holding circuit type, is energized, and
(3) The condition of the automatic operation is indicated by pilot lights.

E5.4.2.5 "Jog" ("Inch") Circuits. "Jog" ("Inch") circuits shall be designed so that the prevention of "Run" or "Automatic" operation during jogging shall be inherent.

*E5.4.2.6 "Anti-Repeat" Operation. On equipment where continuous consecutive cycles of operation of the equipment are not a normal or a desired operation, the circuit shall be arranged so that such operation cannot be obtained by the use of any button or control means available to the equipment operator. Specifically, continuous consecutive cycles shall not result even though the "Cycle Start" button(s) is held continuously in the "Start" position. Timers shall not be used in anti-repeat circuits.

E5.4.2.7 Spindle Drive Interlocked with Feed. Interlocking shall be provided to insure that the spindle drive motor contactor is energized before the tool is driven into the work piece while in the "Automatic" cycle.

E5.4.2.8 Contactor for Control Circuit Loads. The auxiliary contact on any starter or contactor shall not be used in excess of its rating for carrying control circuit loads. An additional relay or contactor shall be used for this purpose.

E5.4.2.9 Changing from Rapid Traverse to Feed. Hydraulically actuated heads shall not require an energizing operation to change from rapid traverse to feed rate.

E5.4.2.10 One Station for Motor Starting. There shall be only one station effective at any time for starting all motors concurrently. However, multiple "Stop" stations may be used.

*E5.4.2.11 Overspeed Protection for DC Motors. Shunt and compound-wound DC motors shall be equipped with overspeed or field-loss protection to prevent excessive motor speed.

E5.4.2.12 Sequence Control by Pressure Switches. Pressure switches alone shall not be used to determine sequence of operation.

E5.4.2.13 Rotary Cam Limit Switches Used as Sequence Control. Rotary cam switches shall not be used as sequence controls on equipment unless the position of the equipment component or the location of the material in process is indicated by separate controls, such as limit switches, which are interlocked with the rotary cam switch.

Exception: This requirement does not apply to presses.

*E5.4.2.14 Control of Valves. Electrically controlled (solenoid) hydraulic and pneumatic valves shall be applied in such a manner that in the event of power failure there will be no hazard or damage to the equipment.

(1) Workpiece clamping applications. The clamping solenoid valve shall remain energized throughout the working cycle and until the unclamp solenoid is energized.

Example: Clamps actuated by hydraulic or pneumatic means and controlled by two-position, double-solenoid-operated four-way valves.

(2) Indexing applications.

Example No. 1: Hydraulic indexing mechanisms controlled by three-position, spring-centered, double-solenoid-operated four-way valves.

Example No. 2: Pneumatic indexing mechanisms controlled by two single-solenoid, spring-offset, three-way valves; or a two or three-position four-way valve.

**E5.4.2.15 Two-Hand Operation. Two pushbuttons shall be provided for each operator for protection against pinch points or other movement hazards and shall include all of the following:

(1) The circuits shall require maintained depression of each button throughout the cycle or until a point is reached in the cycle where the hazard ceases,
(2) Each pair of buttons shall be located and arranged so that operation by means other than the two hands of the operator is prevented, and
(3) The circuit shall be designed and wired so that the equipment cannot be operated unless both buttons at each station are released between successive operations.

**E5.4.2.16 Multiple Start Stations. Where more than one cycle start station is provided, all "Start" buttons shall be concurrently depressed to initiate the cycle, and released between successive operations, unless interlocking is provided to require either (1) the use of one station at a time, or (2) the initiation of the cycle by depressing buttons in a specified sequence.

**E5.4.2.17 Limit Switch Interlocking. Where necessary, limit switches shall be interlocked by the use of both the normally-open and the normally-closed contacts to prevent damage caused by sticking of the switch in the tripped position.

**E5.4.2.18 Indexing Interlocked with Full Depth Operation. In the "Automatic" mode, interlocking shall be provided on indexing equipment so that each head must reach the full limit of its operation and return to its starting position before indexing can occur.

**E5.4.2.19 Independent Return of Heads Such as Drills, Taps and Reamers. Each head unit shall return to its starting position upon completion of its feed cycle independently of other units.

E5.4.3 Whenever practicable, limit switches shall be used to (1) sense the position of equipment elements and parts in process, and (2) control the proper sequencing of the equipment.

E5.4.4 Hinged or sliding doors to compartments containing belts, gears or other moving parts which may expose hazardous conditions, shall be interlocked through limit switches or other means to prevent equipment from operating when doors are not closed.

E6. Control Equipment

E6.1 Standards.

E6.1.1 Control devices shall conform to ANS C19.1, Industrial Control Apparatus, and NEMA Standard IC-1, Industrial Control.

E6.1.2 Polyphase control apparatus shall conform to ANS C19.1, Industrial Control Apparatus, and NEMA Standard IC-1, Industrial Control, and be suitable for 600 volt service regardless of voltage applied.

*E6.1.3 Control circuit transformers shall conform to NEMA Standard ST-1, Specialty Transformers, Section 4, Machine Tool Transformers, and shall be Type 1, without integral overcurrent protection. The transformer primary winding shall be dual rated 240/480 volts at 60 cycles with a single secondary winding rated 120 volts. Ratings for other frequencies shall be as specified in the NEMA standard.

Exception: Transformers rated less than 75 volt-amperes (e.g., for use in combination motor starters) shall conform to NEMA Standard ST-1, Section 3, Control Transformers.

E6.1.4 Control devices external to the control enclosure, such as limit switches, pushbuttons, selector switches, valve solenoid enclosures and pressure switches, shall be oil-tight.

E6.1.5 Precision and other small devices used for control which do not come within the scope of the above standards shall conform to applicable accepted standards.

E6.2. General Requirements.

**E6.2.1* Panel mounted control devices shall be front-mounted, connected and wired.

Exception: This does not apply to such direct current and large alternating current equipment not commercially available for front connection. (See E7.5.2)

**E6.2.2* Screw-type terminals with captive saddle straps or equivalent means of retaining stranded conductors shall be provided on control devices.

Exception: This requirement does not apply to devices mounted external to the control enclosure and normally equipped with leads, such as valve solenoids and clutches. (See E6.2.4)

E6.2.3 Control devices and coils shall be marked in accordance with published pertinent standards or with the maker's name or trademark, ordering number and applicable descriptive electrical specifications such as voltage and frequency.

Exception: Where the device is too small to identify, the information shall be shown on the diagram or stock list.

**E6.2.4* Electrically energized devices located external to the control enclosure, such as clutches, solenoids and other coil-operated devices, shall be enclosed and include an oil-tight enclosure for conduit termination and connection purposes. Coils shall have leads which extend a minimum of four inches outside the enclosure. Leads shall be equipped with pressure connectors. Connections shall be bolted and taped.

E6.2.5 Control contacts operated by slow moving mechanisms shall be of the quick-make and quick-break type.

Exception: This does not apply to pushbuttons, selector switches or instruments.

***E6.2.6* The application of limit switches having more than one normally-open and one normally-closed pole shall require the purchaser's approval.

***E6.2.7* Solenoids used for actuating valves, brakes and other mechanisms shall have a continuous duty rating.

***E6.2.8* Additional transformer capacity of 25 percent above requirements, but not less than 100 volt-amperes nor more than 1000 volt-amperes, shall be furnished, or a separate transformer shall be provided and mounted on the control panel.

Exception: This requirement does not apply to control transformers used in combination motor starters.

***E6.2.9* Rectifiers used in a control circuit for dynamic braking of AC motors shall be supplied from isolating transformers other than the regular control transformer.

***E6.2.10* Relays shall have a complete set of contacts (e.g., a four-pole block shall have all contacts furnished).

***E6.2.11* The following devices should not be used:

(1) Stepping switches
(2) Push selector switches for start-stop operations
(3) Latch relays, except for memory indication
(4) Relays with overlapping contacts
(5) Neutral position switches

E6.3 Motor Starters

E6.3.1 Across-the-line starting shall be employed for alternating current motors.

Exception No. 1: Where the purchaser specifies otherwise.

Exception No. 2: Where the equipment requires limited accelerating torque.

E6.3.2 Alternating current motor starters shall open all of the power conductors connected to associated motors.

E6.3.3 Several motors may be controlled by one starter or contactor if all of the following are complied with:

(1) Ratings of the starter or contactor for horsepower, locked rotor current and other characteristics listed in NEMA Standard IC-1, Parts 21B and 27B, shall not be exceeded,
(2) Each motor shall have individual overload relays, and
*(3) All overload relays shall be the same make.

E6.3.4 The rating of starters for plug-stop, plug-reverse, or jogging duty requiring repeated interruption of stalled motor current or repeated closing of high transient currents encountered in rapid motor reversal involving more than five openings per minute shall be in accordance with Table 6-1.

E6.3.5 Conversion equipment, such as from AC to DC, shall be furnished for any electrical apparatus unless otherwise specified by the purchaser.

**E6.3.6* Polyphase motor starters shall be of the magnetic type and shall not be smaller than NEMA Size 1. For alternating current motors the starter shall be capable of interrupting the stalled rotor current of the motor or motors.

E6.4 Group Starting of Motors. The starting of motors shall be in sequence so that a group of motors started simultaneously will not exceed either of the following:

(1) An aggregate of 100 horsepower, when the smallest motor of the group is 10 horsepower or larger, or
(2) An aggregate of 75 horsepower, when the smallest motor of the group is 7½ horsepower or smaller.

E7. Control Enclosures and Compartments

E7.1 General. This section does not apply to combination motor starters except that they shall be in NEMA Type 12 enclosures.

E7.1.1 Control enclosures and compartments shall be constructed in conformance with applicable sections of this standard and both of the following:

(1) NEMA Type 12 (See NEMA Standard IC-1, Industrial Control)

Table 6-1—Starter Ratings for Plug-Stop or Jogging Duty†

Size Starter	Maximum Horsepower Rating	
	230 Volts, Three Phase	460/575 Volts, Three Phase
1	3	5
2	10	15
3	20	30
4	30	60
5	75	150
6	150	300

†See NEMA Standard IC-1, Industrial Control.

(2) Underwriters' Laboratories Standard UL 508, Industrial Control Equipment.

Exception: Equipment normally requiring ventilation may be housed in ventilated enclosures or compartments, provided they are located so that the equipment is capable of operating satisfactorily and without hazard.

**E7.1.2* Where heating from control devices results in a temperature rise which is detrimental to the contained equipment or its operation, forced air ventilation or forced circulated air shall be used. Any ventilating opening shall be designed to prevent the entrance of any deleterious substance. When forced air ventilation is required, the cabinets shall be pressurized. Air filters shall be commercially available types and sizes.

E7.1.3 The thickness of sheet steel used for walls and doors of enclosures or compartments shall be as shown in Table 7-1.

Exception No. 1: If a supporting frame or equivalent reinforcement is used, the minimum enclosure wall thickness for areas over 1200 square inches shall be 0.075 inch if made of sheet steel.

Exception No. 2: The thickness of walls and doors of compartments shall be a minimum of $\frac{1}{8}$ inch for cast material.

E7.1.4 The depth of the control enclosure or compartment should be a minimum consistent with the maximum depth of the control devices plus the required electrical clearances.

***Exception No. 1: In no case shall the depth of the enclosure be less than eight inches.

***Exception No. 2: When the panel area of floor-mounted enclosures exceeds 3600 square inches, the minimum depth shall be 12 inches.

**E7.1.5* The height and width of the door opening shall be at least one inch greater than the corresponding height and width of the control panel to be enclosed.

E7.1.6 A permanent metal data pocket shall be attached to the inside of the enclosure or compartment. If space permits, the pocket should be at least $10\frac{1}{2}$ inches wide and of adequate depth and thickness to accommodate all electrical diagrams.

E7.1.7 Compartment doors, enclosures and enclosure doors shall be designed to have sufficient rigidity to assure continuing proper alignment between mating parts, such as door fasteners and locking devices.

E7.1.8 Door aligning guides may be used to insure alignment. Reinforcements shall be used, as necessary, to prevent door warpage.

**E7.1.9* The interior of enclosure and panel shall be finished in a light color.

E7.2 Size Definition.

E7.2.1 A small enclosure or compartment is one which accommodates a panel having less than 1500 square inches of area.

E7.2.2 A large enclosure or compartment is one which accommodates a panel(s) having 1500 square inches or more of area.

E7.3 Enclosures.

Table 7-1—Metal Thickness for Walls and Doors of Enclosures or Compartments

Maximum Area of Any Surface, Square Inches	Maximum Dimension, Inches	Minimum Thickness (Nominal) of Metal, Inches	Equivalent Manufacturer's Standard Gage, MSG
Less than 360	18	0.075	14
360	24	0.075	14
1200	48	0.075	14
1500	60	0.106	12
Over 1500	—	0.132	10

**E7.3.1* Mounting feet or other suitable means external to the enclosure shall be provided for equipment-mounted enclosures. Separately mounted enclosures shall be free-standing.

**E7.3.2* There shall be no holes in the enclosure for mounting the enclosure or mounting controls within the enclosure.

***E7.3.3* There shall be no knockout holes through the enclosure for mounting components on the enclosure except as provided in E8.2.3.

***E7.3.4* Conduit or wireway openings shall be cut only as required. One additional hole may be cut in the side or bottom for temporary power line connection. Where wireway and conduit are disconnected for shipment, such openings shall be sealed prior to shipment.

***E7.3.5* Other equipment shall not be mounted on the exterior of the control enclosure unless specified by the purchaser.

E7.4 Compartments.

E7.4.1 Compartments for built-in controls shall be isolated from coolant and oil reservoirs.

E7.4.2 Compartments shall be readily accessible and enclosed.

E7.4.3 Compartments shall not be considered enclosed if they are open to (1) the floor, (2) the foundation on which the equipment rests, or (3) other compartments of the equipment which are not clean and dry.

E7.4.4 Where ventilation is required, the requirements of E7.1.1 and E7.1.2 shall apply.

E7.5 Doors.

E7.5.1 Hinged doors which swing horizontally shall be provided for control enclosures and compartments.

E7.5.2 Control enclosures containing panels with back-connected devices shall be equipped with rear access doors to those panels. (See E6.2.1)

E7.5.3 Doors shall not exceed 36 inches in width.

**E7.5.4* Door swing shall be a minimum of 165 degrees.

***E7.5.5* Door swing shall be such that ready access to the disconnect handle is not blocked.

***E7.5.6* Doors on large enclosures should be reinforced to prevent door warpage. Welded construction should be used.

***E7.5.7* Continuous hinges (piano type), welded in place, are preferred for all enclosure doors.

E7.6 Door Fasteners.

**E7.6.1* Door fasteners on small enclosures and compartments shall be designed to seal the door tightly around its perimeter. Vault-type hardware, which latches simultaneously at the top and bottom, shall be used on small enclosure doors.

E7.6.2 Door fasteners on large enclosures and compartments shall be designed to seal the door tightly around its perimeter. Vault-type hardware, which latches simultaneously at the top, center and bottom, shall be used on large enclosure doors.

***E7.6.3* The vault-type hardware in both E7.6.1 and E7.6.2 on the door enclosing the disconnecting means shall be interlocked with the disconnecting means. (See E3.9 and E3.10)

E8. Location and Mounting of Control Equipment

E8.1 General Requirements.

E8.1.1 Control equipment external to the control enclosure, such as limit switches, pressure switches, brakes, solenoids, pushbutton stations, etc., shall be (1) mounted rigidly in a readily accessible and reasonably dry and clean location, (2) provided with adequate clearance for replacement, and (3) free from accidental operation by normal movement of machine components or operator.

**E8.1.2* Controls should be mounted on an exterior

surface of the equipment between 1½ and 7 feet, but in no case less than 12 inches, above the operating floor line. Terminal blocks shall be mounted a minimum of 18 inches above the operating floor line. Terminal blocks located in compartments at sectional points shall not be recessed more than four inches from the equipment surface.

E8.1.3 Control equipment shall be so mounted and located that it will not interfere with machine adjustments or maintenance.

E8.1.4 Pipe lines, tubing or devices for handling air, gases or liquids shall not be located in electrical control enclosures or compartments.

E8.1.5 Terminal blocks shall be mounted to provide unobstructed access to the terminals and their conductors. The blocks shall not be mounted above each other in a plane perpendicular to the panel.

**E8.1.6* Separately-mounted terminal strips shall be used for power circuits and control circuits.

E8.2 Control Panels.

**E8.2.1* Control devices, normally panel-mounted, shall be mounted in one enclosure or compartment.

E8.2.2 Starters, contactors and other control devices shall be front-mounted on a rigid metal panel so that the complete panel can be removed through the enclosure opening. Such panel shall be a minimum of 0.106 inch, nominal (MSG No. 12) for mounting devices with screws 1/4 inch or smaller. Additional reinforcement or heavier gage panels shall be provided where larger screws are required. All mounting screws shall have the Unified form of thread. Equipment shall be mounted so that any component can be replaced without removing the panel. No components shall be mounted behind door pillars unless adequate space is provided for replacement and servicing.

**E8.2.3* Control equipment shall not be mounted on the door or sides of the enclosure except for such devices as pushbuttons, selector switches and pilot lights. Such devices shall be wired from terminal strips on the control panel.

E8.2.4 Swing-out panels located between the enclosure or compartment door and the control panel shall not be used.

Exception: Electronic panels may be of the swing-out or sliding type for servicing.

**E8.2.5* Panel-mounted control components, such as relays, shall be mounted in numerical order from left to right and top to bottom corresponding to the panel layout. Starters and contactors should be mounted in a similar manner.

E8.2.6 Any device(s) mounted on the control panel, carrying line voltage or a combination of line voltage and control voltage, shall be grouped above or to the side and segregated from devices which carry only the control voltage. This does not apply where the line voltage is 115 volts. In no case shall any device be mounted directly above the disconnecting means.

**E8.2.7* Spare terminals shall be provided on each control panel. The number shall be ten percent of the total in use on the panel or a minimum of eight for control conductors and three for power conductors.

E8.2.8 Where required for maintenance, space shall be provided adjacent to all devices mounted on the control panel.

***E8.2.9* A minimum of 15 percent of clear panel mounting space shall be provided on large panels and 30 percent on small panels to permit adding future control devices. On large panels, the total space should be divided into two or more spaces. (See Appendix B, Panel and Control Station Layout)

Exception: This does not apply to combination starters.

E8.3 Control Panel Enclosure.

E8.3.1 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.

E8.3.2 The panel shall not be set to such depth from door frame or other projecting portion of the equipment as to interfere with inspection and servicing.

E8.3.3 No portion of the equipment immediately above the door opening and less than six feet from the floor should project more than six inches beyond the door frame.

***E8.3.4* The bottom of the lowest panel-mounted control device shall not be less than 18 inches above the operating floor line. In no case shall the top of panel-mounted control devices be more than seven feet above the operating floor line.

E8.4 Clearances in Enclosures.

E8.4.1 Enclosures or compartments for mounting control panels shall provide ample room between the panel and the enclosure for proper maintenance and wiring to terminals.

E8.4.2 Exposed, non-arcing, current-carrying parts within an enclosure or compartment shall have an air space between them and the uninsulated walls of the enclosure or compartment, other than the device-mounting plate or panel, including conduit fittings, of not less than one-half inch for 250 volts or less, and not less than one inch for voltages between 250 and 600 volts.

E8.4.3 Where barriers between metal enclosures or compartments and arcing parts of control are required, they shall be of flame-retardant insulating materials which will not readily carbonize.

E8.5 Miscellaneous Control Equipment.

E8.5.1 Limit switches or position-sensors and their associated actuators shall be installed so that accidental overtravel will not damage them.

E8.5.2 Limit switch actuators shall be designed and applied in accordance with the switch manufacturer's specifications for travel, fly-back and other related characteristics.

E8.5.3 Solenoids shall be accessible and shall not be submerged in oil.

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

E8.5.4 Solenoids for operating devices shall be mounted so that liquids will drain away from the enclosure.

E8.5.5 Devices with a rotating member shall be mounted so as to prevent rotation of the stationary member.

E8.5.6 Plug-in devices and assemblies should be mechanically secured. Automatic locking upon full insertion is preferred.

E8.5.7 Female threaded fasteners, providing at least two full threads engagement, may be used to mount devices on readily removable sub-assemblies.

E9. Operator's Control Stations and Devices

E9.1 Device Requirements.

E9.1.1 Pushbutton operators, selector switch operators and indicating lights shall be of the oil-tight type.

E9.1.2 Pushbutton operators shall retain their color identification throughout their life. The color code for pushbuttons shall be as shown in Table 9-1.

E9.1.3 Emergency pushbutton operators shall be of the palm or mushroom type.

E9.1.4 Palm or mushroom type buttons shall not be used in start circuits, unless two or more are connected in series.

E9.1.5 "START" button operators shall be of the fully-guarded type.

Table 9-1—Pushbutton Color Code

Color	Typical Function	Example
Red	Stop, Emergency Stop	Stop of one or more motors; master stop.
Yellow	Return, Emergency Return	Return of machine elements to start position.
Black	Start Motors, Cycle, etc. Any operation for which no other color is specified	Start of one or more motors; start cycle or partial sequence.

Table 9-2—Pilot Light Lens Color Code

Color	Typical Function	Example
Red	Danger, Abnormal Condition, Fault Condition	Voltage applied; cycle in automatic; faults in air, water, lubricating or filtering systems; ground detector circuits.
Amber (Yellow)	Attention	Motors running; machine in cycle; unit or head in forward position.
Green	Safe Condition (Security)	End of cycle; unit or head returned; motors stopped; motion stopped; contactors open.
White or Clear	Normal Condition	Normal pressure of air, water, lubrication.

****Table 9-3—Multiple Station Pilot Light Requirements***

Color	Typical Function	Example
Red	Power On, Emergency On, Automatic Cycle	Ground detectors; lubrication failure; master relay on; pressure failure (water, air, gas).
Amber (Yellow)	Motors Running, Machine in Cycle, Full Depth	Machine elements in advanced position; manual cycle.
Green	End of Cycle, Heads in Returned Position	
White or Clear	Parts in Place, Lubrication Normal, Pressure Normal (Water, Air, Gas)	

E9.1.6 The color code for pilot lights shall be as shown in Table 9-2.

***E9.1.7* "STOP" button operators shall be of the unguarded type.

***E9.1.8* Indicating lights shall be of the push-to-test type, powered by individual transformers mounted integrally with the lamp base. The secondary voltage shall be less than six volts for use with six volt lamps.

E9.2 Fixed Stations.

E9.2.1 Fixed control stations shall be dust, moisture and oil-tight, complete with metal enclosure and cover.

**E9.2.2* Pushbutton and pilot light enclosures with six or more units shall be equipped with hinged covers.

**E9.2.3* Where more than 16 units are required, terminal strips shall be furnished in the enclosure.

E9.3 Control Station Component Arrangement.

E9.3.1 "START" buttons shall be mounted above or to the left of their associated "STOP" buttons.

Exception: This requirement does not apply to "START" buttons in series.

E9.3.2 A legend (name) plate shall be provided for each control station component to identify its function and located so that it can be read easily by the equipment operator from his normal work position. Markings on the plate shall be permanent, such as by embossing or engraving.

E9.4 Control Station Location.

E9.4.1 Control stations shall be mounted in a reasonably clean and dry location.

E9.4.2 Control stations shall be located within easy reach of the equipment operator and placed so that the operator does not have to reach past spindles or other moving parts.

E9.4.3 Controls shall be free from possibility of accidental operation either by normal movement of the equipment or the operator.

**E9.4.4* Pushbuttons shall be mounted on a surface which is not less than 45 degrees from the horizontal plane.

E9.4.5 Pipe lines, tubing or devices for handling air, gases, or liquids shall not be located in control stations.

***E9.4.6* Ground detector lamps shall be mounted on the front of the main control enclosure. (See E15.1.1)

E9.5 Pendant Stations.

E9.5.1 Pendant stations shall be oil-tight.

E9.5.2 A wobble stick or rod operator at the bottom of the station may be used for "EMERGENCY STOP" control.

E9.5.3 Pendant pushbutton stations shall be supported by suitable means other than the flexible electrical conduit or multiconductor cable.

E9.5.4 For grounding requirements, see E15.3.

****E9.6** Multiple Station Equipment.

****E9.6.1* Pilot lights shall be furnished to show (1) the position of mechanical components, such as clamps, transfers, transfer fingers and locators, and (2) the functions shown in Table 9-3.

****E9.6.2* Pilot lights shall be located at the main control station and arranged in accordance with the sequence of operations.

****E9.6.3* Pushbuttons shall be provided at the operator's main control station to provide complete manual operation in accordance with the sequence of operation.

****E9.6.4* An operator's control station, including a selector switch, shall be provided at each station for manual operation of individual heads. The control circuit shall be interlocked to prevent operation from the main control station when the local selector switch is set in either "MANUAL" or "OFF" position. The nameplate on the selector switch shall read from left to right, "AUTOMATIC - MANUAL - OFF."

E10. Electrical Accessories

E10.1 Plugs and Receptacles.

E10.1.1 Plugs and receptacles shall be approved for the voltage applied and conform to all of the following:

(1) A locking feature to prevent accidental disconnections,
(2) A skirt or shroud that will contain any arc and will protect the poles when not in use,
(3) A grommet around the cord which will prevent entrance of contaminants, and
(4) Means which effectively seal the receptacle whenever the plug is removed.

Exception: Items (3) and (4) above do not apply to subassemblies mounted within the control enclosure.

E10.1.2 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 plug have been disconnected.

E10.1.3 The grounding pole of both plugs and receptacles shall only be used for grounding purposes and not as a normal current-carrying pole.

E10.2 Work Lights.

E10.2.1 The lighting circuit voltage shall not exceed 150 volts between conductors.

E10.2.2 Work lights, where furnished, shall be supplied from one of the following sources:

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

(2) The 115 volt control circuit, with separate overcurrent protection for the lighting circuit. This system may be used only with a grounded control circuit.
(3) The plant lighting circuit.
(4) The line side of the main disconnecting means where a separate primary disconnecting means, isolating transformer and secondary overcurrent protection are furnished in a NEMA Type 1 enclosure and mounted within the control enclosure, adjacent to the main disconnecting means.

E10.2.3 The conductors to stationary or built-in lights shall conform to E11, Conductors. The conductors within fixtures shall be not smaller than AWG No. 18.

E10.2.4 Flexible cords shall be all thermoplastic, Type STO.

E10.2.5 For grounding requirements, see E15.2.

E10.2.6 Incandescent lampholders shall be of the medium base, screw shell type and rated 660 watts, 250 volts.

E10.2.7 Lampholders shall not incorporate a switch or receptacle.

E10.2.8 Stroboscopic effects from lights shall be avoided.

E11. Conductors

E11.1 Specifications.

E11.1.1 Conductors (other than those specified in E11.2 and E11.4) shall conform to one of the following:
(1) Type MTW.
(2) Types THWN or THHN having all characteristics equal to Type MTW, except insulation thickness.
(3) Multiconductor, all thermoplastic cable, Type STO.
(4) Multiconductor, control cable having individual conductors of Type MTW, THWN, or THHN construction and a jacket similar to Type STO construction.
(5) Mineral-insulated metal-sheathed cable, Type MI.

E11.1.2 Conductors shall be not smaller than:
(1) Power circuits, No. 14 AWG.
*(2) Control circuits in raceways and on the equipment, No. 14 AWG.
Exception: No. 16 AWG may be used in jacketed multiconductor cables.
(3) Control circuits on panel and within the operator's control station, No. 16 AWG.
*(4) Internal wiring of electronic, static and precision devices, No. 22 AWG.

E11.1.3 Conductors shall be annealed stranded copper, conforming to the requirements of ASTM Standard B8, Class C for non-flexing service and B174 Class K for flexing service. Table 11-1 shows minimum stranding for single conductors.

Exception: Stranding for MTW conductors in sizes 1 AWG through 4/0 AWG inclusive may be 19 strand, and 37 strand for sizes 250 MCM through 500 MCM inclusive.

E11.1.4 Conductors in multiconductor cable shall meet the requirements in E11.1.3.

Exception: Stranding shall be for constant flexing service as shown in Table 11-2.

E11.1.5 The insulation on the conductor shall have a readily identifiable continuous marking to indicate: National Electrical Code Type, voltage, size, temperature rating and manufacturer. In no case shall any part of the identification be obtained by the use of fibrous material.

E11.1.6 Metal-clad cable shall not be used.

***E11.2** Special Insulations. Where required by ambient conditions, other conductor insulating material should be used. Wiring in and external to panels used on or adjacent to high heat generating equipment, such as furnaces, ovens, heat treating equipment, etc., shall have Underwriters' approved Type AVA, SFF2 or equal insulation unless otherwise specified by the purchaser.

E11.3 Conductor Ampacity.

E11.3.1 The allowable ampacity of conductors in raceways containing more than six conductors with ambient temperature not greater than 40 C (104 F), and conductors not close to heat dissipating components, shall not exceed the limits specified in Table 11-3. These ampacities are based on the number of conductors in raceways ac-

Table 11-1—Single Conductor Stranding

Conductor Size, AWG or MCM	Stranding	
	Class C	Class K
22	19	†
20	19	†
18	19	†
16	19	26
14	19	41
12	19	65
10	19	104
8	19	
6	19	
4	19	
3	19	
2	19	
1	37	
0	37	
2/0	37	
3/0	37	
4/0	37	
250	61	
300	61	
350	61	
400	61	
500	61	

†Use Class C Stranding.

Table 11-2—Multiconductor Cable Stranding (Constant Flexing Service)

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

Table 11-3—Conductor Ampacity

Conductor Size, AWG or MCM	Rating in Amperes		
	In Control Enclosure	In Conduit or Wireway	
	Power and Control	Control	Power
22	3	—	—
20	5	—	—
18	6	—	—
16	8	8	—
14	12	12	11
12	16	16	14
10	24	24	21
8	32	32	28
6	45	45	39
4	57	57	49
3	65	65	56
2	77	77	67
1	90	90	77
0	102	102	88
2/0	119	119	102
3/0	135	135	116
4/0	160	160	138
250	177	—	151
300	196	—	168
350	213	—	182
400	229	—	196
500	262	—	224
750	327	—	280
1000	373	—	319

cording to Table 13-1. For raceways containing less than six conductors, refer to NFPA 79, Table 200-A, for conductor ampacity.

E11.3.2 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.

E11.4 Electronic, Precision, Static and Similar Control.

E11.4.1 Conductors used to connect electronic, precision, static or similar devices or panels shall conform to the following:

(1) Conductor insulation shall be water and oil resistant, flame retardant material with an operating temperature rating of 90 C in dry locations. Special insulations suitable for higher temperatures shall be used where necessary. Conductor insulation shall be adequate for the voltage on that conductor.
(2) Where the conductors are run with or adjacent to other conductors, all conductors shall be insulated for the maximum voltage involved. In no case shall insulation rated less than 300 volts be used.

Exception: Bare conductors (such as resistor and capacitor leads, "jumpers" between adjacent terminals, etc.) may be used if the method of securing insures adequate electrical clearance.

E12. Wiring Methods and Practices

E12.1 General Requirements.

E12.1.1 Conductors shall be color-coded as follows:

(1) Black—Line, load and control circuits at line voltage, AC or DC.
(2) Red—AC control circuits.
(3) Blue—DC control circuits.
(4) Yellow—Interlock control circuits wired from an external power source.
(5) Green (with or without a yellow stripe)—Equipment grounding conductors.
(6) 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: Equipment for use outside the United States where the above color code is not in agreement with established electrical codes.

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

E12.1.2 Conductors shall be identified at each termination by marking with a number to correspond with the diagram(s).

E12.1.3 Identification tags shall be made of oil-resistant material. If wrap-type adhesive strips are used, they shall be a minimum of $1\frac{3}{8}$ inches long. Sleeve-type tags shall be undersized so that they will not slip off the conductor if the conductor is removed from its termination point.

E12.1.4 Terminals on terminal blocks shall be plainly and permanently marked to correspond with the identification shown on the electrical diagram(s).

**E12.1.5* Terminals on terminal blocks shall be numbered in numerical ascending order, starting from top to bottom, or from left to right.

Exception: Terminals for remote interlock wiring shall be grouped separately. (See E12.4.16)

E12.1.6 There shall be no exposed terminals external to control enclosures, compartments and junction boxes.

E12.1.7 Conductors and cables shall be run without splices from terminal to terminal.

*Exception: Splices may be made to leads attached to electrical devices, such as motors and solenoids, and shall be insulated with oil-resistant electrical tape. Splices shall be made according to E6.2.4.

E12.1.8 Taped connections shall be covered with oil-resistant adhesive tape which will not support combustion and conforms to Military Specification MIL-I-7798A.

E12.1.9 Terminal blocks shall be wired and mounted so that internal and external wiring does not cross over the terminals. Not more than two conductors shall be terminated at each terminal connection.

***E12.1.10* Power wiring external to the control enclosure shall be sized for the next larger horsepower motor, up to and including 25 horsepower.

E12.2 Electrical Connections.

**E12.2.1* Electrical connections to motors, solenoids and similar devices with integral leads, size No. 4 AWG and smaller, shall be made with ring-type pressure connectors approved in accordance with Underwriters' Laboratories Standard UL 486. The connectors shall be bolted and taped. Soldered or insulation-piercing type connectors (lugs) are not acceptable.

**E12.2.2* Ring-type pressure connectors shall be used to connect conductors to devices with lug-type terminals which are not equipped with saddle straps or equivalent means of retaining conductor strands.

Exception No. 1: Soldered connections may be used within the protective shell of a plug or receptacle and for internal connections of a sub-assembly which can be re-

Table 12-1—Number of Conductors in Panel Wireways†

Wireway Size, Inches	No. 14 AWG Conductors			No. 16 AWG Conductors	
	MTW 3/64 in. insulation; Maximum no.	MTW 2/64 in. insulation; Maximum no.	THWN, THHN Maximum OD 0.110 in; Maximum no.	MTW 2/64 in. insulation; Maximum no.	THWN, THHN Maximum OD 0.100 in; Maximum no.
1 × 1	20	30	53	38	64
1 × 2	40	59	105	76	127
1 × 3	60	89	158	113	191
1½ × 2	60	89	158	113	191
2 × 2	80	118	210	152	254
1½ × 3	90	133	236	170	286
2 × 3	120	178	316	226	381
2½ × 3	150	222	394	283	477
3 × 3	180	266	473	340	572

Table 12-1 is based on 50 percent of area fill of wireway using stranded conductors.
†When conductors other than No. 14 or 16 AWG are used, determine equivalent number of No. 14 conductors by multiplying number of conductors of sizes other than No. 14 or 16 by "conductor equivalent" from Tables 13-2 and 13-3. Add the result to the number of No. 14 conductors and use total for selecting size of wireway from Table 12-1.

moved for bench service.

E12.3 Panel Wiring.

E12.3.1 Panel wiring shall be contained in panel wireways, unless the total number of starters, relays and timers is less than six. Where wireways are not used, conductors shall be bundled to keep them in place.

E12.3.2 The number of conductors in panel wireways shall not exceed the values listed in Table 12-1.

E12.3.3 The panel wireway material shall not support combustion. It shall be made of non-warping, insulating material rated for the highest voltage applied to any conductor contained. The wireway shall not contain exposed metal parts, except for the mounting screws where used.

**E12.3.4* Control panels shall be equipped with terminal blocks for all external wiring requiring No. 4 AWG and smaller conductors. Conductors larger than No. 4 AWG may be terminated directly on the device.

Exception: This does not apply to supply line conductors. (See E3.7)

E12.4 Equipment Wiring.

E12.4.1 Conductors and their connections external to the control panel enclosure shall be totally enclosed in suitable metal raceways or enclosures as described in E13, except as otherwise permitted in this section.

**E12.4.2* Multiconductor cable or liquid-tight flexible metal conduit may be used for flexible connections to pendant pushbutton stations.

**E12.4.3* Multiconductor cable, Type STO, having a yellow color and secured at each end with an oil-tight connector, or liquid-tight flexible conduit, shall be used for connections to stationary or infrequently moved devices, such as limit switches and solenoids, operated at control voltage. The exposed length of cable or flexible conduit between connectors shall not exceed three feet. Minimum wire size of cable shall be No. 16 AWG.

E12.4.4 Liquid-tight flexible metal conduit and fittings shall enclose conductors to stationary or infrequently moved devices, such as motors, brakes and other apparatus, operated at line voltage. The length shall not exceed three feet.

E12.4.5 Connections to continuously moving parts shall be made with extra flexible conductors (Class K in Table 11-1) encased in liquid-tight flexible metal or nonmetallic conduit not exceeding 1½ inches trade size, or with extra flexible multiconductor cable (See Table 11-2). Flexible cable and conduit shall have vertical connections and shall have sufficient slack to avoid sharp flexing and straining.

Exception: Horizontal connections may be used if the flexible cable or conduit is adequately supported.

E12.4.6 The installation of flexible conduit and cable shall be such that liquids drain away from the fittings.

E12.4.7 Where liquid-tight flexible metal conduit is used for flexing applications, fittings shall include basket weave or equivalent grips.

E12.4.8 Where there is relative motion between flexible conduit or cable and parts in process or equipment components, the construction and supporting means shall be such that there will be a clearance of at least one inch under all operating conditions. Barriers or guides shall be provided where the clearance cannot be maintained.

E12.4.9 Where practicable, conductors of any circuit shall be contained in the same raceway.

E12.4.10 Conductors connected in AC circuits and conductors connected in DC circuits may occupy the same raceway, regardless of voltage, provided they are all insulated for the maximum voltage on any conductor in the raceway.

E12.4.11 Where equipment must be removed and electrical circuits broken, plugs and receptacles may be used, provided they are polarized and of the grounding type. The male plug shall be connected to the load circuit. Power and control circuits shall not be carried in the same plug.

**E12.4.12* Where equipment is constructed so that wiring must be disconnected for shipment, terminal blocks in an accessible enclosure shall be provided at the sectional points. Spare terminals shall be provided in each terminal enclosure, external to the control panel. The number shall be ten percent of the total in use or a minimum of six, whichever is greater.

E12.4.13 Sharp edges, burrs, rough surfaces or threads, with which the insulation of the conductors may come in contact, shall be removed from conduit fittings, raceways or any other parts. Where necessary, additional protection consisting of a flame-retardant, oil-resistant, insulating material shall be provided to protect conductor insulation.

**E12.4.14* Wiring external to the control panel shall have a termination at the terminal blocks on the control panel. One wire shall be returned, for test purposes, from a connection between limit switches, pushbuttons or other devices connected in series. The common side of the control circuit shall be wired to a terminal in master terminal boxes.

**E12.4.15* Where specified, a raceway complete with conductors shall be furnished between a separately-mounted control enclosure and terminal boxes mounted on the equipment. Exterior wireways (not conduit) complete with conductors shall be furnished when the number of conductors required exceeds that for which three-inch conduit is suitable. In either case, terminal boxes shall be furnished on the equipment for terminating conductors from the control enclosure.

***E12.4.16* Interlock control circuit wiring, which is energized from a remote control power source, shall be segregated in terminal boxes and readily identified with yellow insulation so the conductors can be distinguished from other wiring in the box. Boxes containing such wiring shall be indicated on a plate affixed to the outside of the cover which reads: Separately Energized Interlock Wiring.

E13. Raceways, Fittings and Boxes

E13.1 General Requirements.

E13.1.1 Minimum Conduit Size. No conduit, rigid or flexible, smaller than 1/2 inch diameter trade size shall be used.

E13.1.2 Grounding. See E15 for acceptable means of grounding.

E13.1.3 Type of Fittings. Fittings used with raceways and multiconductor cables shall be liquid-tight.

E13.1.4 Accessibility of Covers. Covers shall be readily accessible.

E13.1.5 Gaskets. Gaskets shall conform to E17.

E13.1.6 Number of Conductors. The number of conductors in conduit and wireways shall not exceed the quantity listed in Table 13-1.

E13.2 Rigid Metal Conduit and Fittings.

**E.13.2.1* Corrosion Resistance. Rigid conduit and fittings shall be of a galvanized or sherardized steel, meeting the requirements of ANS C80.1, Zinc Coated Rigid Steel Conduit, and C80.4, Fittings for Rigid Steel Conduit, or when requested, of a corrosion resistant material suitable for the conditions. Dissimilar metals in contact which would cause galvanic action shall not be used. Conduit shall be protected against corrosion, inside and outside, except at threaded joints.

E13.2.2 Type of Fittings. Unless structural difficulties prevent, fittings shall be threaded. They shall be made of malleable or ductile iron and have impact strength comparable to that of the conduit. Covers on conduit fittings shall be gasketed.

Table 13-1—Number of Conductors in Conduit and External Wireways†

Conduit-C or Wireway-W, Size, Inches	No. 14 AWG Conductors		
	MTW 3/64 in. insulation, Maximum no.	MTW 2/64 in. insulation, Maximum no.	THWN, THHN Maximum OD 0.110 in. Maximum no.
½-C	5	7	12
¾-C	9	13	22
1-C	14	20	36
1¼-C	24	35	63
1½-C	33	48	85
2-C	54	79	141
2½-C	77	113	201
3-C	120	174	310
3 × 3-W	144	210	374
3½-C	160	230	416
4-C	200	300	535
4 × 4-W	260	375	694
5-C	320	470	842
5 × 5-W	400	585	1050
6-C	465	680	1215
6 × 6-W	580	850	1500

Table 13-1 is based on 40 percent of area fill of raceway using stranded conductors.
†When conductors other than No. 14 AWG are used, determine equivalent number of No. 14 conductors by multiplying number of conductors of sizes other than No. 14 by "conductor equivalent" from Tables 13-2 and 13-3. Add the result to the number of No. 14 conductors and use total for selecting size of conduit or wireway from Table 13-1.

E13.2.3 Running Threads. Running threads shall not be used on conduit.

E13.2.4 Conduit Support. All conduit shall be securely held in place and supported at each end. Where threadless fittings must be used, due to difficulty in assembly, conduit shall be fastened to the equipment so that it cannot be accidentally pulled apart.

E13.2.5 Size of Bends. Bends of rigid conduit shall be made so that the conduit will not be damaged and 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 13-4.

E13.2.6 Number of Bends. A run of conduit shall not contain more than the equivalent of four quarter-bends (360 degrees total).

E13.2.7 Use of Locknuts, Bushings and Seals.

*E13.2.7.1 Where conduit terminates in a threadless opening, a locknut shall be provided both inside and outside the enclosure, and the conduit end shall be equipped with an insulating bushing. A suitable oil-tight means (such as an oil-resistant synthetic rubber O-ring and a metal cup) shall be provided between the outside locknut and opening. When the conduit enters the opening through a conduit connector, the shoulder of the connector may serve as the outside locknut. The O-ring assembly or an equivalent sealing device shall also be furnished when a locknut is used as a jam nut on connectors fitted to threaded hubs.

E13.2.7.2 When the conduit enters the opening through a conduit connector equipped with a tapered surface or similar sealing action, no locknuts or gaskets are required, providing the resulting seal is liquid-tight.

E13.3 Liquid-tight Flexible Conduit and Fittings. Flexible conduit shall be installed in a manner that liquids will tend to run off the surface instead of draining toward the fittings.

E13.3.1 Metallic Conduit. Liquid-tight flexible metal conduit shall consist of an oil-resistant, liquid-tight jacket or lining in combination with flexible metal reinforcing tubing.

E13.3.2 Non-Metallic Conduit.

E13.3.2.1 Liquid-tight flexible non-metallic 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.

Table 13-2—MTW Conductor Equivalents

Conductor size, AWG	Insulation thickness, 64th inches	Maximum OD, Inches	Equivalent No. 14 AWG 64th inch Insulation Conductors
16	2	0.130	0.53
14	2	0.147	0.68
14	3	0.178	1.0
12	2	0.166	0.87
12	3	0.197	1.2
10	2	0.190	1.15
10	3	0.221	1.5
8	3	0.252	2.0
8	4	0.283	2.5
6	4	0.321	3.3
4	4	0.370	4.3
3	4	0.402	5.1
2	4	0.432	5.9
1	5	0.513	8.3
0	5	0.546	9.4
00	5	0.593	11.0
000	5	0.645	13.0
0000	5	0.702	16.0

For conductors 250 MCM and larger, use actual area of conductors and calculate conduit size on basis of 40 percent conduit area fill.

Table 13-3—THWN and THHN Conductor Equivalents

Conductor size, AWG	Maximum OD, Inches	Equivalent No. 14 AWG THWN, THHN Conductor	Equivalent No. 14 AWG 64th inch Insulation MTW Conductors
16	0.100	0.83	0.31
14	0.110	1.0	0.38
12	0.130	1.39	0.53
10	0.170	2.39	0.91
8	0.220	4.0	1.52
6	0.257	5.5	2.1
4	0.328	8.9	3.4
3	0.356	10.5	4.0
2	0.388	12.6	4.8
1	0.452	17.0	6.5
0	0.492	20.2	7.7
00	0.541	24.1	9.2
000	0.590	28.6	10.9
0000	0.647	34.6	13.2

For conductors 250 MCM and larger, use actual area of conductors and calculate conduit size on basis of 40 percent conduit area fill.

Table 13-4—Minimum Radii of Conduit Bends

Conduit Size, Inches	Radius of Conduit Bends, Inches
½	4
¾	5
1	6
1¼	8
1½	10
2	12
2½	15
3	18
3½	21
4	24
5	30
6	36

Table 13-5—Liquid-Tight Flexible Non-Metallic Conduit Dimensions

Trade Size, Inches	Nominal Inside Diameter, Inches	Minimum 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

E13.3.2.2 The conduit shall be resistant to kinking and shall have physical characteristics comparable to the jacket of multiconductor cable.

E13.3.2.3 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.

E13.3.2.4 The conduit shall have dimensions as near as practicable to the limits given in Table 13-5.

E13.3.3 Standards for Fittings. Connectors for liquid-tight flexible metal and non-metallic conduit shall be liquid-tight, made of metal, designed to electrical trade sizes and meet the requirements of Underwirters' Laboratories Standard UL 514. Fittings shall have sufficient thread length to accommodate a gasket assembly, a box wall thickness of 0.125 inch and a locknut and bushing.

E13.4 Compartments and Raceways.

E13.4.1 Description. Raceways, junction boxes and wiring should be external to the base or column of the equipment. However, compartments and raceways within the column or base may be used to enclose conductors, provided they are isolated from coolants and oil reservoirs and are enclosed except as noted in E13.4.2. Conductors shall be protected from mechanical damage and abrasion. General purpose flexible conduit may be used as additional protection in compartments and raceways if fastened at each end.

E13.4.2 Drainage of Raceways. Raceways integral with equipment bases or columns shall be arranged to drain to convenient points. Openings of 1/4 inch diameter shall be provided at such points to permit drainage.

E13.4.3 Compartment Door Hinges. Compartment doors exceeding 150 square inches should be hinged.

E13.5 Junction, Pull and Terminal Boxes. Boxes shall be readily accessible.

*****E13.5.1* Construction. Junction, pull and terminal boxes shall not have knockouts and shall be provided with gasketed covers. Boxes shall be oil-tight. Mounting means external to the box shall be provided. Covers larger than 150 square inches shall be hinged. Covers not hinged shall be captive to the box.

Boxes 24 square inches and smaller shall be made of sheet steel, a minimum of 0.060 inch thick, and those larger than 24 but less than 320 square inches, not less than 0.075 inch thick. Cast boxes shall be made of metal and shall conform to UL Standard 508. Cover fasteners shall be external to the enclosed area and captive to the box or cover.

Terminal enclosures 320 square inches and larger shall conform to Section E7. Vault-type hardware need not be furnished on the door unless the surface enclosed exceeds 1500 square inches.

E13.5.2 Motor Junction (Conduit) Boxes. Motor junction (conduit) boxes shall not be used for wiring to solenoid valves, limit switches and other control devices.

Exception No. 1: Leads from separately mounted motor brakes may be connected in the box if the brake is connected directly to the motor terminal leads and has no other connections.

Exception No. 2: Connections for motor-mounted devices, such as brakes, thermostats, plugging switches or tachometer generators, may be connected in the motor junction (conduit) box.

E13.6 Wireways. Exterior wireways may be used when rigidly supported and clear of all operating or contaminating portions of the equipment and shall conform to the following:

(1) Wireways shall be oil-tight.
(2) Metal thickness shall be a minimum of 0.075 inch (No. 14 MSG gage).
(3) Covers on wireways shall be hinged, shaped to overlap the sides and held closed by captive screws or other suitable fasteners exterior to the wireways. Gaskets for covers and section joints shall conform to E17. For sections mounted horizontally the covers shall be on top.
(4) Wireways with knockouts are not acceptable. Only such openings as are required for wiring the equipment shall be provided.
(5) Corners, bends, edges, etc., shall have all burrs removed. Additional protection shall be provided to protect conductor insulation at all sharp bends and drop points. Such protection may consist of fibre, plastic or other material to cover the edge or corner with sufficient radius to prevent damage to the insulation.
(6) Conductor fill shall not exceed 40 percent of the wireway cross-sectional area.

E14. Motors

E14.1 Standards. Except as noted in this standard, motors shall meet the requirements of the following:

(1) ANS C6.1, Terminal Markings for Electrical Apparatus.
(2) ANS C50, Rotating Electrical Machinery.
(3) NEMA Standard MG-1, Motors and Generators.

E14.2 Type of Motor.

*****E14.2.1* AC motors shall be standard Design B, foot-mounted, single-end shaft, anti-friction bearings. Motors up to and including 100 horsepower, 1800 rpm, are to be totally-enclosed, fan-cooled, except motors smaller than frame size 184 need not be fan-cooled. Where polyphase power is available, motors 1/4 horsepower and larger shall be polyphase.

Note: The use of motors with short-time ratings and all other motors not conforming to E14.2.1 shall require written approval.

E14.2.2 Integral horsepower AC motors, NEMA Frame 445 or smaller, but not exceeding 100 horsepower, 1800 rpm, shall be dual voltage. Motor voltage ratings shall be as specified by purchaser.

Exception: Multi-speed motors may be single voltage.

E14.3 Mounting of Motors.

E14.3.1 Each motor shall be mounted where it is readily accessible for maintenance and not subject to damage. All motor-driven couplings, belts and chains shall be easily replaceable.

E14.3.2 The motor mounting arrangement shall be such that all motor hold-down bolts can be removed easily and replaced and junction (conduit) boxes shall be readily accessible.

E14.3.3 Motor compartments shall be clean and dry and adequately vented directly to the exterior of the equipment. Unless other compartments meet the requirements of the motor compartment, there shall be no openings of any kind between the motor compartment and any other compartment of the equipment. Where a conduit or pipe is run into the motor compartment from another compartment not meeting the motor compartment requirements, any clearance around the conduit or pipe shall be sealed.

E14.3.4 Direct-coupled, foot-mounted motors shall be aligned properly. Couplings shall be flexible type.

E14.3.5 Motors mounted within machine compartments or enclosures shall be provided with sufficient space for ease of lubrication, servicing and replacement. Sufficient air circulation shall be provided so that the motor, when under full-load conditions, will not exceed its rated temperature rise.

****E14.3.6** The motor compartment or mounting space shall be of sufficient size to accommodate a NEMA frame size motor, complete with junction box, two NEMA horsepower sizes larger, at the same speed, than that recommended by the industrial equipment builder for driving the equipment.

***E14.4** Direction Arrow. A permanent metal arrow to indicate the proper direction of rotation of each motor shall be provided. The arrow shall not be mounted on the motor.

E14.5 Special Characteristics.

E14.5.1 Special motors with static and dynamic balance and noise control shall be used only to eliminate machine trouble from these sources. In no case shall the degree of balance be less than that specified in NEMA Standard MG-1, Motors and Generators.

E14.5.2 Special characteristics of AC motors shall be shown on a separate nameplate mounted adjacent to the conventional motor nameplate. The manufacturer's catalog numbers shall not be considered sufficient to designate such characteristics. Typical examples are:

(1) Special insulation.
(2) Special shaft length.
(3) Special torque.
(4) Special balance.
(5) Special lubrication.

****E14.6** Motor Junction Boxes. Integral-horsepower motor junction boxes shall not have knockouts. A gasket shall be furnished on the cover of the motor junction box, and between the junction box and the motor frame.

E15. Grounding

E15.1 Control Circuits

**E15.1.1* Ungrounded control circuits shall be equipped with ground detector lights. For typical connections, see Sample Elementary Diagram, Appendix B.

Exception: Ground detector lamps are not required where a combination motor starter is the only control on the equipment.

E15.1.2 When a grounded control circuit is specified, the side of the circuit connected to the coils shall be permanently grounded. There shall be no contacts between solenoids and the grounded conductor (See E5.3.1). Insulation on the grounded conductor shall be white and shall be connected directly to the control transformer without overcurrent protection. The grounding conductor shall be green (with or without a yellow stripe) or bare.

E15.1.3 Exposed control circuits operating at 25 volts or less shall be grounded. (See E5.2.1, Exception No. 2.)

E15.2 Lighting Circuits. One conductor of the lighting circuit fed from a separately mounted isolating transformer shall be grounded only at the transformer.

Exception: Where the lighting circuit is fed from the plant lighting circuit, the grounded conductor shall be identified by a white or natural gray colored insulation.

E15.3 Stationary Equipment. All exposed, non-current carrying metal parts of equipment, such as control enclosures, raceways, control stations, separately mounted apparatus, and portable and pendant accessories, shall be grounded. For separately mounted electrical apparatus, a bonding conductor shall be included in the wiring for bonding such apparatus to the equipment.

E15.4 Methods of Grounding. Bonding by attaching the equipment to the machine with bolts or screws shall be considered a satisfactory ground where all paint and dirt are removed from joint surfaces. Moving machine parts, other than removable accessories or attachments, having metal-to-metal bearing surfaces shall be considered as adequately bonded. Sliding parts separated by oil or air under pressure are not considered bonded together.

E15.5 Equipment Grounding Conductors

E15.5.1 A copper or other corrosion-resistant conductor shall be used for grounding and bonding purposes. Where a conductor other than copper is used, its electrical resistance per lineal foot shall not exceed, and its tensile strength shall not be less than that of the allowable copper conductor.

E15.5.2 Equipment grounding conductors may be insulated or bare and shall be protected from damage by means equivalent to those provided for live conductors. If an insulated equipment-grounding conductor is used, the insulation shall be green (with or without a yellow stripe).

E15.5.3 Raceways shall not be used in lieu of a grounding or bonding conductor.

E15.5.4 The size of the equipment grounding conductor shall be as shown in Table 15-1. Column "A" indicates maximum capacity in amperes of the overcurrent protective device in the circuit ahead of the equipment.

Table 15-1—Size of Grounding Conductors

Column "A" Amperes	Copper Wire Size, AWG
20	14 or 16†
30	14
40	12
60	10
100	8
200	6
400	4
600	2
800	0
1000	00
1200	000

†No. 16 wire will be permitted only in multiconductor cable.

Table 16-1—High Potential Test Voltages

Circuit Voltage	Test Voltage
115	1230
230	1460
380	1760
460	1920
550	2100

E16. Testing

E16.1 Circuit Tests. When all wiring of the electrical system is complete, the builder shall test each circuit for continuity, short circuits and fault grounds.

E16.2 Test Voltages. Wiring shall be capable of withstanding the appropriate test voltage shown in Table 16-1. See NEMA Standard IC-1, Industrial Control. Devices which do not fall within the scope of Industrial Control Standards (e.g., meters, rectifiers, lamp holders, snap switches, electronic equipment, ground detector lamps, etc.) and which require lower test voltages than specified above, should be disconnected before high voltage tests are made.

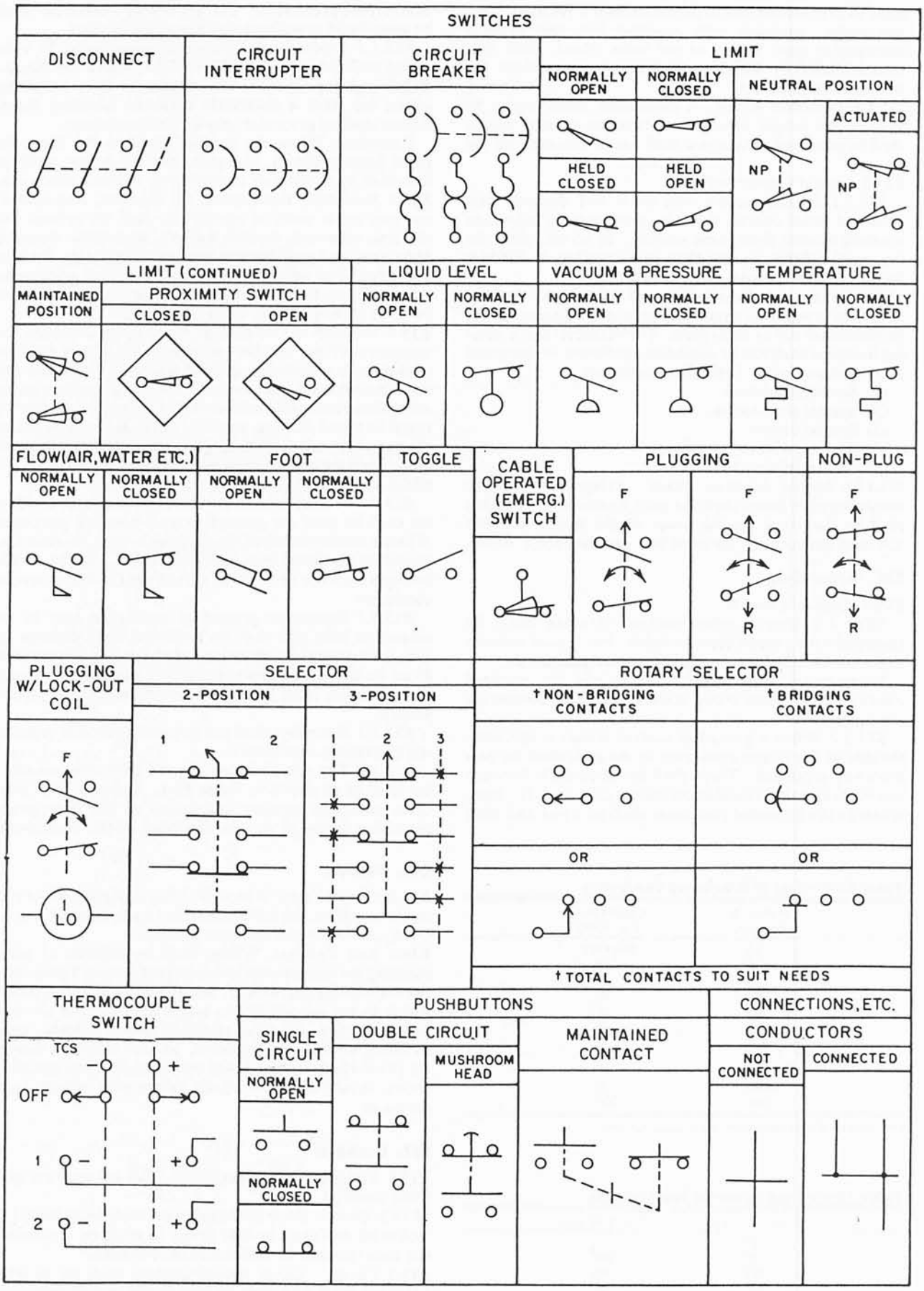
E17. Gaskets

E17.1 Materials. Gaskets shall be of an oil-resistant synthetic material.

***E17.2** Doors. Door sealing gaskets shall be at least 1/8 inch thick and shall be held firmly in place by a continuous metal retainer in addition to the adhesive.

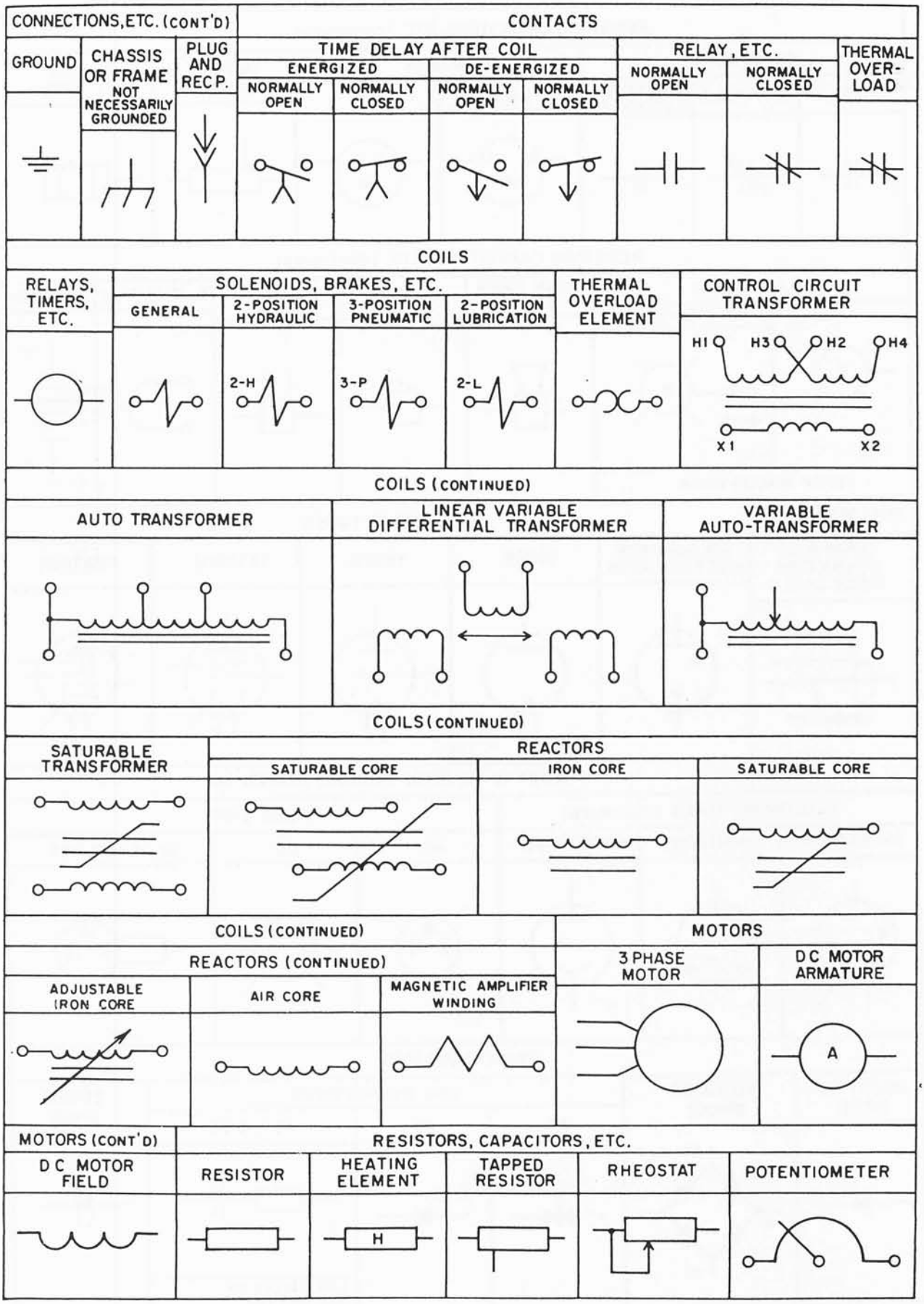
E17.3 Covers. Cover sealing gaskets shall be at least 1/16 inch thick and shall be held firmly and permanently in place.

*Appendix A—Typical Graphic Symbols for Electrical Diagrams



(CONTINUED)

** Appendix A (continued)—Typical Graphic Symbols for Electrical Diagrams*



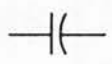
(CONTINUED)

** Appendix A (continued)—Typical Graphic Symbols for Electrical Diagrams*

RESISTORS, CAPACITORS, ETC. (CONTINUED)

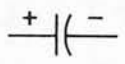
CAPACITORS

FIXED



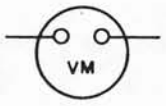
ADJUSTABLE

POLARIZED ELECTROLYTIC

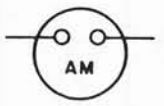


METERS

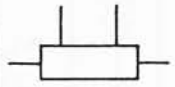
VOLT



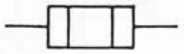
AMP



METER SHUNT

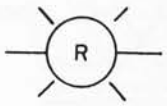


FUSES (ALL TYPES)

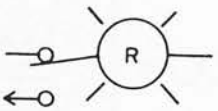


RESISTORS, CAPACITORS, ETC. (CONTINUED)

PILOT LIGHTS

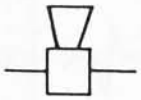


PUSH-TO-TEST

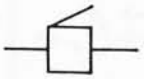


LETTER DENOTES COLOR

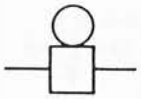
HORN, SIREN ETC.



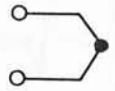
BUZZER



BELL



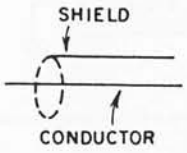
THERMOC'PLE



BATTERY

SHIELDED CABLE

SHOW ALL CONDUCTORS INSIDE SHIELD

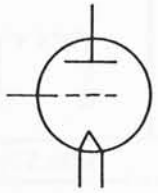


ELECTRONIC TUBES

COLD CATHODE VOLT. REGULATOR

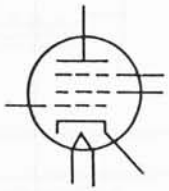
DIODE

TRIODE



TETRODE

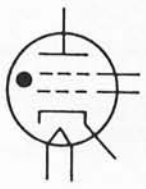
PENTODE



● DOT IN ANY TUBE ENVELOPE DENOTES GAS

ELECTRONIC TUBES (CONTINUED)

THYRATRON



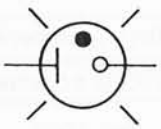
IGNITRON

PHOTOTUBE

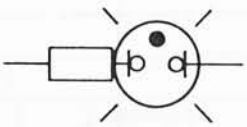
NEON LIGHT

AC

DC



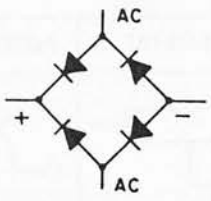
AC W/INT. RES.



SEMICONDUCTORS

RECTIFIER DIODE

RECTIFIER BRIDGE

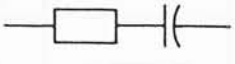


ARC SUPPRESSORS

AC

DC

AC AND DC



LIST VALUES OF RES. AND CAP.

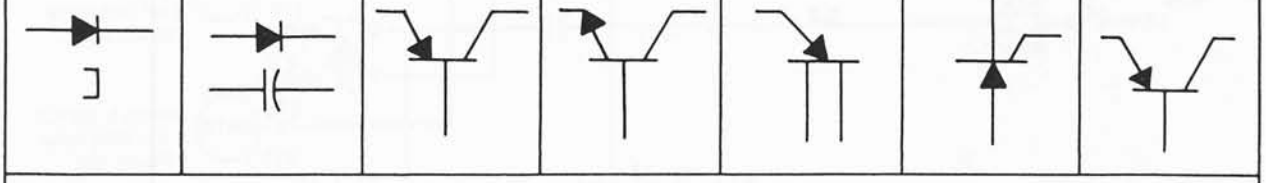
ZENER DIODE

(CONTINUED)

** Appendix A (continued)—Typical Graphic Symbols for Electrical Diagrams*

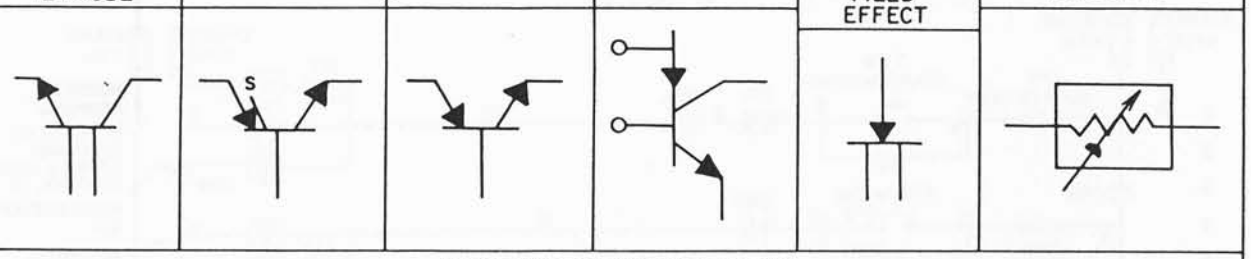
SEMICONDUCTORS (CONTINUED)

TUNNEL DIODE | VARICAP DIODE | TRANSISTOR PNP | TRANSISTOR NPN | TRANSISTOR UNIJUNCTION | SILICON CONTROLLED RECTIFIER | TRANSISTOR SURFACE BARRIER



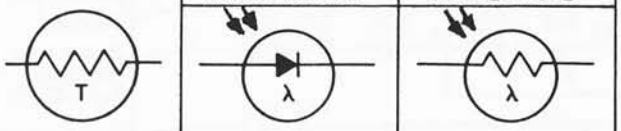
SEMICONDUCTORS (CONTINUED)

TRANSISTOR TETRODE | TRINISTOR | TRIGISTOR | BINISTOR | TRANSISTOR FIELD EFFECT | VARISTOR



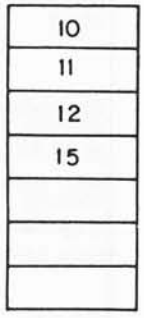
SEMICONDUCTORS (CONTINUED)

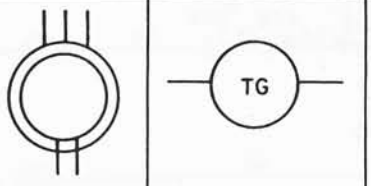
THERMISTOR | PHOTOSENSITIVE CELLS (ASYMMETRICAL, SYMMETRICAL)

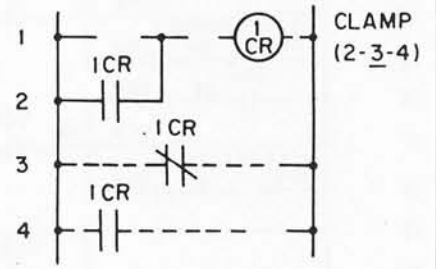


MISCELLANEOUS

TERMINAL BLOCK | SYNCHRO OR RESOLVER | TACHOMETER GENERATOR | CORE OF SQUARE LOOP MATERIAL | LOCATION OF RELAY CONTACTS



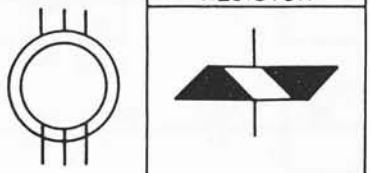




NUMBERS IN PARENTHESES DESIGNATE THE LOCATION OF RELAY CONTACTS.

A LINE BENEATH A NUMBER SIGNIFIES A NORMALLY CLOSED CONTACT.

DIFFERENTIAL SYNCHRO | SYMMETRICAL NON-LINEAR RESISTOR



SEQUENCE CHARTS

PROGRAM OR SEQUENCE TIMER

TIMER CONTACT	RESET POSITION	TIMING (MINUTES) 1 2 3 4 5 6 7 8 9	OPERATION TIME (MINUTES) CLOSES	OPENS
1TR-1			0	2
1TR-2			3.75	7.2
1TR-3			1.9	8.5

SHADED PORTION INDICATES CONTACT CLOSED

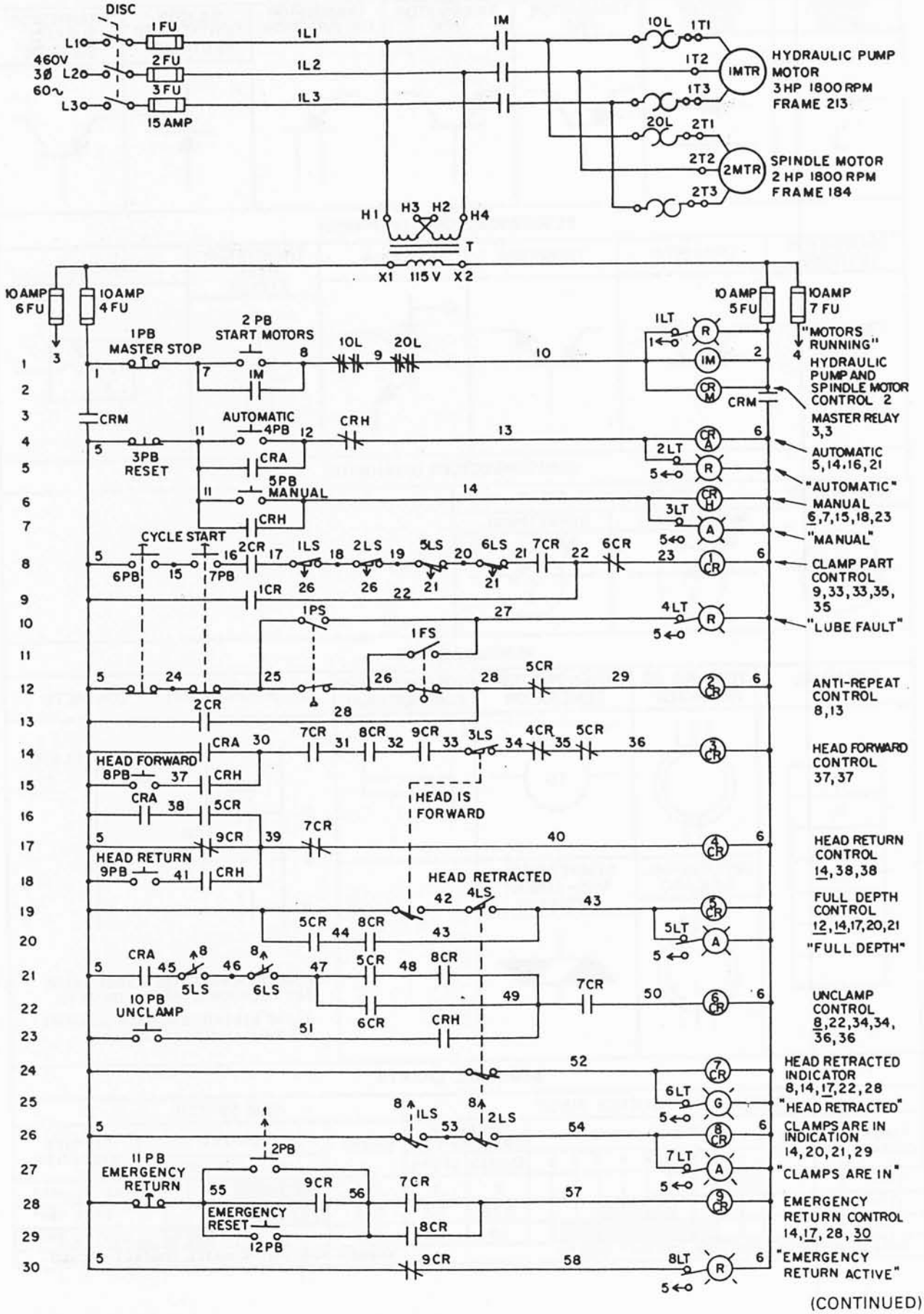
CAM SWITCH

SWITCH	DEGREES 90 180 270	DEGREES OPERATION
1CS		22° TO 180°
2CS		0° TO 194°
3CS		225° TO 360°

SHADED PORTION INDICATES CONTACT CLOSED

*Appendix B—Sample Electrical Diagrams

The drawings which follow are intended only to illustrate proper electrical drafting practices outlined in the standard. Diagram shown is for ungrounded control circuit.



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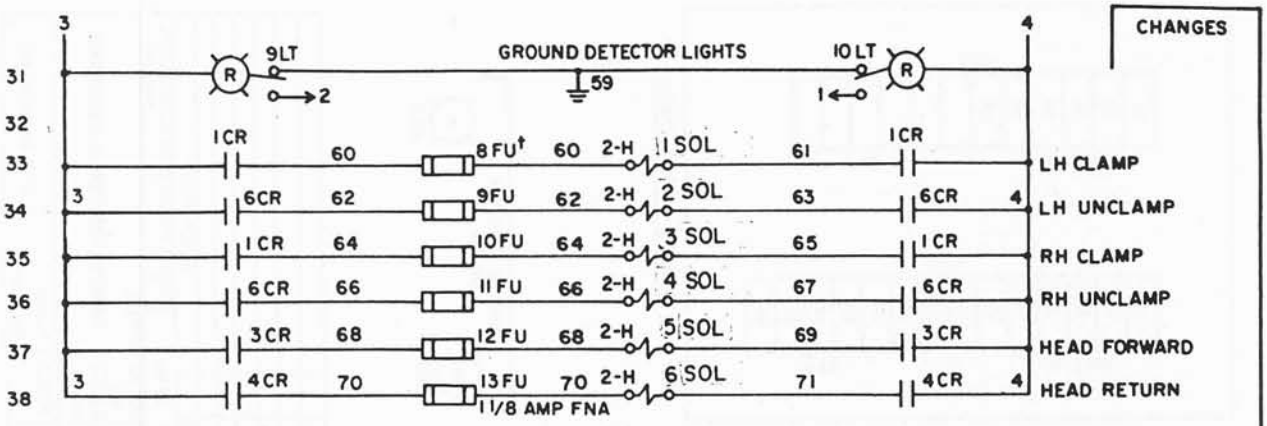


† WHERE SOLENOID FUSE IS PART OF TERMINAL STRIP ASSEMBLY, CONDUCTOR NUMBER DOES NOT CHANGE

SEQUENCE OF OPERATION

A. PRESS "START MOTORS" PUSHBUTTON "2PB". MOTORS START. "MOTORS RUNNING" LAMP "1LT" AND "CRM" ARE ENERGIZED.

B. PRESS EITHER AUTOMATIC "4PB" OR MANUAL "5PB" PUSHBUTTON. CORRESPONDING RELAY AND LAMP ARE ENERGIZED. NOTE: TO SWITCH FROM MANUAL TO AUTOMATIC, OPERATOR MUST PRESS "RESET" PUSHBUTTON "3PB" BEFORE PRESSING AUTOMATIC PUSHBUTTON "4PB".

C. AUTOMATIC CYCLE: WITH MOTORS RUNNING AND "CRA" ENERGIZED, MACHINE IS SET FOR AUTOMATIC CYCLE. HEAD MUST BE RETRACTED AND PART UNCLAMPED TO START CYCLE.

1. OPERATOR LOADS PART IN FIXTURE AND PRESSES BOTH "CYCLE START" PUSHBUTTONS "6PB" AND "7PB", ENERGIZING "1CR" (SOL A AND SOL C) TO CLAMP PART.
2. CLAMPED PART TRIPS "1LS" AND "2LS", ENERGIZING "8CR". RELAY "3CR" (SOL E) IS ENERGIZED MOMENTARILY, STARTING HEAD FORWARD IN RAPID ADVANCE. HEAD CAMS VALVE INTO FEED.
3. WHEN HEAD IS IN FORWARD POSITION, "3LS" IS TRIPPED, ENERGIZING RELAY "5CR".
4. "5CR" CONTACT ENERGIZES RELAY "4CR" (SOL F) AND HEAD RETURNS.
5. WHEN HEAD IS FULLY RETRACTED, "4LS" IS TRIPPED, DE-ENERGIZING "4CR" AND ENERGIZING "7CR" WHICH ENERGIZES "6CR" (SOL B AND SOL D) UNCLAMPING PART.
6. WHEN PART IS UNCLAMPED, "5LS" AND "6LS" ARE TRIPPED, DE-ENERGIZING RELAY "6CR".
7. "2CR" RELAY PREVENTS MACHINE RE-CYCLING IF BOTH "CYCLE START" PUSHBUTTONS ARE NOT RELEASED.

D. MANUAL CYCLE:

1. WITH HEAD RETRACTED AND PART UNCLAMPED, PRESS "CYCLE START" PUSHBUTTONS "6PB" AND "7PB", ENERGIZING RELAY "1CR" (SOL A AND SOL C) TO CLAMP PART.
2. PRESS "HEAD FORWARD" PUSHBUTTON "8PB", ENERGIZING "3CR" (SOL E) TO START HEAD FORWARD.
3. TO RETURN HEAD TO RETRACTED POSITION, PRESS "HEAD RETURN" PUSHBUTTON "9PB", ENERGIZING "4CR" (SOL F).
4. WITH HEAD RETRACTED, PRESS "UNCLAMP" PUSHBUTTON "10PB", ENERGIZING "6CR" (SOL B AND SOL D) TO UNCLAMP PART.

E. EMERGENCY RETURN: IF "EMERGENCY RETURN" PUSHBUTTON "11PB" IS PRESSED ON EITHER "AUTOMATIC" OR "MANUAL" CYCLE, THE HEAD WILL RETURN AND REMAIN IN THE RETRACTED POSITION. IN ORDER TO START CYCLE, THE "EMERGENCY RESET" PUSHBUTTON "12PB" OR "START MOTORS" PUSHBUTTON "2PB" MUST BE PRESSED.

F. LUBRICATION FAULT: IF OVER-PRESSURE OR INADEQUATE SUPPLY IS INDICATED BY THE OPERATION OF PRESSURE SWITCH "1PS" OR FLOAT SWITCH "1FS", "LUBE FAULT" LAMP "4LT" IS LIGHTED AND RELAY "2CR" WILL REMAIN DE-ENERGIZED AT THE END OF THE MACHINE CYCLE. WHEN THE FAULT IS CORRECTED, "2CR" WILL BE ENERGIZED WHICH ALLOWS THE OPERATOR TO RESUME NORMAL OPERATION OF THE MACHINE.

LIMIT SWITCHES

1LS (8,26) TRIPPED WHEN PART IS CLAMPED
2LS (8,26 TRIPPED WHEN PART IS CLAMPED
3LS (14,19) TRIPPED WHEN HEAD IS FORWARD
4LS (19,24) TRIPPED WHEN HEAD IS RETRACTED
5LS (8,21) TRIPPED WHEN PART IS UNCLAMPED
6LS (8,21) TRIPPED WHEN PART IS UNCLAMPED
1PS (10,12) OPERATED BY LUBE SYSTEM OVER-PRESSURE
1FS (11,12) OPERATED BY ADEQUATE LUBE SUPPLY

FOR PANELS AND CONTROL STATION LAYOUT SEE SHEET 2
FOR HYDRAULIC DIAGRAM SEE _____
FOR LUBRICATION DIAGRAM SEE _____

LAST WIRE NUMBER USED 71
LAST RELAY NUMBER USED 9CR

SUPPLIER'S DWG. NO. _____
SUPPLIER'S NAME _____

PURCHASE ORDER NO. P.O. 1234

SERIAL NO. OF MACHINE TYP 5678

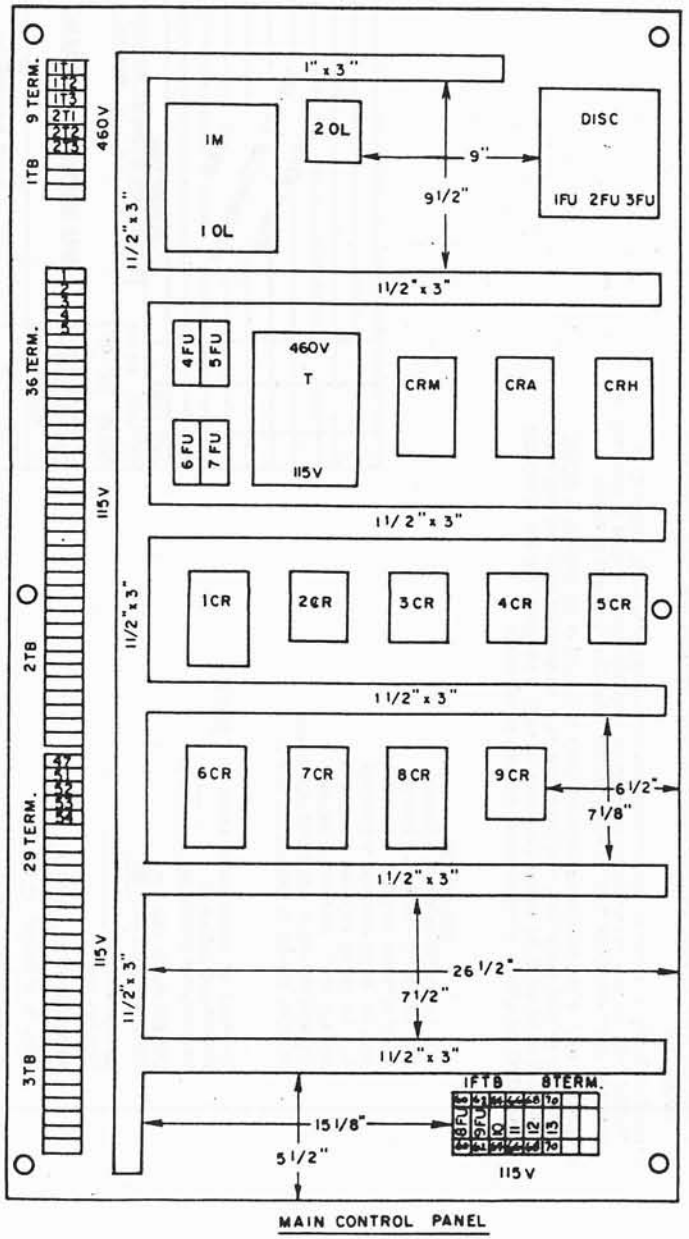
THESE DIAGRAMS USED FOR MACHINE NO. _____

FULL CATALOG DESCRIPTION OF ALL ITEMS

AMT.	SYM		DESCRIPTION			
PART. NO. XY.100				SHEET 2	SHEETS	DWG. No. Purchaser's dwg. No.
DES. BY J.I.C		DET. BY W.T.	SAMPLE ELECTRICAL DIAGRAMS			
CHECKED BY R.S.		SAFETY OK P.N.				
DATE 8-2-66		SCALE	PLANT DIVISION		XYZ MACHINE CO.	

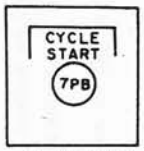
(CONTINUED)

PANELS AND CONTROL STATION LAYOUT

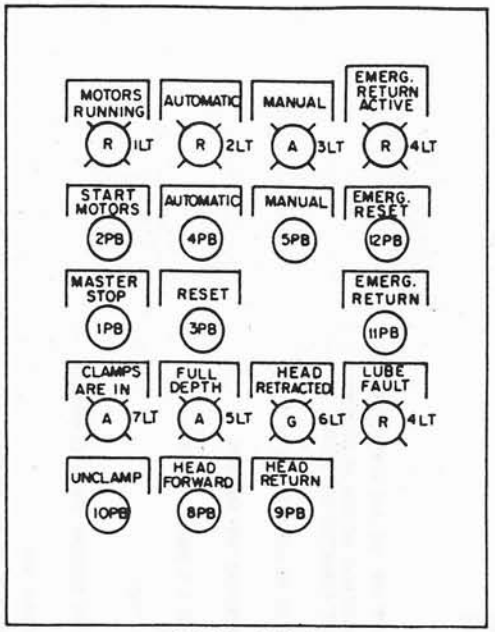


MAIN CONTROL PANEL

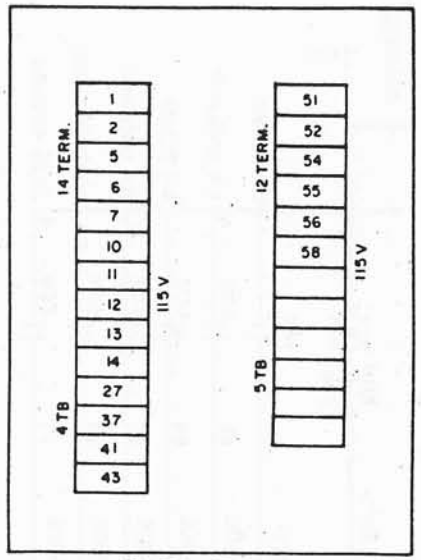
CYCLE START STATION



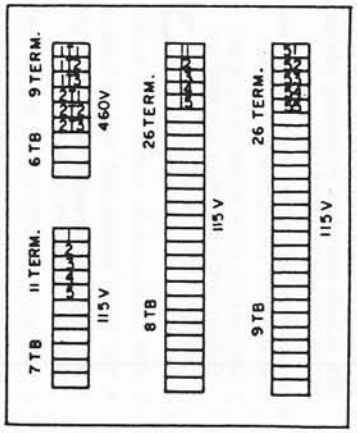
CYCLE START STATION



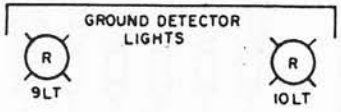
CONTROL STATION



CONTROL STATION PANEL



MASTER TERMINAL BOX PANEL



AMT.	SYM		DESCRIPTION
PART NO. XY100		SHEET 2	SHEETS / DWG. No. Purchaser's dwg. No.
DES. BY J.I.C	DET. BY W.T.	TITLE	SAMPLE ELECTRICAL DIAGRAMS
CHECKED BY R.S.	SAFETY OK P.N.		
DATE 8-2-66	SCALE	PLANT DIVISION	XYZ MACHINE CO.

Appendix C—Glossary of Terms

Actuator. The cam, arm or similar mechanical device used to trip limit switches.

Ambient Conditions. The condition of the atmosphere adjacent to the electrical apparatus. The specific reference may apply to temperature, contamination, humidity, etc.

Ambient Temperature. Ambient temperature is the temperature of the surrounding cooling medium, such as gas or liquid, which comes into contact with the heated parts of the apparatus.

Ampacity. Current-carrying capacity expressed in amperes. (NEC-NFPA No. 70)

Anti-Plugging Protection. Anti-plugging protection is the effect of a control function or a device which operates to prevent application of counter-torque by the motor until the motor speed has been reduced to an acceptable value. (NEMA IC-1)

Apparatus. Control apparatus is a set of control devices used to accomplish the intended control functions. (ANS C42.25)

Auxiliary Contacts. Auxiliary contacts of a switching device are contacts in addition to the main-circuit contacts and function with the movement of the latter. (NEMA IC-1)

Auxiliary Device. Any electrical device other than motors and motor starters necessary to fully operate the machine or equipment.

Block Diagram. A block diagram is a diagram showing the relationship of separate sub-units (blocks) in the control system.

Bonding Conductor. A bonding conductor is one which serves to connect exposed metal surfaces together.

Branch Circuit. A branch circuit is that portion of a wiring system extending beyond the final overcurrent device protecting the circuit. (A device not approved for branch circuit protection, such as a thermal cutout or motor overload protective device, is not considered as the overcurrent device protecting the circuit.) (NEC-NFPA No. 70)

Captive Screw. Screw-type fastener that is retained in some manner when unscrewed and cannot easily be separated from the part it secures.

Chassis. Sheet metal box, frame, or simple plate on which electronic components and their associated circuitry can be mounted.

Circuit Breaker. A device designed to open and close a circuit by non-automatic means, and to open the circuit automatically on a predetermined overload of current, without injury to itself when properly applied within its rating. (NEC-NFPA No. 70)

Circuit Interrupter. A circuit interrupter is a non-automatic manually operated device designed to open, under abnormal conditions, a current-carrying circuit without injury to itself.

Combination Starter. A magnetic starter having a manually operated disconnecting means built into the same enclosure with the magnetic contactor.

Compartment. A space within the base, frame or column of the equipment.

Component. See "device."

Conduit, Flexible Metal. A flexible metal conduit is a flexible raceway of circular cross section specially constructed for the purpose of the pulling in or the withdrawing of wires or cables after the conduit and its fittings are in place. (ANS C42.95)

Conduit, Flexible Non-Metallic. A flexible non-metallic conduit is a flexible raceway of circular cross section specially constructed for the purpose of the pulling in or the withdrawing of wires or cables after the conduit and its fittings are in place.

Conduit, Rigid Metal. A rigid metal conduit is a raceway specially constructed for the purpose of the pulling in or the withdrawing of wires or cables after the conduit is in place and made of metal pipes of standard weight and thickness permitting the cutting of standard threads. (ANS C42.95)

Contactor. A contactor is a device for repeatedly establishing and interrupting an electric power circuit. (ANS C42.25)

Continuous Rating. Continuous rating is the rating which defines the substantially constant load which can be carried for an indefinitely long time. (NEMA IC-1)

Control. See "controller, electric."

Control Circuit. The control circuit of a control apparatus or system is the circuit which carries the electric signals directing the performance of the controller, but does not carry the main power circuit. (NEC-NFPA No. 70)

Control Circuit Transformer. A control circuit transformer is a voltage transformer utilized to supply a voltage suitable for the operation of control devices. (ANS C42.25)

Control Circuit Voltage. The control circuit voltage is the voltage provided for the operation of shunt coil magnetic devices.

Control Compartment. A control compartment is a space within the base, frame, or column of the machine used for mounting the control panel.

Control Panel. See "panel."

Control Station. See "operator's control station."

Controller, Electric. An electric controller is a device, or group of devices, which serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected. (ANS C42.25)

Device (Component). A control device is an individual device used to execute a control function. (ANS C42.25)

Disconnecting Means. A disconnecting means is a device whereby the current-carrying conductors of a circuit can be disconnected from their source of supply

Disconnect Switch (Motor Circuit Switch). A motor circuit switch is a switch intended for use in a motor branch circuit. It is rated in horsepower, and it is capable of interrupting the maximum operating overload current of a motor of the same rating at the rated voltage. (ANS C42.25) (Also see NEMA IC-1 for definition of operating overload.)

Dynamic Braking. Dynamic braking of an electric drive is a system of braking in which the motor is used as a generator, and the kinetic energy of the motor and driven machinery is employed as actuating means of exerting a retarding force. (ANS C42.25)

Electrical Equipment. In this standard the term "Electrical Equipment" includes electro-magnetic, electronic and static apparatus as well as the more common electrical devices.

Electrical System. The organized arrangement of all electrical and electro-mechanical components and devices in a way that will properly control the particular machine tool or industrial equipment.

Electro-Mechanical. Electro-mechanical is the term applied to any device in which electrical energy is used to magnetically cause mechanical movement.

Electronic Control. The term applied to define electronic, static, precision and associated electrical control equipment.

Elementary (Schematic) Diagram. An elementary (schematic) wiring diagram is a diagram using symbols and a plan of connections to illustrate in simple form the scheme of control.

Enclosure. The case, box or structure surrounding the electrical equipment, which protects it from contamination. The degree of tightness is usually specified (e.g., NEMA Type 12). (See NEMA Standard IC-1 for various enclosure descriptions and ANS C42.95, Section 91, Qualifying Terms.)

External Control Devices. All control devices mounted external to the control panel.

Eyelet. Eyelets are used on printed circuit boards to make reliable electrical connections from one side of the board to the other side.

Fail-Safe Operation. An electrical system so designed that the failure of any component in the system will prevent unsafe operation of the controlled equipment.

Feeder. A feeder is the circuit conductors between the service equipment, or the generator switchboard of an isolated plant, and the branch circuit overcurrent device. (NEC-NFPA No. 70)

Field Loss Relay. See "motor-field failure relay."

Grounded. Grounded means connected to earth or to some conducting body which serves in place of the earth. (NEC-NFPA No. 70)

Grounded Circuit. A grounded circuit is a circuit in which one conductor or point (usually the neutral or neutral point of transformer or generator windings) is intentionally grounded (earthed), either solidly or through a grounding device. (ANS C42.15)

Grounding Conductor. A grounding conductor is one which, under normal conditions, carries no current, but serves to connect exposed metal surfaces to an earth ground, to prevent hazards in case of breakdown between current-carrying parts and the exposed surfaces. The conductor, if insulated, is colored green, with or without a yellow stripe.

Guarded. Covered, shielded, fenced, enclosed or otherwise protected by means of suitable covers or casings, barriers, rails or screens, mats or platforms to remove the likelihood of dangerous contact or approach by persons or objects to a point of danger. (ANS C42.95)

Inching. See "jogging."

Inrush Current. The inrush current of a solenoid or coil is the steady-state current taken from the line with the armature blocked in the rated maximum open position.

Isolating Transformer. See "insulating transformer."

Insulating (Isolating) Transformer. An insulating (or isolating) transformer is a transformer used to insulate one circuit from another. (ANS C42.15)

Interconnecting Wire. The term "interconnecting wire" refers to those connections between sub-assemblies, panels, chassis and remotely mounted devices and does not necessarily apply to the internal connections of these units.

Interconnection Diagram. A diagram showing all terminal blocks in the complete system with each terminal identified.

Interlock. An interlock is a device actuated by the operation of some other device with which it is directly associated, to govern succeeding operations of the same or allied devices. NOTE: Interlocks may be either electrical or mechanical. (ANS C42.25)

Intermittent Duty. Intermittent duty is a requirement of service that demands operation for alternate intervals of (1) load and no-load; or (2) load and rest; or (3) load, no-load and rest; such alternate intervals being definitely specified. (NEMA IC-1)

Interrupting Capacity. Interrupting capacity is the highest current at rated voltage that the device can interrupt.

Jogging (Inching). Jogging is the quickly repeated closure of the circuit to start a motor from rest for the purpose of accomplishing small movements of the driven machine. (ANS C42.25)

Joint. A joint is a connection between two or more conductors. (ANS C42.95)

Large Enclosures. See E7.2 of these JIC Standards.

Latching Relay. A latching relay is one that can be mechanically latched in a given position manually, or when operated by one element, and released manually or by the operation of a second element. (ANS C42.20)

Legend Plates. Legend plates identify the function of operator controls, indicating lights, etc.

Limit Switch. A limit switch is a switch which is operated by some part or motion of a power-driven machine or equipment to alter the electric circuit associated with the machine or equipment. (ANS C42.25)

Locked-Rotor Current. The locked-rotor current of a motor is the steady-state current taken from the line with the rotor locked and with rated voltage (and rated frequency in the case of alternating-current motors) applied to the motor. (ANS C42.10)

Logic Control Panel Layout. The physical position or arrangement of the devices on a chassis or panel.

Logic Diagram. A logic diagram is a diagram showing the relationship of standard logic elements in a control system. No internal detail of the logic elements need be shown.

Magnetic Device. A magnetic device is a device actuated by electro-magnetic means.

Magnetic Starter. A magnetic starter is a starter actuated by electro-magnetic means.

Master Terminal Box. The main enclosure on the equipment containing terminal blocks for the purpose of terminating conductors from the control enclosure. (Normally associated with equipment requiring a separately mounted control enclosure.)

Motor-Circuit Switch. See "disconnect switch."

Motor Junction (Conduit) Box. An enclosure on a motor for the purpose of terminating a conduit run and joining motor to power conductors.

Motor-Field Failure Relay (Field Loss Relay). A motor-field failure relay is a relay which functions to disconnect the motor armature from the line in the event of loss of field excitation. (NEMA IC-1)

Nominal Voltage. Nominal voltage is the utilization voltage. See the appropriate NEMA Standard for device voltage ratings.

Normally Open and Normally Closed. The terms "normally open" and "normally closed," when applied to a magnetically operated switching device, such as a contactor or relay, or to the contacts thereof, signify the position taken when the operating magnet is de-energized. These terms apply only to non-latching types of devices. (NEMA IC-1)

Operating Floor. A floor or platform used by the operator under normal operating conditions.

Operating Overload. Operating overload is the overcurrent to which electric apparatus is subjected in the course of normal operating conditions that it may encounter. (ANS C42.25)

(Note 1: The maximum operating overload is considered to be six times normal full-load current for alternating-current industrial motors and control apparatus; four times normal full-load current for direct-current industrial motors and control apparatus used for reduced-voltage starting; and ten times normal full-load current for direct-current industrial motors and control used for full-voltage starting.)

(Note 2: It should be understood that these overloads are currents that may persist for a very short time only, usually a matter of seconds.)

Operator's Control Station (Pushbutton Station). A pushbutton station is a unit assembly of one or more externally operable pushbutton switches, sometimes includ-

ing other pilot devices such as indicating lights or selector switches, in a suitable enclosure. (ANS C42.25)

Outline Drawing. Drawing showing approximate overall shape with no detail.

Overcurrent. Overcurrent in an electric circuit is that current which will cause an excessive or dangerous temperature in the conductor or conductor insulation.

Overcurrent Protective Device. A device operative on excessive current which causes and maintains the interruption of power in the circuit.

Overlapping Contacts. Overlapping contacts are combinations of two sets of contacts, actuated by a common means, each set closing in one of two positions, and so arranged that the contacts of one set open after the contacts of the other set have been closed. (NEMA IC-1)

Overload Relay. A device that provides overload protection for electrical equipment.

Panel. A subplate upon which the control devices are mounted inside the control compartment or enclosure.

Panel Layout. The physical position or arrangement of the components on a panel or chassis.

Pendant (Station). A pendant station is a pushbutton station suspended from overhead and connected by means of flexible cord or conduit, but supported by a separate cable.

Plugging. Plugging is a control function which provides braking by reversing the motor line voltage polarity or phase sequence so that the motor develops a countertorque which exerts a retarding force. (NEMA IC-1)

Plug-In Device. Component or group of components and their circuitry which can be easily installed or removed from the equipment. Electrical connections are made by mating contacts.

Polarized Plug. A plug so arranged that it may be inserted in its receptacle only in a predetermined position.

Potting. Potting is a method of securing a component or group of components by encapsulation.

Precision Device. A precision device is a device that will operate within prescribed limits and will consistently repeat operations within those limits.

Pressure Connector. A conductor terminal applied with pressure so as to make the connection mechanically and electrically secure.

-Proof (used as a suffix). Apparatus is designated as splashproof, dustproof, etc., when so constructed, protected or treated that its successful operation is not interfered with when subjected to the specified material or condition.

Pushbutton Station. See "operator's control station."

Raceway. Any channel for holding wires, cables or busbars, which is designed expressly for, and used solely for, this purpose. (NEC-NFPA No. 70)

Readily Accessible. Capable of being reached quickly for operation, renewal, or inspection without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. (NEC-NFPA No. 70)

Relay. A relay is a device which is operative by a variation in the conditions of one electric circuit to effect the operation of other devices in the same or another electric circuit. (NEMA IC-1)

Schematic Diagram. See "elementary diagram."

Semiconductor. A device which can function either as a conductor or a non-conductor, depending on the polarity of the applied voltage such as a rectifier or transistor which has a variable conductance depending on the control signal applied.

Sequence of Operation. A written detailed description of the order in which electrical devices and other parts of the equipment should function.

Shielded Cable. Shielded cable is single or multiple conductor cable surrounded by a separate conductor (the "shield") intended to minimize the effects of adjacent electrical circuits.

Short-Time Rating. The short-time rating is the rating that defines the load which can be carried for a short and definitely specified time; the machine, apparatus or device being at approximately room temperature at the time the load is applied. (NEMA IC-1)

Small Enclosure. See E7.2 of these JIC Standards.

Solenoid. A solenoid magnet (solenoid) is an electromagnet having an energized coil approximately cylindrical in form and an armature whose motion is reciprocating within and along the axis of the coil. (ANS C42.25)

Starter. A starter is an electric controller for accelerating a motor from rest to normal speed. (NOTE: A device designed for starting a motor in either direction of rotation includes the additional function of reversing and should be designated a controller.) (NEMA IC-1)

Static Device. As associated with electronic and other control or information handling circuits, the term "static" refers to devices with switching functions that have no moving parts.

Stepping Relay (Switches). A multi-position relay in which moving wiper contacts mate with successive sets of fixed contacts in a series of steps, moving from one step to the next in successive operations of the relay. (ANS C83.16)

Sub-Assembly. A sub-assembly is an assembly of electrical or electronic components mounted on a panel or chassis which forms a functional unit by itself.

Subplate. A rigid metal panel on which control devices can be mounted and wired.

Swingout Panel. A panel which is hinge-mounted in such a manner that the back of the panel may be made accessible from the front of the enclosure.

Symbol. A sign, mark or drawing agreed upon to represent an electrical device or component part thereof.

Temperature Control. A control device responsive to temperature.

Terminal. A point of connection in an electrical circuit.

Terminal Block. A terminal block is an insulating base or slab equipped with one or more terminal connectors for the purpose of making electrical connections thereto. (NEMA IC-1)

Tie Point. A distributing point in circuit wiring, other than a terminal connection, where junctions of leads are made.

-Tight (used as a suffix). Apparatus is designated as watertight, dust-tight, etc., when so constructed that the enclosing case will exclude the specified material. (ANS C42.95)

Undervoltage Protection. Undervoltage or low-voltage protection is the effect of a device, operative on the reduction or failure of voltage, to cause and maintain the interruption of power to the main circuit. (ANS C42.25)

Vault-Type Hardware. See E7.6 of these JIC Standards.

Wire-Wrapping. Wire-wrapping is a technique used to terminate conductors.

Wireway. Wireways are sheet metal troughs with hinged covers for housing and protecting electrical conductors and cable and in which conductors are laid in place after the wireway has been installed as a complete system.

Wobble Stick. A wobble stick is a rod extending from a pendant station to operate the "Stop" contacts and will function when pushed in any direction.

Appendix D—Device Designations

The device designations given below are intended for use on diagrams in connection with the corresponding graphical symbols to indicate the function of the particular device. These device designations are based on the assignment of a standard letter or letters to the fundamental function that is performed by a component or device. Suitable prefix numbers (1, 2, 3, 4, etc.) and suffix letters (A, B, C, D, etc.) may be added to the basic designation to differentiate between devices performing similar functions.

The assignment of a designation to a device on a specific equipment is governed by the function of that device on that particular equipment and not by the type or nature of the device or its possible use for other functions in other equipment. The same type of device may perform different functions on different equipment or even on the same equipment and, consequently, may be identified by different designations.

Designation	Device
A	Accelerating Contactor or Relay
ABE	Alarm or Annunciator Bell
ABU	Alarm or Annunciator Buzzer
AH	Alarm or Annunciator Horn
AM	Ammeter
AT	Autotransformer
B	Brake Relay
CAP	Capacitor
CB	Circuit Breaker
CH	Chassis or Frame (not necessarily grounded)
CI	Circuit Interrupter
CON	Contactor
COS	Cable Operated (Emergency) Switch
CR	Control Relay
CRA	Control Relay, Automatic
CRE	Control Relay, Electronically-Energized
CRH	Control Relay, Manual
CRL	Control Relay, Latch
CRM	Control Relay, Master
CRU	Control Relay, Unlatch
CS	Cam Switch
CT	Current Transformer
CTR	Counter
D	Diode
DAS	Diode Arc Suppressor
DB	Dynamic Braking Contactor or Relay
DISC	Disconnect Switch
DT	Tunnel Diode
DVC	Varicap Diode
DZ	Zener Diode
F	Forward
FA	Field Accelerating Contactor or Relay
FB	Fuse Block
FD	Field Decelerating Contactor or Relay
FF	Full Field Contactor or Relay
FL	Field Loss Contactor or Relay
FLD	Field
FLS	Flow Switch
FS	Float Switch
FTB	Fusible Terminal Block
FTS	Foot Switch
FU	Fuse
FW	Field Weakening
GRD	Ground
HTR	Heating Element
INST	Instrument
IOL	Instantaneous Overload
LO	Lock-Out Coil (located in plugging switch)
LS	Limit Switch
LT	Pilot Light
LVT	Linear Variable Differential Transformer
M	Motor Starter
MAX	Magnetic Amplifier Winding
MB	Magnetic Brake
MC	Magnetic Clutch
MCS	Motor Circuit Switch
MF	Motor Starter – Forward
MR	Motor Starter – Reverse
MSH	Meter Shunt
MTR	Motor
NLT	Neon Light
OL	Overload Relay
PB	Pushbutton
PC	Printed Circuit
PL	Plug
PLS	Plugging Switch
POT	Potentiometer
PRS	Proximity Switch
PS	Pressure Switch
PSC	Photosensitive Cell
Q	Transistor
QBN	Binistor
QFE	Transistor, Field-Effect
QSB	Transistor, Surface-Barrier
QT	Transistor, Tetrode
QTG	Trigistor
QTM	Thermistor
QTN	Trinistor
QU	Transistor, Unijunction
QVR	Varistor
R	Reverse
REC	Rectifier
RECP	Receptacle
RES	Resistor
RH	Rheostat
RSS	Rotary Selector Switch
S	Switch
SCR	Silicon Controlled Rectifier
SOC	Socket
SOL	Solenoid
SS	Selector Switch
ST	Saturable Transformer
SX	Saturable Core & Reactor
SYN	Synchro or Resolver
T	Transformer
TACH	Tachometer Generator
TAS	Temperature-Actuated Switch
TB	Terminal Block
T/C	Thermocouple
TCS	Thermocouple Switch
TGS	Toggle Switch
TR	Time Delay Relay
TRE	Timer Relay, Electronically-Energized
TVM	Tachometer Indicator
V	Electronic Tube
VAT	Variable Autotransformer
VM	Voltmeter
VS	Vacuum Switch
WLT	Work Light
WM	Wattmeter
X	Reactor

Appendix E—References to Other Codes and Standards

1. American Society for Testing Materials (ASTM)
   260 South Broad Street, Philadelphia, Pennsylvania 19107
   A. D2219, D2220, Insulation for Wire and Cable
   B. B8, B174, Conductors
2. American National Standards Institute, Inc. (ANSI)
   1430 Broadway, New York, New York 10018
   Formerly American Standards Association (ASA) and United States of America Standards Institute (USASI)
   A. Y32.2, Graphic Symbols for Electrical and Electronics Diagrams
   B. C19.1, Industrial Control Apparatus
   C. C80.1, Rigid Steel Conduit
   D. C6.1, Terminal Marking for Electrical Apparatus
   E. C50, Rotating Electrical Machinery
3. British Standards Institution (BSI)
   British Standards House, 2 Park Street, London, W1
   A. BS2771, Electrical Equipment of Machine Tools
4. State of California
   Printing Division, Documents Section, Sacramento, California 95814
   A. California State Electrical Safety Orders
5. Canadian Standards Association (CSA)
   National Research Building, Ottawa 2, Ontario
   A. Canadian Electrical Code
6. Electronic Industries Association (EIA)
   2001 Eye Street, NW, Washington, D.C. 20006
   A. RS-281, Construction Standards—Numerical Machine Tool Control
7. National Electrical Manufacturers Association (NEMA)
   155 East 44th Street, New York, New York, 10017
   A. IC-1, Industrial Control
   B. KS-1, Enclosed Switches
   C. AB-1, Molded Case Circuit Breakers
   D. FU-1, Low-Voltage Cartridge Fuses
   E. ST-1, Specialty Transformers
   F. MG-1, Motors and Generators
8. National Fire Protection Association (NFPA)
   60 Batterymarch Street, Boston, Massachusetts 02110
   A. NFPA No. 70, National Electrical Code (NEC)
   B. NFPA No. 79, Electrical Standard for Metal-Working Machine Tools
9. Superintendent of Documents
   Government Printing Office, Washington, D.C. 20401
   A. MIL-I-7798A, Insulation Tape, Electrical, Pressure-Sensitive Adhesive, Plastic
10. Underwriters' Laboratories, Inc. (UL)
    207 East Ohio Street, Chicago, Illinois 60611
    A. UL 508, Industrial Control Equipment
    B. UL 496, Edison-Base Lampholders
    C. UL 758, Provisional Requirements for Machine-Tool Wires and Cables
    D. UL 83, Thermoplastic-Insulated Wires
    E. UL 62, Flexible Cord and Fixture Wire
    F. UL 486, Wire Connectors and Soldering Lugs
    G. UL 514, Outlet Boxes and Fittings

**Appendix F—Sample Electrical Equipment Data Form

Note: This is a sample form. Each company may develop appropriate forms as required.

ABC COMPANY _____

DATE _____

DESCRIPTION OF EQUIPMENT _____

_____

REF. PURCHASE INQUIRY NO. _____ REF. PURCHASE ORDER NO. _____

FOR USE IN _____ DIVISION _____ PLANT

FOR TECHNICAL INFORMATION CONTACT:

NAME _____ PHONE _____ EXT. _____

CITY _____ STATE _____

INSTRUCTIONS TO BUILDER

1. Electrical equipment and wiring shall conform with:
   - ☐ JIC Electrical Standard for Mass Production Equipment
   - ☐ Other Standard and/or Code (Specify): _____
2. Equipment Power Supply: Voltage _____ Phase _____ Cycles _____
3. Motor voltage rating shall be: 1. Dual: 220/440 ☐ 230/460 ☐
   2. Other (Specify): _____
4. Approved Materials: See separate material list attached hereto.
   (Purchaser may attach an approved list of items.)
5. Type of Disconnecting Means
   - ☐ Circuit Breaker with interrupting rating of _____ amperes.
   - ☐ Fused Disconnect Switch
   - ☐ As furnished by supplier
   - ☐ Other (Specify) _____
6. Control Circuit
   - ☐ Ungrounded ☐ Grounded
7. Machine Work Lights ☐ Required ☐ Not Required
   Power Source:
   - ☐ From Isolating Transformer
   - ☐ From Machine Control Circuit
   - ☐ From Plant Lighting Circuit
8. Raceway and Wiring
   Raceway and wiring between separately mounted control enclosure and equipment shall be:
   - ☐ Furnished ☐ Not Furnished
9. Diagrams and Data:

PRELIMINARY			FINAL	
Reproducibles	Copies		Reproducibles	Copies
		Elementary Schematic Diagram		
		Electrical Stock List		
		Sequence of Operations		
		Electrical Layout		
		Panel & Control Station Layout		
		Foundation Drawing		

10. Purchaser's Assigned Drawing Number _____
11. Special Operating Requirements
    a. Reduced Voltage Starting: Method _____ Horsepower _____
    b. Ambient Temperatures Other Than Normal _____
    c. High Altitude Operation (Specify Altitude) _____
    d. Tropical Environment (Specify Type) _____
12. Other Requirements (Explain) _____

E1. General

E1.1 Purpose. The purpose of this Electrical Standard is to provide detailed specifications for the application of electrical systems to machine tools which will promote:

(1) Safety to personnel.
(2) Uninterrupted production.
(3) Long life of the equipment.
(4) Ease and low cost of maintenance.

This standard is not intended to limit or inhibit advancement in the art of electrical or mechanical engineering.

E1.2 Scope. The provisions of this standard shall apply to all electrical systems, furnished as part of the machine tools, which operate from a supply voltage of 600 volts or less, commencing at the power supply terminals on the disconnecting means.

Exception No. 1: Hazardous Locations. This standard shall not be considered adequate for machine tools intended for use in locations designated as hazardous in the National Electrical Code.

*Exception No. 2: Fixed or Portable Tools. This standard is not intended to apply to fixed or portable tools judged under the requirements of a recognized testing laboratory.

E1.3 Definitions.

**E1.3.1* Machine Tool. A machine tool is a power driven machine, not portable by hand, used to shape or form metal by cutting, impact, pressure, electrical techniques, or by a combination of these processes.

E1.3.2 Electrical Systems. Electrical systems shall include:

(1) Electrical equipment consisting of motors, solenoid-operated devices, limit switches, pressure switches, control station electrical components and similar contact-making devices, together with the associated wiring.
(2) Electronic equipment together with the associated wiring and devices.
(3) Static control equipment together with the associated wiring and devices.

E1.3.3 Nominal Voltages. All voltages hereinafter will be considered nominal 115 volts, 230 volts and 460 volts. (See Appendix C for definition of nominal voltage.)

E1.4 Additional Codes and Specifications. On any point for which specific provisions are not made in this standard, the provisions of the National Electrical Code (NEC) and state and local codes shall be observed. The National Fire Protection Association (NFPA) Standard 79, included with the National Electrical Code applies specifically to machine tools. Articles 500 through 540 of the National Electrical Code apply, as applicable, to Hazardous Locations.

E1.5 Specific Standards and Revisions. Whenever a specific standard is mentioned in this standard, it is understood it will be "the latest revision thereof" unless otherwise specified.

E1.6 Deviations. Deviations from this standard shall have the approval of the purchaser in writing. Any waivers granted shall apply only to the order in question and shall not be considered as permanent.

E1.7 Use of "Shall" and "Should." The word "shall" is understood as a requirement; the word "should" as a recommendation.

***E1.8** Conformity to JIC Standards. When a purchaser desires electrical equipment and installation of such equipment by the builder to conform to this JIC Electrical Standard and other requirements, he should so specify in his original inquiry and on his purchase order, the clause, "Electrical Equipment shall conform to the JIC Electrical Standards for General Purpose Machine Tools."

***E1.9** Additional User Requirements. The purchaser should specify, in his inquiry and on purchase order, such additional details as are required to meet his local requirements, such as:

(1) Power supply characteristics (voltage, phase and frequency).
(2) Preferred make of the electrical equipment where the equipment usually furnished by the machine tool builder is not desired.
(3) Type of motor enclosure desired.
(4) Type of supply circuit disconnecting means desired.
(5) Type of machine overcurrent protection desired.
(6) Extra copies of wiring diagram, if desired.
(7) Any conditions for which unusual provisions must be made, such as:
    (a) Power supply voltage other than nominal.
    (b) Limited power supply.
    (c) Power line disturbances (line "hash," surges, etc.) which might affect equipment operation.
    (d) Ambient temperature over 40 C.
    (e) Installation where control might require air filtering, forced ventilation, etc.
    (f) High altitude operations.
    (g) Conditions not normally encountered in a standard installation.
(8) Whether or not raceway and wiring are to be furnished between the machine tool and separately mounted enclosure.

E2. Diagrams, Data, Nameplates and Identification

E2.1 Diagrams, General.

**E2.1.1* Drawing Size. The electrical diagrams, including panel layout, stock list, and sequence of operations should be shown on one sheet where practicable. Where more than one sheet is required, they shall be cross-referenced. All sheets shall be multiples of $8\frac{1}{2}$" × 11" or 9" × 12" and the maximum size shall be 24" × 36". All information shall be clearly legible. (For sample diagrams, see Appendix B.)

**E2.1.2* Diagrams Supplied. Diagrams of the electrical system shall be furnished. The diagrams shall show the machine serial number, the purchaser's drawing number, purchase order number, or similar identification which will indicate the particular equipment to which the diagrams apply. The diagrams shall show all equipment in the electrical system.

Exception: On machine tools having only one motor and one starter, the diagram normally furnished with the combination starter is satisfactory provided the diagram shows all of the electrical apparatus on the machine tool.

E2.1.3 Symbols and Device Designations.

E2.1.3.1 Standard electrical symbols as shown in Appendix A shall be used for all diagrams. For symbols not shown in Appendix A refer to United States of America Standard Y32.2. Symbols for logic devices shall be in accordance with NEMA Standard IC-1, Industrial Control.

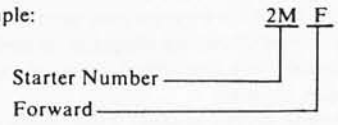
Exception: Special symbols may be used where there is no standard symbol; such symbols shall be identified and explained both on the diagrams and in instruction manuals.

E2.1.3.2 The symbols for devices shall be identified by a number or number-letter combination, using abbreviations shown in Appendix D. For special abbreviations not listed, refer to NEMA Standard IC-1, Industrial Control.

E2.1.3.3 The following alphabetical designations shall be used for the devices indicated and shall not be used for other identification purposes:

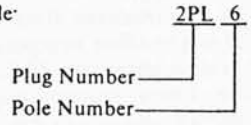
Items	Examples
Relays—General Use	CR, 1CR, 2CR
—Master	CRM
—Automatic	CRA
—Electronically Energized	CRE, 1CRE, 2CRE
—Manual (hand)	CRH
—Latch	CRL, 1CRL, 2CRL
—Unlatch	CRU, 1CRU, 2CRU
Timers	TR, 1TR, 2TR
Overload Relay	OL, 1OL, 2OL
Motor Starters	1M, 2M, etc.
Reversing Motor Starters	1MF (Forward)—1MR (Reverse)

Example:



Plugs	1PL, 2PL, etc.

Example:



Solenoids	1SOL, 2SOL, 3SOL
Limit Switches	1LS, 2LS, 3LS
Pressure Switches	1PS, 2PS, 3PS

E2.1.3.4 Special abbreviations not covered by the above paragraphs may be used and shall be identified on the diagrams and in the instruction manual.

E2.1.4 Conductor Identification. Each conductor shall be identified by a number, letter or number-letter combination. Consecutive numbering is preferred. The identification shall be used only once in the electrical system. Each conductor shall have the same identification at all terminals and tie points. All conductors connected to the same terminal or tie point shall have the same identification. Where multiconductor cable is used, a color code may be used to supplement the above identification. Where color-coded multiconductor cable is used for wiring identical components, such as limit switches, the color code shall be consistent and charted on related diagrams.

E2.1.5 Sub-assembly Terminal Identification. Terminal numbers, letters or number-letter combinations for sub-assemblies or components shall be identified distinctively and associated with the sub-assembly or component.

E2.2 Elementary (Schematic) Diagram.

E2.2.1 An elementary diagram shall be furnished for each electrical system. A logic diagram may be furnished in lieu of or in combination with an elementary diagram.

E2.2.2 The elementary diagram shall be drawn between vertical lines which represent the source of control power. All control devices shall be shown between these lines. Actuating coils of control devices shall be shown on the right-hand side. All contacts shall be shown between the coils and the left vertical line.

Where the internal wiring diagrams of sub-assemblies are furnished on separate sheets, they shall be shown as a rectangle in the elementary diagram with all external points identified and cross-referenced to the separate sheet(s) of the control circuit. Coils and contacts internal to the sub-assemblies shall be shown in the rectangle connected to their terminal points.

Exception No. 1: Where relay and electronic circuits are mixed, diagrams may be drawn between horizontal lines which represent the source of control power.

Exception No. 2: Overload relay contacts may be connected to the right of the coil (common) if the conductors between such contacts and the coils of the magnetic devices do not extend beyond the control enclosure.

E2.2.2.1 Control device symbols should be shown in the order in which the controls are energized and positioned on the diagram for clarity.

*E2.2.2.2 A cross-referencing system shall be used in conjunction with each relay coil so that associated contacts may be readily located on the diagram.

E2.2.2.3 Only contacts actually used shall be shown.

E2.2.2.4 Limit, pressure, float, flow, temperature-sensitive and similar switch symbols shall be shown on the elementary diagram with all utilities turned off (electric power, air, gas, oil, water, lubrication, etc.) and with the equipment at its normal starting position.

E2.2.2.5 Contacts of multiple-contact devices (e.g., selector switches) shall be shown on the line of the elementary diagram where they are connected in a circuit. A mechanical connection between the multiple contacts shall be indicated by a dotted line or arrow. This does not apply to control relays, starters or contactors.

E2.2.2.6 Additional charts or diagrams may be used to indicate the position of multiple-contact devices such as drum, cam and selector switches.

E2.2.2.7 The connections between pushbuttons, limit switches and similar items connected in series shall be shown as test points on the diagram as required in E12.4.14.

E2.2.2.8 The purpose or function of all switches shall be shown either adjacent to the symbols, or in a switch description chart. The chart shall be on the same sheet as the symbol.

*E2.2.2.9 Solenoid function shall be shown adjacent to the symbol.

E2.2.2.10 Values of capacitors and resistors shall be shown on the diagram.

E2.2.2.11 Descriptive terms for command and status functions shall be in the present or past tense. For example, Raise Transfer–Transfer Raised; Advance Transfer–Transfer Advanced. Terms such as Transfer Up shall not be used.

E2.2.3 Electronic Diagram. Electronic diagrams shall include pertinent data for maintenance purposes as follows:

(1) Voltage and current data necessary for maintenance purposes.
(2) Normal voltages on transformer windings.
(3) Signal input and output voltages.
(4) Potentials applied to tube elements.
(5) Oscilloscope traces, showing wave form and peak-to-peak voltages where meter readings are inadequate.
(6) The type and sensitivity of test instruments to be used and the condition of the circuit.
(7) The instantaneous polarity of each transformer winding in phase-sensitive circuits.
(8) The electrical values of capacitors, resistors, inductances and other electronic components.

E2.3 Block and Logic Diagrams.

E2.3.1 Block Diagram. Where the complexity of the control system warrants, a block diagram of control functions shall be furnished. Each block shall be identified and cross-referenced in a manner that the internal circuitry may be found readily on the elementary diagram.

E2.3.2 Logic Diagram. A logic diagram of the electrical system shall be furnished when static control or logic modules are supplied. The diagram need not show power connections.

E2.4 Panel Layout and Interconnection Diagram.

**E2.4.1* It is recommended that panel layouts be furnished with each electrical system. The panel layout shall show the general physical arrangement of all components on the control panel. Devices may be represented by rectangles or squares and shall be identified with the same marking as used on the elementary diagram. Spare panel space shall be dimensioned. The drawings shall include a layout of the operator console or pushbutton station, but terminal numbers need not be shown. This layout may be

combined on the same drawing with the interconnection diagram or wiring table. (See Sample Diagram in Appendix B.)

E2.4.2 Photographs of electronic chassis and similar complex devices may be furnished in lieu of panel layouts, provided each component is clearly visible and identified.

E2.4.3 An interconnection diagram or wiring table shall be furnished to indicate the interconnecting conductors between all terminals on each terminal block for all panels and chassis comprising the complete electrical system. Each connection shall be identified as shown on the elementary diagram. Blank spaces and spare terminals shall be shown.

E2.5 Stock List. The stock list shall show quantity, manufacturer's name, type or model and catalog number of each device used; plus motor horsepower, frame size, type of enclosure and speed; and any other information necessary to order replacement electrical and electronic items.

E2.6 Sequence of Operation. The sequence of operation shall indicate the progression of operations of all push-buttons, limit switches, relays, solenoids and other devices as shown and identified on the elementary diagram. Graphical representations, such as bar charts, may be used to supplement written descriptions.

E2.7 Instruction Manuals. On complex equipment, such as numerical control systems, servo controls, electrical variable-speed drives, etc., an instruction manual shall be furnished. The following shall be included:

(1) Information necessary for calibrating and adjusting components, devices and sub-assemblies.
(2) Operation instructions, including all information necessary to describe the operation of the complete system.
(3) Maintenance instructions, including information and suggestions for locating and replacing faulty components, suggested maintenance schedules and related data.
(4) A recommended spare parts list with complete ordering information and suggested quantities.

***E2.8** Electrical Layout. An electrical layout should be furnished with each electrical system. The electrical layout shall consist of an outline of the machine and all electrical equipment in their relative locations, not necessarily to scale, showing the control panel enclosure and its dimensions, operator's console and accessory units not attached directly to the equipment, such as hydraulic power units. All devices shall be identified as shown on the elementary diagram.

E2.9 Foundation Drawing. On equipment requiring conduit in the foundation, the minimum size, purpose and location of the conduit to be used shall be shown on a foundation drawing.

E2.10 Equipment Nameplates.

E2.10.1 Main Nameplate. A permanent non-corrodible nameplate shall be attached to the control enclosure door. This nameplate shall list the following:

(1) Equipment serial number.
(2) Supply voltage, phase and frequency.
(3) Rated KVA or full-load current (see E2.10.1.1).
(4) NEMA interrupting capacity of the circuit breaker (if supplied).
(5) Ampere rating of the largest motor.
(6) Supplier's electrical diagram number.

Exception: Where only a single motor and motor controller are used, the motor nameplate may serve as the electrical equipment nameplate if it is plainly visible.

E2.10.1.1 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 loads, duty cycles, etc., require oversized conductors, the required capacity shall be included in the "full-load current" rating as marked.

E2.10.1.2 Where more than one incoming supply circuit is provided, the nameplate shall state the above information for each circuit.

E2.10.1.3 Where overcurrent protection is provided in accordance with E4.3, Main and Branch Circuit Overcurrent Protection, the nameplate shall be permanently marked "Overcurrent protection provided at equipment supply terminals." A separate nameplate may be used for this purpose.

E2.10.1.4 Where the builder wishes to indicate compliance with this and other standards, it is recommended that the nameplate be marked with a notation similar to the following: "The electrical equipment and wiring on this machine conform to the following standard(s) ....."

E2.10.2 Additional Nameplates. Where electrical equipment is removed from the original enclosure, or where equipment is so placed that the manufacturer's nameplate is not readily visible, an additional nameplate shall be permanently attached to the equipment or enclosure. Nameplates shall not be removed from electrical equipment.

E2.11 Device Identification. Control and power devices shall be plainly and permanently identified, using the same identification as shown on the elementary diagram. Identification shall be shown on a plate mounted adjacent to, not on, the device. Control station components shall be identified by function. (See E9.3.2)

Exception No. 1: Where the size or location of the devices make individual identification impractical, such as on electronic assemblies, group identification shall be used.

Exception No. 2: Where panel layouts do not permit mounting identification plates adjacent to components, such as relays, the permanent relay identification shall be placed on the relay where it is plainly visible, and a second identification provided on the top of the panel wireway cover directly below the relay. The wireway covers shall be identified to show their proper location.

E3. Supply Circuit Disconnecting Means

***E3.1** Scope. This section shall apply to all machine tools except bench-type machines powered by a single motor rated at 2 horsepower or less.

E3.2 Type.

E3.2.1 Where nominal 115 volt, single phase, is the only power supply to the equipment, a fused disconnect switch or circuit breaker of suitable size shall be installed.

E3.2.2 On all other equipment the builder shall furnish, as specified by the purchaser, one of the following disconnecting means:

(1) A fusible or non-fusible motor circuit switch conforming to all requirements, except enclosures, listed in NEMA Standard KS-1, Enclosed Switches, for heavy duty type HD switches, or
(2) A circuit breaker conforming with NEMA Standard AB-1, Molded Case Circuit Breakers, or
(3) A fusible or non-fusible circuit interrupter.

E3.3 Rating.

E3.3.1 The ampacity of the disconnecting means shall be not 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.

E3.3.2 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 the other connected operating equipment.

E3.4 Application. The disconnecting means shall be applied in accordance with E4, Protection.

E3.5 Position Indication. The disconnecting means shall plainly indicate whether it is in the open or closed posi-

tion. (See E3.11.3)

E3.6 Supply Conductors to be Disconnected. The disconnecting means shall disconnect all ungrounded conductors of the supply circuit simultaneously. Where there is more than one supply source, additional individual disconnecting means shall be provided for each supply circuit so that all supply conductors may be interrupted.

E3.7 Supply Line Connection. The incoming supply conductors shall terminate at the disconnecting means with no connection to terminal blocks or other devices ahead of the disconnecting means.

E3.8 Exposed Live Parts. There shall be no exposed live parts when the disconnecting means is in the open position.

E3.9 Mounting.

E3.9.1 The disconnecting means shall be mounted within the control enclosure.

*Exception: Where the connected load exceeds that for which it is practicable to panel-mount the disconnecting means, the machine tool builder shall then furnish, but not mount, an enclosed disconnecting means.

**E3.9.2* Where more than one disconnecting means is provided for multiple supply circuits in a single enclosure, they shall be grouped in one location.

E3.9.2.1 When disconnects are mounted in separate enclosures, each supplying power to part of a complete machine or equipment, the following provisions shall be made:

(1) A main disconnecting means shall be furnished to de-energize the entire system, and

(2) The disconnecting means in any of the separate control enclosures shall de-energize all current-carrying components in that enclosure when placed in the "OFF" position.

Exception: Control devices and terminals located in the enclosure but energized from a remote source need not be de-energized if identified by yellow wiring.

**E3.9.3* The disconnecting means shall be mounted at the top of the control panel with no other equipment mounted directly above it.

E3.10 Interlocking.

E3.10.1 Where there are two or more sources of power to the equipment or where there are two or more independent disconnecting means, not mechanically interlocked with each other, power wiring from each disconnecting means shall be run in separate conduit, and shall not terminate in or pass through common junction boxes.

**E3.10.2* When the disconnecting means is mounted within the control enclosure, it shall be interlocked mechanically or electrically, or both, with the control enclosure door(s). A suitable device, operated by a screwdriver or other common hand tool, shall be provided so that interlocks may be by-passed and the panel doors opened without disconnecting the power. Interlocking must be reactivated automatically when panel doors are closed. Progressive interlocking, door-to-door, shall not be used.

E3.11 Operating Handle.

E3.11.1 Location. The operating handle of the disconnecting means shall be readily accessible. The center of the grip, when in its highest position, shall be not more than 6½ feet above the floor and should not be lower than 3 feet above the floor.

**E3.11.2* Locking. The operating handle shall be so arranged that it may be locked in the "OFF" position.

**E3.11.3* Position Indication. When the control enclosure door is closed, the operating handle shall positively indicate whether the disconnecting means is in the open or closed position. (See E3.5)

E4. Protection

***E4.1** Scope. This section shall apply to all machine tools, except bench-type machines powered by a single motor rated 2 horsepower or less.

Fig. 4-1. Typical diagrams, electrical system protection.

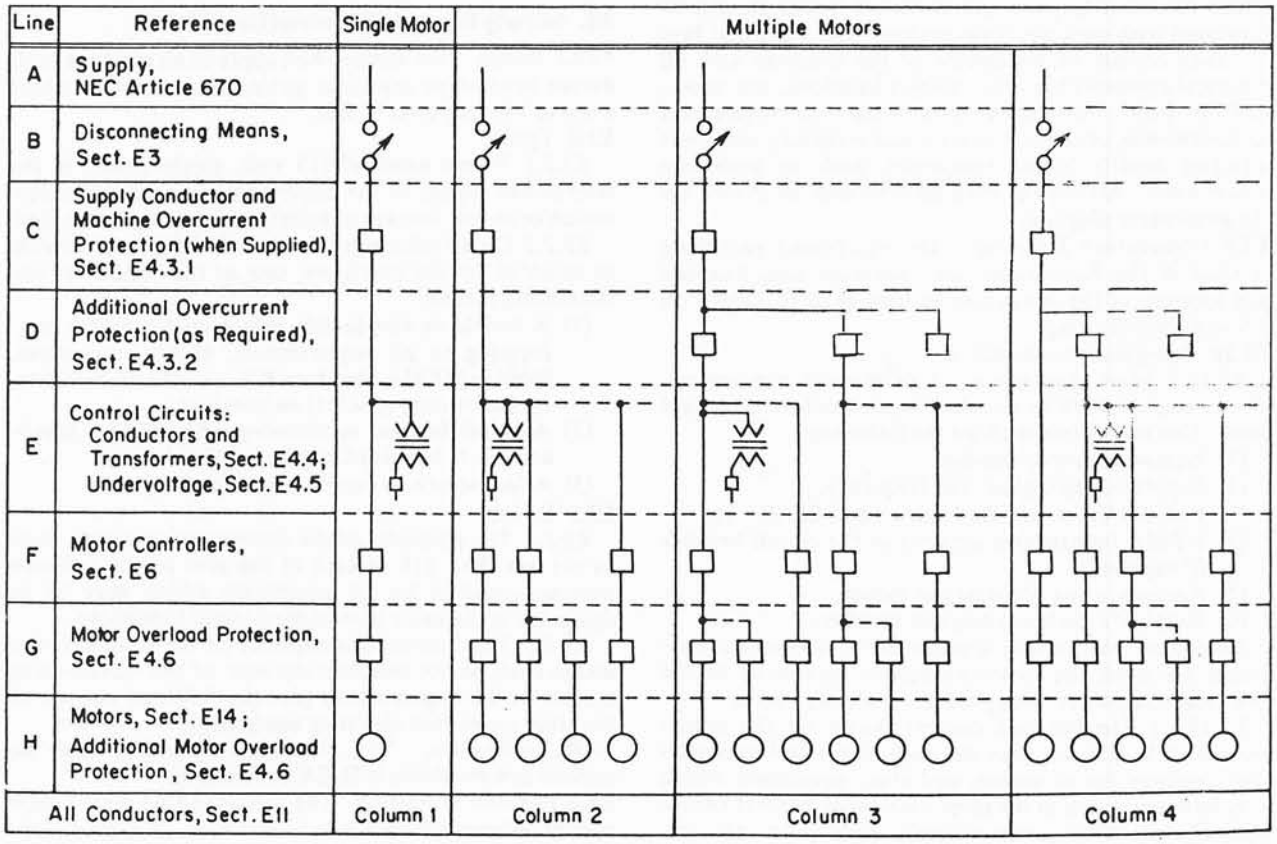


***Table 4-1—Motor Overcurrent Protective Device Rating**

	Percent of Full-load Current		
	Maximum Fuse Rating		Thermal Magnetic Circuit Breaker Maximum Rating or Setting
	Time Delay or Dual Element	Nontime Delay	
Motors Marked with Code Letter Indicating Locked-Rotor KVA			
All AC 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 amperes Full-load Current	125	250	250
More than 30 amperes Full-load Current	125	200	200
Wound Rotor	125	150	150
Direct Current	125	150	150

For motors not included in the table refer to National Electrical Code, Article 430, Table 430-146.
If the calculated values for overcurrent (short circuit) devices do not correspond to standard ratings or sizes, the next larger size or rating may be used.

E4.2 General.

E4.2.1 Figure 4-1 shows typical circuits which are acceptable for protection of electrical systems.

**E4.2.2* Fuses for power and control shall conform to applicable portions of this section.

E4.3 Main and Branch Circuit Overcurrent Protection.

E4.3.1 The main overcurrent protection shown in line "C" of Figure 4-1, Typical Diagrams, Columns 1 through 4 inclusive, may or may not be furnished as part of the electrical system as specified in E3.2. Where furnished as part of the system, it shall consist of a single circuit breaker or set of fuses, and the nameplate shall bear the marking required in E2.10.1.3.

E4.3.2 Additional Overcurrent Protection. On a machine with more than one branch circuit, additional overcurrent protection as shown on line "D" of Figure 4-1, Typical Diagrams, Columns 3 and 4, shall be furnished as part of the electrical system. Overcurrent protection, such as fuses or overcurrent trip units of a circuit breaker, shall be placed in each ungrounded branch circuit conductor. Where a circuit breaker is used, it shall open all ungrounded conductors of the branch circuit.

E4.3.3 Overcurrent protective devices shall be located at the point where the conductor to be protected receives its supply except as follows:

Exception No. 1: Where all of the following conditions are complied with: The conductor (1) has an ampacity at least one-third that of the conductor from which it is supplied, (2) is suitably protected from physical damage, (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: The conductor (1) has an ampacity not less than the sum of the maximum continuous load currents, (2) is not over 10 feet long, and (3) does not extend beyond the control panel enclosure.

E4.3.4 Selecting Overcurrent Devices. If the calculated value for overcurrent (short circuit) devices does not correspond to standard ratings or sizes, the next larger size or rating may be used.

E4.3.5 Individual Motor Overcurrent Protection.

E4.3.5.1 The overcurrent protective (short circuit) 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 obtained when the overcurrent device has a rating or setting not exceeding that shown in Table 4-1.

*E4.3.5.2 Where the overcurrent protection specified in Table 4-1 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 thermal-magnetic-trip circuit breakers and nontime-delay fuses and a maximum of 200 percent for time-delay or dual-element fuses.

E4.3.6 Several Motors on One Branch Circuit. Two or more motors and their control equipment may be connected to a single branch circuit provided all of the following requirements are complied with:

(1) The maximum size of conductors connected to a motor controller shall be in accordance with Table 4-2,

(2) The rating or setting of the overcurrent protective device shall be as low as practicable and shall not exceed the values shown in Table 4-3 for the smallest conductor in the circuit, and

***Table 4-2—Maximum Conductor Size for NEMA Motor Controllers (Starters)†**

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

†See ANS C19.1, Industrial Control Apparatus.

***Table 4-3—Power Conductor Overcurrent Protection**

Conductor Size, AWG	Maximum Rating Nontime Delay Fuses or Circuit Breakers, Amperes	Maximum Rating Time Delay or Dual Element Fuses, Amperes
14	60	30
12	80	40
10	100	50
8	150	80
6	200	100
4	250	125
3	300	150
2	350	175
1	400	200
0	500	250
00	600	300
000	700	350
0000	800	400

(3) Motor and control circuits shall be arranged so that a minimum number of branch circuit overcurrent protective devices are required.

E4.3.7 Lighting Branch Circuits. Overcurrent protection for lighting branch circuits shall not exceed 15 amperes.

E4.4 Control-Circuit Overcurrent Protection.

*****E4.4.1* The control conductors shall be protected against steady overloads and short circuits. An overcurrent device shall be connected in series with each ungrounded leg of all branch control circuits. The overcurrent devices shall be rated at not more than 125 percent of the current rating of the transformer and shall interrupt short circuits without damage to the transformer or conductors.

E4.4.2 The rating of overcurrent protective devices in the control circuit shall be as low as practicable and shall not exceed the values given in Table 4-4 for the smallest conductor in the circuit. In Tables 4-4 and 4-5, the smaller of the computed overload ratings shall be used.

E4.4.3 The transformer for the control circuit shall be protected in the secondary circuit against overloads and short circuits with overcurrent devices selected in accordance with Table 4-5.

******E4.4.4* Combined Protection. The same overcurrent device may be used to provide the protection specified for both the control transformer and conductors in E4.4.

E4.5 Undervoltage Protection. Undervoltage protection shall be provided for all equipment which may initiate a motion upon return of power after an undervoltage condition.

E4.6 Motor Overload Protection.

E4.6.1 Each motor and related conductors shall be protected against running overload by the use of a separate overload device responsive to motor current. Embedded thermal sensing devices may be used in addition to the current responsive devices.

Exception: Short-time rated motors or high reversing duty motors which cannot be adequately protected by external overload devices shall be protected by a thermal overload device mounted in the motor.

E4.6.2 The minimum allowable number and location of overload devices shall be as shown in Table 4-6.

E4.6.3 The rating of the current sensing overload device shall be based on the motor full-load current, except that, if the rating does not match a standard manufactured size, the next larger standard size shall be used, taking into consideration the service factor, ambient temperature of both the motor and its controller and type of motor enclosure.

E4.6.4 Embedded thermal sensing overload devices shall be sensitive to the temperature of the motor or to both temperature and current. In addition, motors shall be protected against stalled conditions by the use of a separate protective device which is responsive to motor current.

E4.6.5 Resetting of the motor overload device shall not restart the motor.

E5. Control Circuits

E5.1 Source of Control Supply. The source of supply for control circuits shall be taken from the load side of the main disconnecting means.

E5.2 Control Voltage.

E5.2.1 AC control voltage shall be nominal 115 volts, single phase, obtained from a transformer with an isolated secondary winding, except as follows:

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

Exception No. 2: Exposed, grounded control circuits may be used when supplied from an isolating 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 magnetic device having an inrush current exceeding 20 amperes at 115 volts may be energized directly from the line through contacts of a contactor or relay rated for line voltage. The coil of the contactor or relay shall be fed from the 115-volt control circuit.

Exception No. 4: Control voltages less than 115 volts may be used where components rated for 60 cycles are applied to a lower frequency (e.g., a coil rated at 115 volts, 60 cycles, may be applied to 95 volts, 50 cycles).

E5.2.2 DC control voltage shall not exceed 250 volts.

Table 4-4—Control Conductor Overcurrent Protection

Conductor Size, AWG	Maximum Rating, Amperes
22	3½
20	6¼
18	8
16	10
14	15
12	20
10	30
8	40
6	60
4	70
3	80
2	100
1	110
0	125
00	150
000	175
0000	200

****Table 4-5—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

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.

Table 4-6—Number and Location of Overcurrent Devices

Type of Motor	Supply System	Number and Location
1-phase AC or DC	2-wire, 1-phase AC or DC, ungrounded	1 in either conductor
1-phase AC or DC	2-wire, 1-phase AC or DC, one conductor grounded	1 in ungrounded conductor
1-phase AC or DC	3-wire, 1-phase AC or DC, grounded neutral	1 in either ungrounded conductor
3-phase AC	3-wire, 3-phase AC, ungrounded	2 in any 2 conductors
3-phase AC	3-wire, 3-phase AC, one conductor grounded	2 in ungrounded conductors
3-phase AC	3-wire, 3-phase AC, grounded neutral	2 in any 2 conductors
3-phase AC	4-wire, 3-phase AC, grounded neutral or ungrounded	2 in any 2 conductors except the neutral

For 2-phase power-supply systems refer to National Electrical Code, Section 430-37.

Exception: Other voltages may be used, where necessary, for the operation of electronic devices used in the electrical system.

E5.3 Connection of Control Devices.

E5.3.1 Indicator lamps, or transformer primary windings for indicator lamps, and operating coils of control devices shall be connected to the same side of the control circuit. Contacts shall be connected in the other side of the control circuit.

Exception No. 1: Overload relay contacts may be connected to the right of the coil (common) if the conductors between such contacts and coils of the magnetic devices do not extend beyond the control enclosure.

Exception No. 2: Where relay and electronic circuits are mixed, control contacts in the electronic circuit may be connected as required.

E5.3.2 Contacts shall not be connected in parallel to increase ampacity.

**E5.3.3* Relays used for selecting automatic circuits shall include a holding circuit and shall not return to the "Automatic" mode after restoration of the control voltage following a power failure, or operation of the "Master Stop".

E5.3.4 Separately mounted solenoid or magnetic brakes may be connected directly across motor terminal leads.

E5.4 Circuit Design and Interlocking.

**E5.4.1* Where there is more than one electrically-controlled or operated device on any equipment, and where possible damage may be caused by the failure of any one device to function properly, the circuits shall be arranged with protective interlocks. Where practicable, these interlocks shall interrupt all operations, provided such interruption does not constitute a hazard or cause damage to the equipment or work in process.

**E5.4.2* Where applicable, the requirements of E5.4.2.1 through E5.4.2.15 inclusive shall be provided.

E5.4.2.1 Opposing Motions Interlocked. Starters, relays, contactors and solenoids which are mechanically interlocked shall also be electrically interlocked to prevent simultaneous energization.

E5.4.2.2 Plugging Circuits. Plugging switches or zero speed switches, used to control the application or removal of power, in order that moving parts may be slowed down, stopped, or reversed, shall be provided with features incorporated in the control circuit to (1) prevent the reapplication of power after the completion of the plugging operation, and (2) prevent the application of power through any manual movement of the plugging switch shaft or of the motor or equipment. Timing relays are not permitted for plugging motors used for tapping at the end of the forward stroke.

E5.4.2.3 "Stop" by De-energization. "Stop" functions shall be initiated through de-energization rather than energization of control devices where possible.

E5.4.2.4 Movement Initiation by Limit Switches. Control circuits shall be designed so that when the equipment is in its "home" or "end of cycle" position, movement of any part of the equipment can be initiated by limit switches only if all of the following conditions are met:

(1) The control is set for automatic operation,
(2) The control is of the holding circuit type, is energized, and
(3) The condition of the automatic operation is indicated by pilot lights.

E5.4.2.5 "Jog" ("Inch") Circuits. "Jog" ("Inch") circuits shall be designed so that the prevention of "Run" or "Automatic" operation during jogging shall be inherent.

*E5.4.2.6 "Anti-Repeat" Operation. On equipment where continuous consecutive cycles of operation of the equipment are not a normal or a desired operation, the circuit shall be arranged so that such operation cannot be obtained by the use of any button or control means available to the equipment operator. Specifically, continuous consecutive cycles shall not result even though the "Cycle Start" button(s) is held continuously in the "Start" position. Timers alone shall not be used in anti-repeat circuits.

E5.4.2.7 Spindle Drive Interlocked with Feed. Interlocking shall be provided to insure that the spindle drive motor contactor is energized before the tool is driven into the work piece while in the "Automatic" cycle.

E5.4.2.8 Contactor for Control Circuit Loads. The auxiliary contact on any starter or contactor shall not be used in excess of its rating for carrying control circuit loads. An additional relay or contactor shall be used for this purpose.

E5.4.2.9 Changing from Rapid Traverse to Feed. Hydraulically actuated heads shall not require an energizing operation to change from rapid traverse to feed rate.

E5.4.2.10 One Station for Motor Starting. There shall be only one station effective at any time for starting all motors concurrently. However, multiple "Stop" stations may be used.

*E5.4.2.11 Overspeed Protection for DC Motors. Shunt and compound-wound DC motors should be equipped with overspeed or field-loss protection to prevent excessive motor speed.

E5.4.2.12 Sequence Control by Pressure Switches. Pressure switches alone shall not be used to determine sequence of operation.

E5.4.2.13 Rotary Cam Limit Switches Used as Sequence Control. Rotary cam switches shall not be used as sequence controls on equipment unless the position of the equipment component or the location of the material in process is indicated by separate controls, such as limit switches, which are interlocked with the rotary cam switch.

Exception: This requirement does not apply to presses.

*E5.4.2.14 Control of Valves. Hydraulic or pneumatic circuits for clamp actuation or index mechanism control shall be designed to prevent uncontrolled movement in all phases of the equipment cycle. When solenoid-operated hydraulic or pneumatic devices are used, the control circuit shall be designed so that positive sequencing is assured.

**E5.4.2.15 Fail-Safe Operation. Fail-safe operation shall be employed in the application of all devices in the electrical system, where practicable.

E5.4.3 Whenever practicable, limit switches shall be used to (1) sense the position of equipment elements and parts in process, and (2) control the proper sequencing of the equipment.

E5.4.4 Hinged or sliding doors to compartments containing belts, gears, or other moving parts which may expose hazardous conditions shall be interlocked through limit switches or other means to prevent equipment from operating when doors are not closed.

E6. Control Equipment

E6.1 Standards.

E6.1.1 Control devices shall conform to ANS C19.1, Industrial Control Apparatus, and NEMA Standard IC-1, Industrial Control.

E6.1.2 Polyphase control apparatus shall conform to ANS C19.1, Industrial Control Apparatus, and NEMA Standard IC-1, Industrial Control, and be suitable for 600-volt service regardless of voltage applied.

**E6.1.3* Control circuit transformers shall conform to NEMA Standard ST-1, Specialty Transformers, Section 4, Machine Tool Transformers.

E6.1.4 Control devices external to the control en-

closure, such as limit switches, pushbuttons, selector switches, valve solenoid enclosures and pressure switches, shall be oil-tight.

E6.1.5 Precision and other small devices used for control which do not come within the scope of the above standards shall conform to applicable accepted standards.

E6.2 General Requirements.

**E6.2.1* Panel-mounted control devices shall be suitable for front connection.

Exception: This does not apply where equipment suitable for front connection is not commercially available. (See E7.5.2 and E8.2.4)

**E6.2.2* Convenient means for making conductor connections shall be provided on, or adjacent to, all control devices mounted in the control enclosure.

E6.2.3 Control devices and coils shall be marked in accordance with published pertinent standards or with the maker's name or trademark, ordering number and applicable descriptive electrical specifications such as voltage and frequency.

Exception: Where the device is too small to identify, the information shall be shown on the diagram or stock list.

**E6.2.4* Electrically energized devices located external to the control enclosure such as motor brakes, clutches, solenoids, and other coil-operated devices shall:

(1) Be protected from physical damage, and
(2) Have metal enclosures for the termination of conduit as well as provisions for making connections to the coil.

E6.2.5 Control contacts operated by slow moving mechanisms shall be of the quick-make and quick-break type.

Exception: This does not apply to pushbuttons, selector switches or instruments.

***E6.2.6* Sub-panels with concealed or inaccessible internal wiring or components may be used. Where used, they shall be mounted and wired so as to be readily removable for rapid replacement or bench repair.

E6.3 Motor Starters.

E6.3.1 Across-the-line starting shall be employed for alternating-current motors.

Exception No. 1: Where the purchaser specifies otherwise.

Exception No. 2: Where the equipment requires limited accelerating torque.

E6.3.2 Alternating-current motor starters shall open all of the power conductors connected to associated motors.

E6.3.3 Several motors may be controlled by one starter or contactor if all of the following are complied with:

(1) Ratings of the starter or contactor for horsepower, locked-rotor current and other characteristics listed in NEMA Standard IC-1, Parts 21B and 27B, shall not be exceeded,
(2) Each motor shall have individual overload relays, and
*(3) All overload relays should be the same make.

E6.3.4 The rating of starters for plug-stop, plug-reverse, or jogging duty requiring repeated interruption of stalled motor current or repeated closing of high transient currents encountered in rapid motor reversal involving more than five openings per minute shall be in accordance with Table 6-1.

E6.3.5 Conversion equipment, such as from AC to DC, shall be furnished for any electrical apparatus unless otherwise specified by the purchaser.

**E6.3.6* Each starter shall be capable of starting and stopping the motor or motors which it controls. For alternating-current motors the starter shall be capable of interrupting the stalled rotor current of the motor or motors.

E6.4 Group Starting of Motors. The starting of motors shall be in sequence so that a group of motors started simultaneously will not exceed either of the following:

(1) An aggregate of 100 horsepower, when the smallest motor of the group is 10 horsepower or larger, or
(2) An aggregate of 75 horsepower, when the smallest motor of the group is $7\frac{1}{2}$ horsepower or smaller.

E7. Control Enclosures and Compartments

E7.1 General. This section does not apply to combination motor starters except that they shall be in NEMA Type 12 enclosures.

E7.1.1 Control enclosures and compartments shall be constructed in conformance with applicable sections of this standard and both of the following:

(1) NEMA Type 12 (See NEMA Standard IC-1, Industrial Control)
**Exception: See E7.3.2
(2) Underwriters' Laboratories Standard UL 508, Industrial Control Equipment.

Exception: Equipment normally requiring ventilation may be housed in ventilated enclosures or compartments, provided they are located so that the equipment is capable of operating satisfactorily and without hazard.

**E7.1.2* Any ventilating opening shall be designed to prevent the entrance of any deleterious substance.

E7.1.3 The thickness of sheet steel used for walls and doors of enclosures or compartments shall be as shown in Table 7-1.

Exception No. 1: If a supporting frame or equivalent reinforcement is used, the minimum enclosure wall thickness for areas over 1200 square inches shall be 0.075 inch if made of sheet steel.

Exception No. 2: The thickness of walls and doors of compartments shall be a minimum of $\frac{1}{8}$ inch for cast material.

E7.1.4 The depth of the control enclosure or compartment should be a minimum consistent with the maximum depth of the control devices plus the required electrical clearances.

**E7.1.5* The height and width of the door opening should be at least one inch greater than the corresponding height and width of the control panel to be enclosed.

E7.1.6 A permanent metal data pocket shall be attached to the inside of the enclosure or compartment.

Table 6-1—Starter Ratings for Plug-Stop or Jogging Duty†

Size Starter	Maximum Horsepower Rating	
	230 Volts, Three Phase	460/575 Volts, Three Phase
**0	1	1
1	3	5
2	10	15
3	20	30
4	30	60
5	75	150
6	150	300

†See NEMA Standard IC-1, Industrial Control.

Table 7-1—Metal Thickness for Walls and Doors of Enclosures or Compartments

Maximum Area of Any Surface, Square Inches	Maximum Dimension, Inches	Minimum Thickness (Nominal) of Metal, Inches	Equivalent Manufacturer's Standard Gage, MSG
Less than 360	18	0.075	14
360	24	0.075	14
1200	48	0.075	14
1500	60	0.106	12
Over 1500	—	0.132	10

If space permits, the pocket should be at least 10½ inches wide and of adequate depth and thickness to accommodate all electrical diagrams.

E7.1.7 Compartment doors, enclosures and enclosure doors shall be designed to have sufficient rigidity to assure continuing proper alignment between mating parts, such as door fasteners and locking devices.

E7.1.8 Door aligning guides may be used to insure alignment. Reinforcements shall be used, as necessary, to prevent door warpage.

**E7.1.9* The interior of enclosure and panel should be finished in a light color.

E7.2 Size Definition.

E7.2.1 A small enclosure or compartment is one which accommodates a panel having less than 1500 square inches of area.

E7.2.2 A large enclosure or compartment is one which accommodates a panel(s) having 1500 square inches or more of area.

E7.3 Enclosures.

**E7.3.1* Mounting feet or other suitable means external to the enclosure should be provided for equipment-mounted enclosures. Separately mounted enclosures shall be freestanding.

**E7.3.2* There shall be no unfilled holes in the enclosure for mounting the enclosure or mounting controls within the enclosure.

E7.4 Compartments.

E7.4.1 Compartments for built-in controls shall be isolated from coolant and oil reservoirs.

E7.4.2 Compartments shall be readily accessible and enclosed.

E7.4.3 Compartments shall not be considered enclosed if they are open to (1) the floor, (2) the foundation on which the equipment rests, or (3) other compartments of the equipment which are not clean and dry.

E7.4.4 Where ventilation is required, the requirements of E7.1.1 and E7.1.2 shall apply.

E7.5 Doors.

E7.5.1 Hinged doors which swing horizontally shall be provided for control enclosures and compartments.

E7.5.2 Control enclosures containing panels with back-connected devices shall be equipped with rear-access doors to those panels. (See E6.2.1)

E7.5.3 Doors shall not exceed 36 inches in width.

**E7.5.4* Door swing should be a minimum of 165 degrees.

E7.6 Door Fasteners.

**E7.6.1* Door fasteners on small enclosures and compartments shall be designed to seal the door tightly around its perimeter without penetrating the control compartment or enclosure. All parts of such fasteners shall remain captive when the door is opened. Vault-type hardware, which latches simultaneously at the top and the bottom of the door, may be used.

E7.6.2 Door fasteners on large enclosures and compartments shall be designed to seal the door tightly around its perimeter. Vault-type hardware, which latches simultaneously at the top, center and bottom, shall be used on large enclosure doors.

E8. Location and Mounting of Control Equipment

E8.1 General Requirements.

E8.1.1 Control equipment external to the control enclosure, such as limit switches, pressure switches, brakes, solenoids, pushbutton stations, etc., shall be (1) mounted rigidly in a readily accessible and reasonably dry and clean location, (2) provided with adequate clearance for replacement, and (3) free from accidental operation by normal movement of machine components or operator.

**E8.1.2* Control equipment and terminals should be located above the operating floor line of the machine to provide safe and ready access.

E8.1.3 Control equipment shall be so mounted and located that it will not interfere with machine adjustments or maintenance.

E8.1.4 Pipe lines, tubing or devices for handling air, gases or liquids shall not be located in electrical control enclosures or compartments.

E8.1.5 Terminal blocks shall be mounted to provide unobstructed access to the terminals and their conductors. The blocks shall not be mounted above each other in a plane perpendicular to the panel.

**E8.1.6* Terminal blocks for power circuits shall be grouped separately from control circuits.

E8.2 Control Panels.

**E8.2.1* Control devices, normally panel-mounted for any one machine, should be mounted in one enclosure or compartment; where more than one enclosure is required, they should be grouped together.

E8.2.2 Starters, contactors and other control devices shall be front-mounted on a rigid metal panel so that the complete panel can be removed through the enclosure opening. Such panel shall be a minimum of 0.106 inch, nominal (MSG No. 12) for mounting devices with screws ¼ inch or smaller. Additional reinforcement or heavier gage panels shall be provided where larger screws are required. All mounting screws shall have the Unified form of thread. Equipment shall be mounted so that any component can be replaced without removing the panel. No components shall be mounted behind door pillars unless adequate space is provided for replacement and servicing.

**E8.2.3* Control equipment should not be mounted on the door or sides of the enclosure except for such devices as pushbuttons, selector switches and pilot lights. Such devices should be wired from terminal strips on the control panel.

E8.2.4 Swing-out panels located between the enclosure or compartment door and the control panel shall not be used.

Exception: Electronic panels may be of the swing-out or sliding type for servicing.

**E8.2.5* Panel-mounted control components, such as relays, should be mounted in numerical order from left to right and top to bottom corresponding to the panel layout. Starters and contactors should be mounted in a similar manner.

E8.2.6 Any device(s) mounted on the control panel, carrying line voltage or a combination of line voltage and control voltage, shall be grouped above or to the side and segregated from devices which carry only the control voltage. This does not apply where the line voltage is 115 volts. In no case shall any device be mounted directly above the disconnecting means.

**E8.2.7* Spare terminals shall be provided on each control panel.

E8.2.8 Where required for maintenance, space shall be provided adjacent to all devices mounted on the control panel.

E8.3 Control Panel Enclosure.

E8.3.1 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.

E8.3.2 The panel shall not be set to such depth from door frame or other projecting portion of the equipment as to interfere with inspection and servicing.

E8.3.3 No portion of the equipment immediately above the door opening and less than six feet from the floor should project more than six inches beyond the door frame.

E8.4 Clearances in Enclosures.

E8.4.1 Enclosures or compartments for mounting control panels shall provide ample room between the panel and the enclosure for proper maintenance and wiring to terminals.

E8.4.2 Exposed, non-arcing, current-carrying parts within an enclosure or compartment shall have an air space between them and the uninsulated walls of the enclosure or compartment, other than the device-mounting plate or panel, including conduit fittings, of not less than one-half inch for 250 volts or less, and not less than one inch for voltages between 250 and 600 volts.

E8.4.3 Where barriers between metal enclosures or compartments and arcing parts of control are required, they shall be of flame-retardant insulating materials which will not readily carbonize.

E8.5 Miscellaneous Control Equipment.

E8.5.1 Limit switches or position-sensors and their associated actuators shall be installed so that accidental overtravel will not damage them.

E8.5.2 Limit switch actuators shall be designed and applied in accordance with the switch manufacturer's specifications for travel, fly-back and other related characteristics.

E8.5.3 Solenoids shall be accessible and shall not be submerged in oil.

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

E8.5.4 Solenoids for operating devices shall be mounted so that liquids will drain away from the enclosure.

E8.5.5 Devices with a rotating member shall be mounted so as to prevent rotation of the stationary member.

E8.5.6 Plug-in devices and assemblies should be mechanically secured. Automatic locking upon full insertion is preferred.

E8.5.7 Female threaded fasteners, providing at least two full threads engagement, may be used to mount devices on readily removable sub-assemblies.

***E8.5.8* It is recommended that resistors and capacitors, except the disc types, exceeding $\frac{3}{8}$ inch in diameter or $1\frac{1}{2}$ inches in length be secured by means other than the connecting leads.

E9. Operator's Control Stations and Devices

E9.1 Device Requirements.

E9.1.1 Pushbutton operators, selector switch operators and indicating lights shall be of the oil-tight type.

E9.1.2 Pushbutton operators shall retain their color identification throughout their life. The color code for pushbuttons shall be as shown in Table 9-1.

E9.1.3 Emergency pushbutton operators shall be of the palm or mushroom type.

E9.1.4 Palm or mushroom type buttons shall not be used in start circuits, unless two or more are connected in series.

E9.1.5 "START" button operators shall be of the fully-guarded type.

E9.1.6 The color code for pilot lights shall be as shown in Table 9-2.

E9.2 Fixed Stations.

E9.2.1 Fixed control stations shall be dust, moisture and oil-tight, complete with metal enclosure and cover.

**E9.2.2* Pushbutton and pilot-light enclosures with 12 or more units should be equipped with hinged covers.

**E9.2.3* Where more than 16 units are required, terminal strips should be furnished in the enclosure.

E9.3 Control Station Component Arrangement.

E9.3.1 "START" buttons shall be mounted above or to the left of their associated "STOP" buttons

Exception: This requirement does not apply to "START" buttons in series.

E9.3.2 A legend (name) plate shall be provided for each control station component to identify its function and located so that it can be read easily by the equipment operator from his normal work position. Markings on the plate shall be permanent, such as by embossing or engraving.

E9.4 Control Station Location.

E9.4.1 Control stations shall be mounted in a reasonably clean and dry location.

E9.4.2 Control stations shall be located within easy reach of the equipment operator and placed so that the operator does not have to reach past spindles or other moving parts.

E9.4.3 Controls shall be free from possibility of accidental operation either by normal movement of the equipment or the operator.

**E9.4.4* Pushbuttons should be mounted on a surface which is not less than 45 degrees from the horizontal plane.

E9.4.5 Pipe lines, tubing or devices for handling air, gases, or liquids shall not be located in control stations.

E9.5 Pendant Stations.

E9.5.1 Pendant stations shall be oil-tight.

E9.5.2 A wobble stick or rod operator at the bottom of the station may be used for "EMERGENCY STOP" control.

E9.5.3 Pendant pushbutton stations shall be supported by suitable means other than the flexible electrical conduit or multiconductor cable.

E9.5.4 For grounding requirements, see E15.3.

E10. Electrical Accessories

E10.1 Plugs and Receptacles.

E10.1.1 Plugs and receptacles shall be approved for the voltage applied and conform to all of the following:

(1) A locking feature to prevent accidental disconnection,

(2) A skirt or shroud that will contain any arc and will protect the poles when not in use,

(3) A grommet around the cord which will prevent entrance of contaminants, and

Table 9-1—Pushbutton Color Code

Color	Typical Function	Example
Red	Stop, Emergency Stop	Stop of one or more motors; master stop.
Yellow	Return, Emergency Return	Return of machine elements to start position.
Black	Start Motors, Cycle, etc. Any operation for which no other color is specified	Start of one or more motors; start cycle or partial sequence.

Table 9-2—Pilot Light Lens Color Code

Color	Typical Function	Example
Red	Danger, Abnormal Condition, Fault Condition	Voltage applied; cycle in automatic; faults in air, water, lubricating or filtering systems; ground detector circuits.
Amber (Yellow)	Attention	Motors running; machine in cycle; unit or head in forward position.
Green	Safe Condition (Security)	End of cycle; unit or head returned; motors stopped; motion stopped; contactors open.
White or Clear	Normal Condition	Normal pressure of air, water, lubrication.

(4) Means which effectively seal the receptacle whenever the plug is removed.

Exception: Items (3) and (4) above do not apply to sub-assemblies mounted within the control enclosure.

E10.1.2 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 plug have been disconnected.

E10.1.3 The grounding pole of both plugs and receptacles shall only be used for grounding purposes and not as a normal current-carrying pole.

E10.2 Work Lights.

E10.2.1 The lighting circuit voltage shall not exceed 150 volts between conductors.

E10.2.2 Work lights, where furnished, shall be supplied from one of the following sources:

(1) A separate isolating transformer connected to the load side of the equipment disconnecting means. Overcurrent protection shall be provided in the secondary circuit.
(2) The 115 volt control circuit, with separate overcurrent protection for the lighting circuit. This system may be used only with a grounded control circuit.
(3) The plant lighting circuit.
(4) The line side of the main disconnecting means where a separate primary disconnecting means, isolating transformer and secondary overcurrent protection are furnished in a NEMA Type 1 enclosure and mounted within the control enclosure, adjacent to the main disconnecting means.

E10.2.3 The conductors to stationary or built-in lights shall conform to E11, Conductors. The conductors within fixtures shall be not smaller than AWG No. 18.

E10.2.4 Flexible cords shall be all thermoplastic, Type STO.

E10.2.5 For grounding requirements, see E15.2.

E10.2.6 Incandescent lampholders shall be of the medium-base, screw-shell type and rated 660 watts, 250 volts.

E10.2.7 Lampholders shall not incorporate a switch or receptacle.

E10.2.8 Stroboscopic effects from lights shall be avoided.

E11. Conductors

E11.1 Specifications.

E11.1.1 Conductors (other than those specified in E11.2 and E11.4) shall conform to one of the following:

(1) Type MTW.
(2) Types THWN or THHN having all characteristics equal to Type MTW, except insulation thickness.
(3) Multiconductor, all thermoplastic cable, Type STO.
(4) Multiconductor control cable having individual conductors of Type MTW, THWN, or THHN construction and a jacket similar to Type STO construction.
(5) Mineral-insulated metal-sheathed cable, Type MI.

E11.1.2 Conductors shall be no smaller than:

(1) Power circuits, No. 14 AWG.
*(2) Lighting and control circuits in raceways and on the equipment, No. 16 AWG.

Exception: No. 18 AWG may be used in jacketed multiconductor cables.

(3) Control circuits on panel and within the operator's control station, No. 16 AWG.
*(4) Wiring for electronic, static and precision devices. (See E11.4)

E11.1.3 Conductors shall be annealed stranded copper, conforming to the requirements of ASTM Standard B8, Class C for non-flexing service and B174 Class K for flexing service. Table 11-1 shows minimum stranding for single conductors.

Exception: Stranding for MTW conductors in sizes 1 AWG through 4/0 AWG inclusive may be 19 strand, and 37 strand for sizes 250 MCM through 500 MCM inclusive.

E11.1.4 Conductors in multiconductor cable shall meet the requirements in E11.1.3.

Exception: Stranding shall be for constant flexing service as shown in Table 11-2.

E11.1.5 The insulation on the conductor shall have a readily identifiable continuous marking to indicate: National Electrical Code Type, voltage, size, temperature rating and manufacturer. In no case shall any part of the identification be obtained by the use of fibrous material.

E11.1.6 Metal-clad cable shall not be used.

Table 11-1—Single Conductor Stranding

Conductor Size, AWG or MCM	Stranding		Conductor Size, AWG or MCM	Stranding	
	Class C	Class K		Class C	Class K
22	19	†	2	19	
20	19	†	1	37	
18	19	†	0	37	
16	19	26	2/0	37	
14	19	41	3/0	37	
12	19	65	4/0	37	
10	19	104	250	61	
8	19		300	61	
6	19		350	61	
4	19		400	61	
3	19		500	61	

†Use Class C Stranding.

Table 11-2—Multiconductor Cable Stranding (Constant Flexing Service)

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

Table 11-3—Conductor Ampacity

Conductor Size, AWG or MCM	Rating in Amperes		
	In Control Enclosure	In Conduit or Wireway	
	Power and Control	Control	Power
22	3	—	—
20	5	—	—
18	6	—	—
16	8	8	—
14	12	12	11
12	16	16	14
10	24	24	21
8	32	32	28
6	45	45	39
4	57	57	49
3	65	65	56
2	77	77	67
1	90	90	77
0	102	102	88
2/0	119	119	102
3/0	135	135	116
4/0	160	160	138
250	177	—	151
300	196	—	168
350	213	—	182
400	229	—	196
500	262	—	224
750	327	—	280
1000	373	—	319

*E11.2 Special Insulations. Where required by ambient conditions, other conductor insulating material should be used.

E11.3 Conductor Ampacity.

E11.3.1 The allowable ampacity of conductors in raceways containing more than six conductors with ambient temperature not greater than 40 C (104 F), and conductors not close to heat dissipating components, shall not exceed the limits specified in Table 11-3. These ampacities are based on the number of conductors in raceways according to Table 13-1. For raceways containing less than six conductors, refer to NFPA 79, Table 200-A, for conductor ampacity.

E11.3.2 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.

E11.4 Electronic, Precision, Static and Similar Control.

E11.4.1 Conductors used to connect electronic, precision, static or similar devices or panels shall conform to the following:

(1) Conductor insulation shall be water and oil resistant, flame retardant material with an operating temperature rating of 90 C in dry locations. Special insulations suitable for higher temperatures shall be used where necessary. Conductor insulation shall be adequate for the voltage on that conductor.

(2) Where the conductors are run with or adjacent to other conductors, all conductors shall be insulated for the maximum voltage involved. In no case shall insulation rated less than 300 volts be used.

Exception: Bare conductors (such as resistor and capacitor leads, "jumpers" between adjacent terminals, etc.) may be used if the method of securing insures adequate electrical clearance.

**(3) Stranded, tinned copper conductors shall be used.

Exception: Solid copper wire may be used for short "jumpers" and special connection techniques. (See E12.1.6)

**(4) Shielded cable, single or multiple conductor, shall consist of stranded copper not smaller than No. 25 AWG for a single conductor used in sub-assemblies and not smaller than No. 22 AWG for all other uses. The conductor or conductors shall have insulation in accordance with (1) and (2) above, a metallic shield, and an oil- and moisture-resistant covering such as vinyl plastic.

**(5) Special conductors, such as RG-/U transmission-line cable and twin-lead, may be used where necessary for proper functioning of equipment.

***E11.4.2* Size of Conductors.

E11.4.2.1 Conductors in machine raceways shall be not smaller than No. 16 AWG.

Exception: In a jacketed, multiconductor cable assembly, No. 22 AWG or larger conductors may be used.

E11.4.2.2 Conductors not in machine raceways shall be not smaller than No. 22 AWG.

**E11.5 Printed Circuits. Printed circuit board construction shall conform to Electronic Industries Association (EIA) Standard RS-281, Construction Standards—Numerical Machine Tool Control.

E12. Wiring Methods and Practices

E12.1 General Requirements.

E12.1.1 Conductors shall be color-coded as follows:

(1) Black—Line, load and control circuits at line voltage, AC or DC.

(2) Red—AC control circuits.

(3) Blue—DC control circuits.

(4) Yellow—Interlock control circuits wired from an external power source.

(5) Green (with or without a yellow stripe)—Equipment grounding conductors.

(6) 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: Equipment for use outside the United States where the above color code is not in agreement with established electrical codes.

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

E12.1.2 Conductors shall be identified at each termination by marking with a number to correspond with the diagram(s).

E12.1.3 Identification tags shall be made of oil-resistant material. If wrap-type adhesive strips are used, they shall be a minimum of 1½ inches long. Sleeve-type tags shall be undersized so that they will not slip off the conductor if the conductor is removed from its termination point.

E12.1.4 Terminals on terminal blocks shall be plainly and permanently marked to correspond with the identification shown on the electrical diagram(s).

**E12.1.5* Terminals on terminal blocks should be numbered in ascending order, starting from top to bottom, or from left to right.

E12.1.6 There shall be no exposed terminals external to control enclosures, compartments and junction boxes.

E12.1.7 Conductors and cables shall be run without splices from terminal to terminal.

*Exception: Splices may be made to leads attached to electrical devices, such as motors and solenoids, and shall be insulated with oil-resistant electrical tape.

E12.1.8 Taped connections shall be covered with oil-resistant adhesive tape which will not support combustion and conforms to Military Specification MIL-I-7798A.

E12.1.9 Terminal blocks shall be wired and mounted so that internal and external wiring does not cross over the terminals. Not more than two conductors shall be terminated at each terminal connection.

E12.2 Electrical Connections.

**E12.2.1* Electrical connections to motors, solenoids and similar devices with integral leads, size No. 4 AWG and smaller, shall be made with ring-type pressure connectors. The connectors shall be bolted and taped. Soldered or insulation-piercing type connectors (lugs) are not acceptable.

**E12.2.2* Pressure connectors shall be used to connect conductors to devices with lug-type terminals which are not equipped with saddle straps or equivalent means of retaining conductor strands.

Exception No. 1: Soldered connections may be used within the protective shell of a plug or receptacle and for internal connections of a sub-assembly which can be removed for bench service. (See E12.2.3)

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

***E12.2.3* Soldered connections shall conform to the following:

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

(2) Where printed circuit boards or other component

assemblies are dip or wave soldered, special fluxes may be used following techniques developed specifically for these methods of fabrication.

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

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

(5) Insulation shall not be damaged by soldering.

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

****E12.2.4** Shielded conductors shall be carefully terminated to prevent fraying of strands and to permit easy disconnection.

E12.3 Panel Wiring.

E12.3.1 Panel wiring shall be contained in panel wireways, unless the total number of starters, relays and timers is less than six. Where wireways are not used, conductors shall be bundled to keep them in place.

E12.3.2 The number of conductors in panel wireways shall not exceed the values listed in Table 12-1.

E12.3.3 The panel wireway material shall not support combustion. It shall be made of non-warping, insulating material rated for the highest voltage applied to any conductor contained. The wireway shall not contain exposed metal parts, except for the mounting screws where used.

***E12.3.4** Control panels shall be equipped with terminal blocks or attachment plugs and receptacles for all external wiring requiring No. 4 AWG and smaller conductors. Conductors larger than No. 4 AWG may be terminated directly on the device.

Exception: This does not apply to supply line conductors. (See E3.7)

E12.4 Equipment Wiring.

E12.4.1 Conductors and their connections external to the control panel enclosure shall be totally enclosed in suitable metal raceways or enclosures as described in E13, except as otherwise permitted in this section.

***E12.4.2** Multiconductor cable or liquid-tight metallic or non-metallic flexible conduit may be used for flexible connections to pendant pushbutton stations.

***E12.4.3** Multiconductor cable, secured at each end with an oil-tight connector, or liquid-tight flexible conduit may be used for connections to stationary or infrequently moved devices, such as limit switches and solenoids, operated at control voltage. The exposed length of cable or flexible conduit between connectors shall not exceed three feet. Minimum wire size of cable shall be No. 16 AWG.

E12.4.4 Liquid-tight flexible metal conduit and fittings shall enclose conductors to stationary or infrequently moved devices, such as motors, brakes and other apparatus, operated at line voltage. The length shall not exceed three feet.

E12.4.5 Connections to continuously moving parts shall be made with extra flexible conductors (Class K in Table 11-1) encased in liquid-tight flexible metal or non-metallic conduit not exceeding 1½ inches trade size, or with extra flexible multiconductor cable (See Table 11-2). Flexible cable and conduit shall have vertical connections and shall have sufficient slack to avoid sharp flexing and straining.

Exception: Horizontal connections may be used if the flexible cable or conduit is adequately supported.

E12.4.6 The installation of flexible conduit and cable shall be such that liquids drain away from the fittings.

E12.4.7 Where liquid-tight flexible metal conduit is used for flexing applications, fittings shall include basket weave or equivalent grips.

E12.4.8 Where there is relative motion between flexible conduit or cable and parts in process or equipment components, the construction and supporting means shall be such that there will be a clearance of at least one inch under all operating conditions. Barriers or guides shall be provided where the clearance cannot be maintained.

E12.4.9 Where practicable, conductors of any circuit shall be contained in the same raceway.

E12.4.10 Conductors connected in AC circuits and conductors connected in DC circuits may occupy the same raceway, regardless of voltage, provided they are all insulated for the maximum voltage on any conductor in the raceway.

E12.4.11 Where equipment must be removed and electrical circuits broken, plugs and receptacles may be used, provided they are polarized and of the grounding type. The male plug shall be connected to the load circuit. Power and control circuits shall not be carried in the same plug.

***E12.4.12** 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.

E12.4.13 Sharp edges, burrs, rough surfaces or threads, with which the insulation of the conductors may come in contact, shall be removed from conduit fittings, raceways or any other parts. Where necessary, additional protection consisting of a flame-retardant, oil-resistant, insulating material shall be provided to protect conductor insulation.

***E12.4.14** Wiring external to the control panel shall have a termination at the terminal blocks on the control panel, in master terminal boxes on the equipment, or both. One wire shall be returned, for test purposes, from a connection between limit switches, pushbuttons or other devices connected in series. The common side of the con-

Table 12-1—Number of Conductors in Panel Wireways†

Wireway Size, Inches	No. 14 AWG Conductors			No. 16 AWG Conductors	
	MTW 3/64 in. insulation; Maximum no.	MTW 2/64 in. insulation; Maximum no.	THWN, THHN Maximum OD 0.110 in; Maximum no.	MTW 2/64 in. insulation; Maximum no.	THWN, THHN Maximum OD 0.100 in; Maximum no.
1 × 1	20	30	53	38	64
1 × 2	40	59	105	76	127
1 × 3	60	89	158	113	191
1½ × 2	60	89	158	113	191
2 × 2	80	118	210	152	254
1½ × 3	90	133	236	170	286
2 × 3	120	178	316	226	381
2½ × 3	150	222	394	283	477
3 × 3	180	266	473	340	572

Table 12-1 is based on 50 percent of area fill of wireway using stranded conductors.

†When conductors other than No. 14 or 16 AWG are used, determine equivalent number of No. 14 conductors by multiplying number of conductors of sizes other than No. 14 or 16 by "conductor equivalent" from Tables 13-2 and 13-3. Add the result to the number of No. 14 conductors and use total for selecting size of wireway from Table 12-1.

Table 13-1—Number of Conductors in Conduit and External Wireways†

Conduit-C or Wireway-W, Size, Inches	No. 14 AWG Conductors		
	MTW 3/64 in. Insulation, Maximum no.	MTW 2/64 in. Insulation, Maximum no.	THWN, THHN Maximum OD 0.110 in. Maximum no.
½-C	5	7	12
¾-C	9	13	22
1-C	14	20	36
1¼-C	24	35	63
1½-C	33	48	85
2-C	54	79	141
2½-C	77	113	201
3-C	120	174	310
3 × 3-W	144	210	374
3½-C	160	230	416
4-C	200	300	535
4 × 4-W	260	375	694
5-C	320	470	842
5 × 5-W	400	585	1050
6-C	465	680	1215
6 × 6-W	580	850	1500

Table 13-1 is based on 40 percent of area fill of raceway using stranded conductors.
†When conductors other than No. 14 AWG are used, determine equivalent number of No. 14 conductors by multiplying number of conductors of sizes other than No. 14 by "conductor equivalent" from Tables 13-2 and 13-3. Add the result to the number of No. 14 conductors and use total for selecting size of conduit or wireway from Table 13-1.

Table 13-2—MTW Conductor Equivalents

Conductor Size, AWG	Insulation Thickness, 64th inches	Maximum OD, Inches	Equivalent No. 14 AWG ¾ inch Insulation Conductors
16	2	0.130	0.53
14	2	0.147	0.68
14	3	0.178	1.0
12	2	0.166	0.87
12	3	0.197	1.2
10	2	0.190	1.15
10	3	0.221	1.5
8	3	0.252	2.0
8	4	0.283	2.5
6	4	0.321	3.3
4	4	0.370	4.3
3	4	0.402	5.1
2	4	0.432	5.9
1	5	0.513	8.3
0	5	0.546	9.4
00	5	0.593	11.0
000	5	0.645	13.0
0000	5	0.702	16.0

For conductors 250 MCM and larger, use actual area of conductors and calculate conduit size on basis of 40 percent conduit area fill.

Table 13-3—THWN and THHN Conductor Equivalents

Conductor Size, AWG	Maximum OD, Inches	Equivalent No. 14 AWG THWN, THHN Conductor	Equivalent No. 14 AWG ¾ inch Insulation MTW Conductors
16	0.100	0.83	0.31
14	0.110	1.0	0.38
12	0.130	1.39	0.53
10	0.170	2.39	0.91
8	0.220	4.0	1.52
6	0.257	5.5	2.1
4	0.328	8.9	3.4
3	0.356	10.5	4.0
2	0.388	12.6	4.8
1	0.452	17.0	6.5
0	0.492	20.2	7.7
00	0.541	24.1	9.2
000	0.590	28.6	10.9
0000	0.647	34.6	13.2

For conductors 250 MCM and larger, use actual area of conductors and calculate conduit size on basis of 40 percent conduit area fill.

trol circuit shall be wired to a terminal in master terminal boxes.

**E12.4.15* Where specified, a raceway complete with conductors shall be furnished between a separately-mounted control enclosure and terminal boxes mounted on the equipment. Exterior wireways (not conduit) complete with conductors shall be furnished when the number of conductors required exceeds that for which three-inch conduit is suitable. In either case, terminal boxes should be furnished for terminating conductors from the control enclosure.

E13. Raceways, Fittings and Boxes

E13.1 General Requirements.

E13.1.1 Minimum Conduit Size. No conduit, rigid or flexible, smaller than ½ inch diameter trade size shall be used.

E13.1.2 Grounding. See E15 for acceptable means of grounding.

E13.1.3 Type of Fittings. Fittings used with raceways and multiconductor cables shall be liquid-tight.

E13.1.4 Accessibility of Covers. Covers shall be readily accessible.

E13.1.5 Gaskets. Gaskets shall conform to E17.

E13.1.6 Number of Conductors. The number of conductors in conduit and wireways shall not exceed the quantity listed in Table 13-1.

***E13.1.7* Entrance Locations. It is recommended that entrances for raceways and multiconductor cables be located in the sides, back or bottom of enclosures or compartments.

E13.2 Rigid Metal Conduit and Fittings.

**E13.2.1* Corrosion Resistance. Rigid conduit and fittings shall be galvanized steel, meeting the requirements of ANS C80.1, Zinc Coated Rigid Steel Conduit, and C80.4, Fittings for Rigid Steel Conduit, or of a corrosion-resistant material suitable for the conditions. Dissimilar metals in contact which would cause galvanic action shall not be used. Conduit shall be protected against corrosion, inside and outside, except at threaded joints.

E13.2.2 Type of Fittings. Unless structural difficulties prevent, fittings shall be threaded. They shall be made of malleable or ductile iron and have impact strength comparable to that of the conduit. Covers on conduit fittings shall be gasketed.

Table 13-4—Minimum Radii of Conduit Bends

Conduit Size, Inches	Radius of Conduit Bends, Inches	Conduit Size, Inches	Radius of Conduit Bends, Inches
½	4	2½	15
¾	5	3	18
1	6	3½	21
1¼	8	4	24
1½	10	5	30
2	12	6	36

E13.2.3 Running Threads. Running threads shall not be used on conduit.

E13.2.4 Conduit Support. All conduit shall be securely held in place and supported at each end. Where threadless fittings must be used, due to difficulty in assembly, conduit shall be fastened to the equipment so that it cannot be accidentally pulled apart.

E13.2.5 Size of Bends. Bends of rigid conduit shall be made so that the conduit will not be damaged and 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 13-4.

E13.2.6 Number of Bends. A run of conduit shall not contain more than the equivalent of four quarter-bends (360 degrees total).

E13.2.7 Use of Locknuts, Bushings and Seals.

*E13.2.7.1 Where conduit terminates in a threadless

Table 13-5—Liquid-Tight Flexible Non-Metallic Conduit Dimensions

Trade Size, Inches	Nominal Inside Diameter, Inches	Minimum 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

opening, a locknut shall be provided both inside and outside the enclosure, and the conduit end shall be equipped with an insulating bushing. A suitable oil-tight means (such as an oil-resistant synthetic rubber O-ring and a metal cup) shall be provided between the outside locknut and opening. When the conduit enters the opening through a conduit connector, the shoulder of the connector may serve as the outside locknut. The O-ring assembly or an equivalent sealing device should also be furnished when a locknut is used as a jam nut on connectors fitted to threaded hubs.

E13.2.7.2 When the conduit enters the opening through a conduit connector equipped with a tapered surface or similar sealing action, no locknuts or gaskets are required, providing the resulting seal is liquid-tight.

E13.3 Liquid-Tight Flexible Conduit and Fittings. Flexible conduit shall be installed in a manner that liquids will tend to run off the surface instead of draining toward the fittings.

E13.3.1 Metallic Conduit. Liquid-tight flexible metal conduit shall consist of an oil-resistant, liquid-tight jacket or lining in combination with flexible metal reinforcing tubing.

E13.3.2 Non-Metallic Conduit.

E13.3.2.1 Liquid-tight flexible non-metallic 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.

E13.3.2.2 The conduit shall be resistant to kinking and shall have physical characteristics comparable to the jacket of multiconductor cable.

E13.3.2.3 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.

E13.3.2.4 The conduit shall have dimensions as near as practicable to the limits given in Table 13-5.

E13.3.3 Standards for Fittings. Connectors for liquid-tight flexible metal and non-metallic conduit shall be liquid-tight, made of metal, designed to electrical trade sizes and meet the requirements of Underwriters' Laboratories Standard UL 514. Fittings shall have sufficient thread length to accommodate a gasket assembly, a box wall thickness of 0.125 inch and a locknut and bushing.

E13.4 Compartments and Raceways.

E13.4.1 Description. Raceways, junction boxes and wiring should be external to the base or column of the equipment. However, compartments and raceways within the column or base may be used to enclose conductors, provided they are isolated from coolants and oil reservoirs and are enclosed except as noted in E13.4.2. Conductors shall be protected from mechanical damage and abrasion. General purpose flexible conduit may be used as additional protection in compartments and raceways if fastened at each end.

E13.4.2 Drainage of Raceways. Raceways integral with equipment bases or columns shall be arranged to drain to convenient points. Openings of ¼ inch diameter shall be provided at such points to permit drainage.

E13.4.3 Compartment Door Hinges. Compartment doors exceeding 150 square inches should be hinged.

E13.5 Junction, Pull and Terminal Boxes. Boxes shall be readily accessible.

**E13.5.1* Construction. Junction, pull and terminal boxes shall not have knockouts and shall be provided with gasketed covers. Boxes shall be oil-tight. Mounting means external to the box shall be provided. Covers not hinged shall be captive to the box.

E13.5.2 Motor Junction (Conduit) Boxes. Motor junction (conduit) boxes shall not be used for wiring to solenoid valves, limit switches and other control devices.

Exception No. 1: Leads from separately mounted motor brakes may be connected in the box if the brake is connected directly to the motor terminal leads and has no other connections.

Exception No. 2: Connections for motor-mounted devices, such as brakes, thermostats, plugging switches or tachometer generators, may be connected in the motor junction (conduit) box.

E13.6 Wireways. Exterior wireways may be used when rigidly supported and clear of all operating or contaminating portions of the equipment and shall conform to the following:

(1) Wireways shall be oil-tight.
(2) Metal thickness shall be a minimum of 0.075 inch (No. 14 MSG gage).
(3) Covers on wireways shall be hinged, shaped to overlap the sides and held closed by captive screws or other suitable fasteners exterior to the wireways. Gaskets for covers and section joints shall conform to E17. For sections mounted horizontally the covers shall be on top.
(4) Wireways with knockouts are not acceptable. Only such openings as are required for wiring the equipment shall be provided.
(5) Corners, bends, edges, etc., shall have all burrs removed. Additional protection shall be provided to protect conductor insulation at all sharp bends and drop points. Such protection may consist of fibre, plastic or other material to cover the edge or corner with sufficient radius to prevent damage to the insulation.
(6) Conductor fill shall not exceed 40 percent of the wireway cross-sectional area.

E14. Motors

E14.1 Standards. Except as noted in this standard, motors shall meet the requirements of the following:

(1) ANS C6.1, Terminal Markings for Electrical Apparatus.
(2) ANS C50, Rotating Electrical Machinery.
(3) NEMA Standard MG-1, Motors and Generators.

***E14.1.1* Other rotating equipment (e.g., tachometers, synchros, resolvers, etc.) used with electronic, precision, static or similar devices, and which do not come within the scope of the above standards, shall be of the current acceptable quality for the application.

E14.2 Type of Motor.

**E14.2.1* The type of motor enclosure to be used shall be determined by the machine-tool builder, unless otherwise specified.

E14.2.2 Integral-horsepower AC motors, NEMA Frame 445 or smaller, but not exceeding 100 horsepower, 1800 rpm, shall be dual voltage. Motor voltage ratings shall be as specified by purchaser.

Exception: Multi-speed motors may be single voltage.

E14.3 Mounting of Motors.

E14.3.1 Each motor shall be mounted where it is readily accessible for maintenance and not subject to damage. All motor-driven couplings, belts and chains shall be easily replaceable.

E14.3.2 The motor mounting arrangement shall be such that all motor hold-down bolts can be removed

easily and replaced and junction (conduit) boxes shall be readily accessible.

E14.3.3 Motor compartments shall be clean and dry and adequately vented directly to the exterior of the equipment. Unless other compartments meet the requirements of the motor compartment, there shall be no openings of any kind between the motor compartment and any other compartment of the equipment. Where a conduit or pipe is run into the motor compartment from another compartment not meeting the motor compartment requirements, any clearance around the conduit or pipe shall be sealed.

E14.3.4 Direct-coupled, foot-mounted motors shall be aligned properly. Couplings shall be flexible type.

E14.3.5 Motors mounted within machine compartments or enclosures shall be provided with sufficient space for ease of lubrication, servicing and replacement. Sufficient air circulation shall be provided so that the motor, when under full-load conditions, will not exceed its rated temperature rise.

***E14.4** Direction Arrow. A permanent arrow to indicate the proper direction of rotation of each motor shall be provided. The arrow shall not be mounted on the motor.

E14.5 Special Characteristics.

E14.5.1 Special motors with static and dynamic balance and noise control shall be used only to eliminate machine trouble from these sources. In no case shall the degree of balance be less than that specified in NEMA Standard MG-1, Motors and Generators.

E14.5.2 Special characteristics of AC motors shall be shown on a separate nameplate mounted adjacent to the conventional motor nameplate. The manufacturer's catalog numbers shall not be considered sufficient to designate such characteristics. Typical examples are:

(1) Special insulation.
(2) Special shaft length.
(3) Special torque.
(4) Special balance.
(5) Special lubrication.

E15. Grounding

E15.1 Control Circuits.

**E15.1.1* Provision shall be made for grounding one side of the control circuit to the machine. The wiring diagrams shall show the location of the grounding connection with the notation: "To be grounded by user if conditions permit." It shall then be the responsibility of the user to ground the circuit if the local electrical code so requires.

E15.1.2 When a grounded control circuit is specified, the side of the circuit connected to the coils shall be permanently grounded. There shall be no contacts between solenoids and the grounded conductor (See Par. E5.3.1). Insulation on the grounded conductor shall be white and shall be connected directly to the control transformer without overcurrent protection. The grounding conductor shall be green (with or without a yellow stripe) or bare.

E15.1.3 Exposed control circuits operating at 25 volts or less shall be grounded. (See E5.2.1, Exception No. 2.)

E15.2 Lighting Circuits. One conductor of the lighting circuit fed from a separately mounted isolating transformer shall be grounded only at the transformer.

Exception: Where the lighting circuit is fed from the plant lighting circuit, the grounded conductor shall be identified by a white or natural gray colored insulation.

E15.3 Stationary Equipment. All exposed, non-current carrying metal parts of equipment, such as control enclosures, raceways, control stations, separately mounted apparatus, and portable and pendant accessories, shall be grounded. For separately mounted electrical apparatus, a bonding conductor shall be included in the wiring for bonding such apparatus to the equipment.

Table 15-1—Size of Grounding Conductors

Column "A" Amperes	Copper Wire Size, AWG	Column "A" Amperes	Copper Wire Size, AWG
20	14 or 16†	400	4
30	14	600	2
40	12	800	0
60	10	1000	00
100	8	1200	000
200	6		

†No. 16 wire will be permitted only in multiconductor cable.

Table 16-1—High Potential Test Voltages

Circuit Voltage	Test Voltage	Circuit Voltage	Test Voltage
115	1230	460	1920
230	1460	550	2100
380	1760		

E15.4 Methods of Grounding. Bonding by attaching the equipment to the machine with bolts or screws shall be considered a satisfactory ground where all paint and dirt are removed from joint surfaces. Moving machine parts, other than removable accessories or attachments, having metal-to-metal bearing surfaces shall be considered as adequately bonded. Sliding parts separated by oil or air under pressure are not considered bonded together.

E15.5 Equipment Grounding Conductors.

E15.5.1 A copper or other corrosion-resistant conductor shall be used for grounding and bonding purposes. Where a conductor other than copper is used, its electrical resistance per lineal foot shall not exceed, and its tensile strength shall not be less than that of the allowable copper conductor.

E15.5.2 Equipment grounding conductors may be insulated or bare and shall be protected from damage by means equivalent to those provided for live conductors. If an insulated equipment-grounding conductor is used, the insulation shall be green (with or without a yellow stripe).

E15.5.3 Raceways shall not be used in lieu of a grounding or bonding conductor.

E15.5.4 The size of the equipment grounding conductor shall be as shown in Table 15-1. Column "A" indicates maximum capacity in amperes of the overcurrent protective device in the circuit ahead of the equipment.

E16. Testing

E16.1 Circuit Tests. When all wiring of the electrical system is complete, the builder shall test each circuit for continuity, short circuits and fault grounds.

E16.2 Test Voltages. Wiring shall be capable of withstanding the appropriate test voltage shown in Table 16-1. See NEMA Standard IC-1, Industrial Control. Devices which do not fall within the scope of Industrial Control Standards (e.g., meters, rectifiers, lamp holders, snap switches, electronic equipment, ground detector lamps, etc.) and which require lower test voltages than specified above, should be disconnected before high-voltage tests are made.

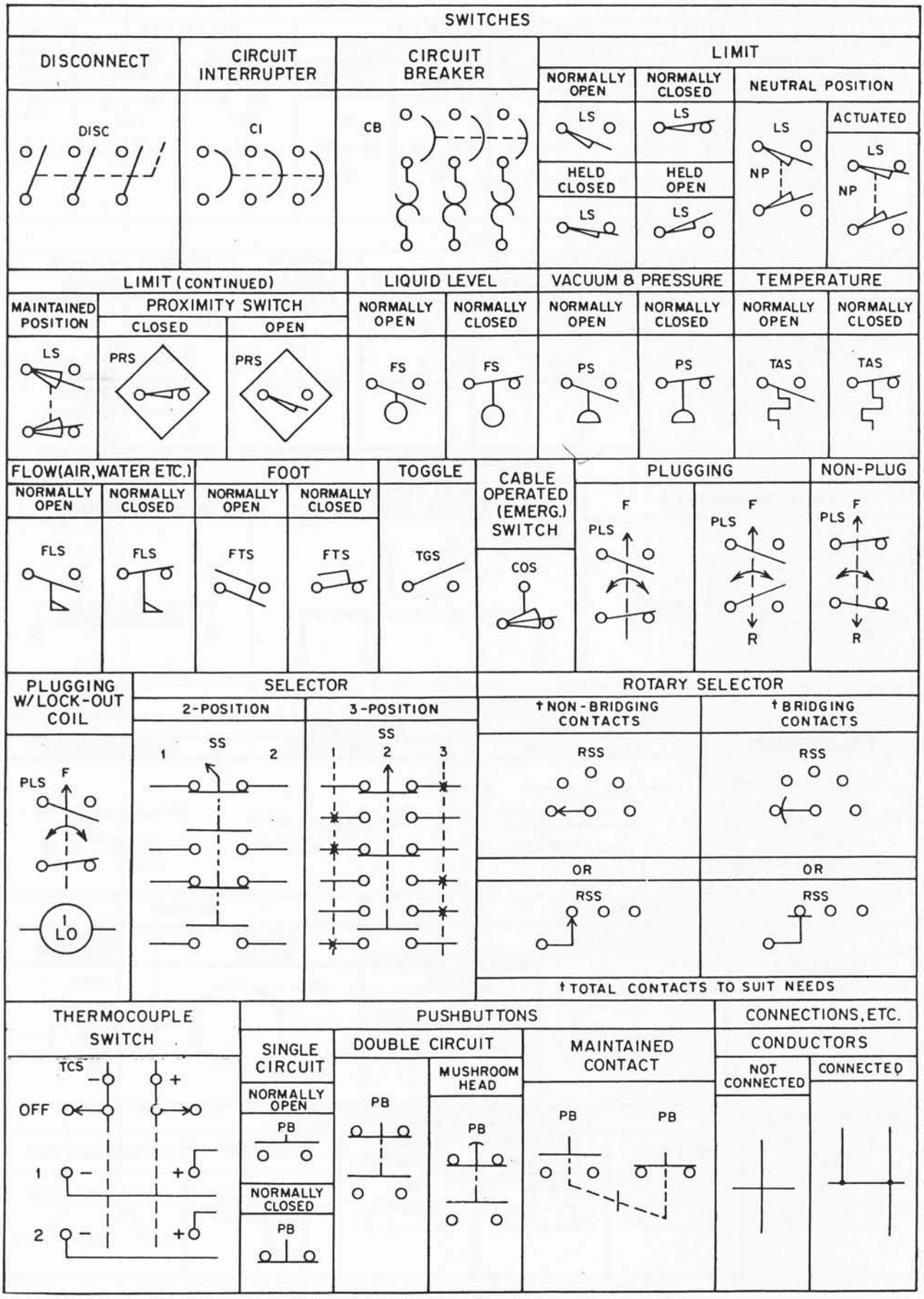
E17. Gaskets

E17.1 Materials. Gaskets shall be of an oil-resistant synthetic material.

***E17.2** Doors. Door sealing gaskets shall be at least $\frac{1}{8}$ inch thick and shall be held firmly and permanently in place.

E17.3 Covers. Cover sealing gaskets shall be at least $\frac{1}{16}$ inch thick and shall be held firmly and permanently in place.

*Appendix A—Typical Graphic Symbols for Electrical Diagrams with Basic Device Designations



(CONTINUED)

** Appendix A (continued)—Typical Graphic Symbols for Electrical Diagrams with Basic Device Designations*

CONNECTIONS, ETC. (CONT'D)			CONTACTS						
GROUND	CHASSIS OR FRAME NOT NECESSARILY GROUNDED	PLUG AND RECP.	TIME DELAY AFTER COIL				RELAY, ETC.		THERMAL OVER-LOAD
			ENERGIZED		DE-ENERGIZED		NORMALLY OPEN	NORMALLY CLOSED	
			NORMALLY OPEN	NORMALLY CLOSED	NORMALLY OPEN	NORMALLY CLOSED			
GRD	CH	PL / RECP	TR	TR	TR	TR	CR M CON	CR M CON	OL IOL

COILS						
RELAYS, TIMERS, ETC.	SOLENOIDS, BRAKES, ETC.				THERMAL OVERLOAD ELEMENT	CONTROL CIRCUIT TRANSFORMER
	GENERAL	2-POSITION HYDRAULIC	3-POSITION PNEUMATIC	2-POSITION LUBRICATION		
CR M TR CON	SOL	SOL 2-H	SOL 3-P	SOL 2-L	OL IOL	H1 H3 H2 H4 T X1 X2

COILS (CONTINUED)		
AUTO TRANSFORMER	LINEAR VARIABLE DIFFERENTIAL TRANSFORMER	VARIABLE AUTO-TRANSFORMER
AT	LVT	VAT

COILS (CONTINUED)			
SATURABLE TRANSFORMER	REACTORS		
	SATURABLE CORE	IRON CORE	SATURABLE CORE
ST	SX	X	SX

COILS (CONTINUED)			MOTORS	
REACTORS (CONTINUED)			3 PHASE MOTOR	DC MOTOR ARMATURE
ADJUSTABLE IRON CORE	AIR CORE	MAGNETIC AMPLIFIER WINDING		
X	X	MAX	MTR	MTR A

MOTORS (CONT'D)	RESISTORS, CAPACITORS, ETC.				
DC MOTOR FIELD	RESISTOR	HEATING ELEMENT	TAPPED RESISTOR	RHEOSTAT	POTENTIOMETER
FLD	RES	HTR	RES	RH	POT

(CONTINUED)

** Appendix A (continued)—Typical Graphic Symbols for Electrical Diagrams with Basic Device Designations*

RESISTORS, CAPACITORS, ETC. (CONTINUED)

CAPACITORS

FIXED	ADJUSTABLE	POLARIZED ELECTROLYTIC
CAP	CAP	CAP

METERS

VOLT	AMP
VM	AM

METER SHUNT

MSH

FUSES (ALL TYPES)

FU

RESISTORS, CAPACITORS, ETC. (CONTINUED)

PILOT LIGHTS

	PUSH-TO-TEST
LT R	LT R

LETTER DENOTES COLOR

HORN, SIREN ETC.

AH

BUZZER

ABU

BELL

ABE

THERMOC'PLE

T/C

BATTERY

BATT + −

SHIELDED CABLE

SHOW ALL CONDUCTORS INSIDE SHIELD

SHIELD

CONDUCTOR

ELECTRONIC TUBES

COLD CATHODE VOLT. REGULATOR	DIODE	TRIODE	TETRODE	PENTODE
V	V	V	V	V

● DOT IN ANY TUBE ENVELOPE DENOTES GAS

ELECTRONIC TUBES (CONTINUED)

THYRATRON	IGNITRON	PHOTOTUBE
V	V	V

NEON LIGHT

AC	DC	AC W/INT. RES.
NLT	NLT	NLT

SEMICONDUCTORS

RECTIFIER DIODE

REC D

RECTIFIER BRIDGE

REC AC + − AC

ARC SUPPRESSORS

AC	DC	AC AND DC
DAS	DAS	RCAS

LIST VALUES OF RES. AND CAP.

ZENER DIODE

DZ

(CONTINUED)

**Appendix A (continued)—Typical Graphic Symbols for Electrical Diagrams with Basic Device Designations*

SEMICONDUCTORS (CONTINUED)

TUNNEL DIODE	VARICAP DIODE	TRANSISTOR PNP	TRANSISTOR NPN	TRANSISTOR UNIJUNCTION	SILICON CONTROLLED RECTIFIER	TRANSISTOR SURFACE BARRIER
DT	DVC	Q	Q	QU	SCR	QSB

SEMICONDUCTORS (CONTINUED)

TRANSISTOR TETRODE	TRINISTOR	TRIGISTOR	BINISTOR	TRANSISTOR FIELD EFFECT	VARISTOR
QT	QTN, S	QTG	QBN	QFE	QVR

SEMICONDUCTORS (CONTINUED)

THERMISTOR	PHOTOSENSITIVE CELLS	
	ASYMMETRICAL	SYMMETRICAL
QTM, T	PSC, λ	PSC, λ

MISCELLANEOUS

TERMINAL BLOCK	SYNCHRO OR RESOLVER	TACHOMETER GENERATOR	CORE OF SQUARE LOOP MATERIAL	LOCATION OF RELAY CONTACTS
TB: 10, 11, 12, 15	SYN	TACH, TG		1CR, CLAMP (2-3-4)
	DIFFERENTIAL SYNCHRO, SYN	SYMMETRICAL NON-LINEAR RESISTOR		

NUMBERS IN PARENTHESES DESIGNATE THE LOCATION OF RELAY CONTACTS.

A LINE BENEATH A NUMBER SIGNIFIES A NORMALLY CLOSED CONTACT.

SEQUENCE CHARTS

PROGRAM OR SEQUENCE TIMER

TIMER CONTACT	RESET POSITION	TIMING (MINUTES) 1 2 3 4 5 6 7 8 9	OPERATION TIME (MINUTES) CLOSES	OPENS
1TR-1			0	2
1TR-2			3.75	7.2
1TR-3			1.9	8.5

SHADED PORTION INDICATES CONTACT CLOSED

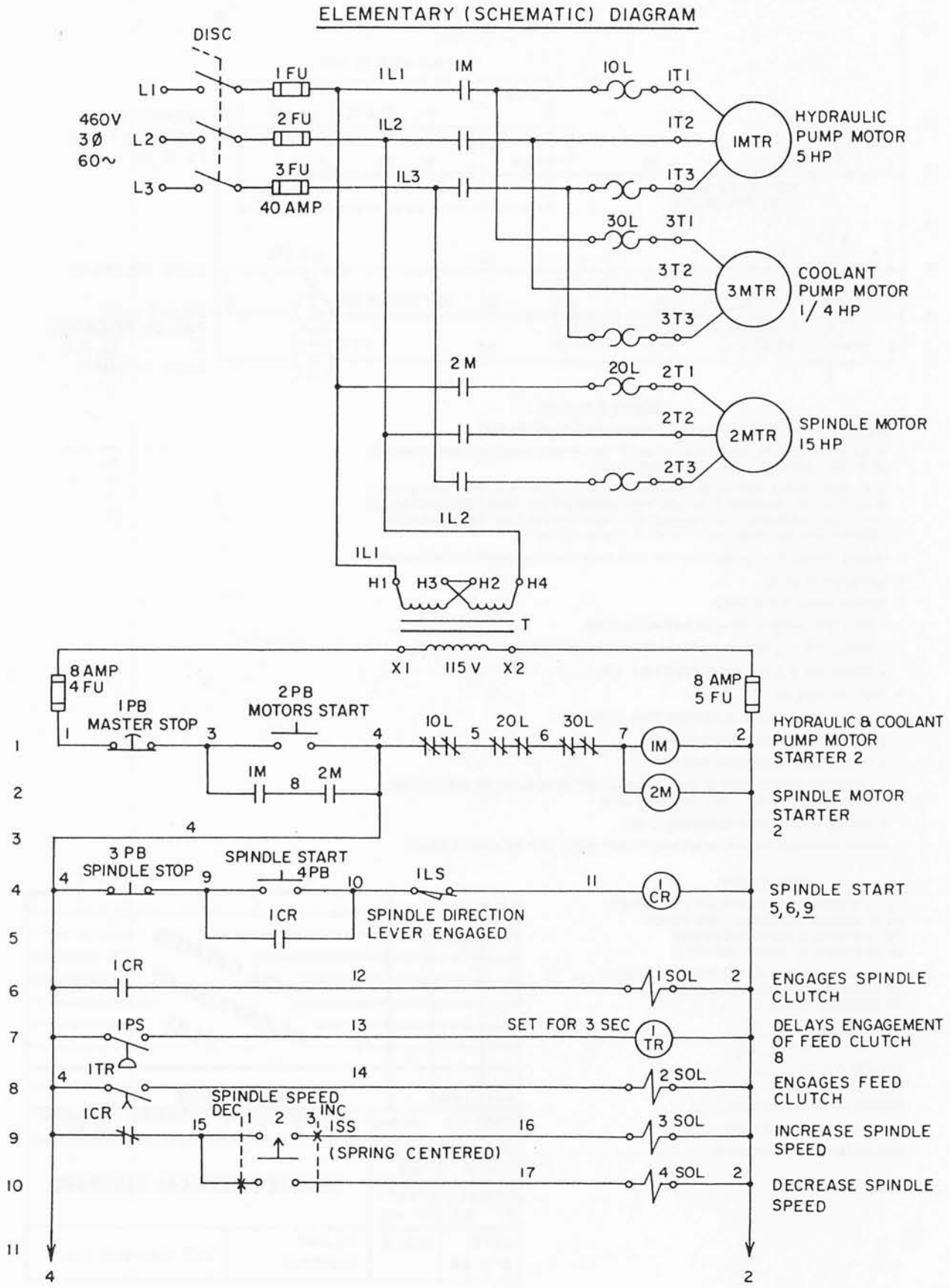
CAM SWITCH

SWITCH	DEGREES 90 180 270	DEGREES OPERATION
1CS		22° TO 180°
2CS		0° TO 194°
3CS		225° TO 360°

SHADED PORTION INDICATES CONTACT CLOSED

*Appendix B—Sample Electrical Diagrams

The drawings which follow are intended only to illustrate proper electrical drafting practices outlined in the standard. Diagram shown is for ungrounded control circuit.



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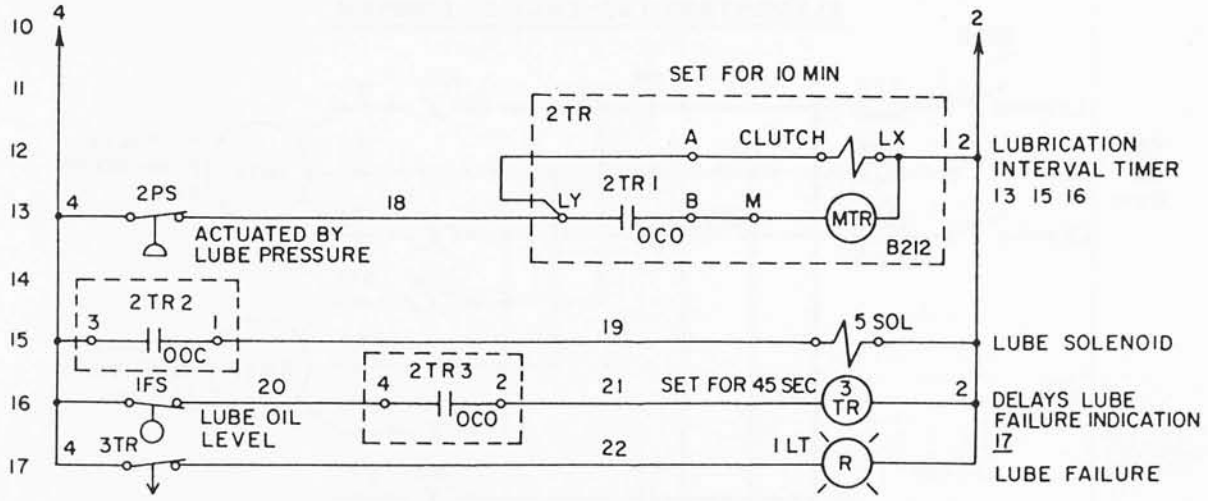
SAMPLE ELECTRICAL DIAGRAMS



SEQUENCE OF OPERATION

A. MACHINE OPERATION: PRESS "MOTORS START" PUSHBUTTON "2PB". MOTORS START.

B. SELECT SPINDLE SPEED BY TURNING SELECTOR SWITCH "1SS" TO "INC", ENERGIZING "3 SOL", TO INCREASE OR TO "DEC", ENERGIZING "4 SOL", TO DECREASE SETTING.

C. WITH CORRECT SPINDLE DIRECTION SELECTED LIMIT SWITCH "1LS" IS ACTUATED. PRESS "SPINDLE START" PUSHBUTTON "4PB" ENERGIZING RELAY "1CR" WHICH ENERGIZES "1 SOL". SPINDLE STARTS AND PRESSURE SWITCH "1PS" IS ACTUATED. "1PS" ENERGIZES "1TR" AND AFTER A TIME DELAY "2 SOL" IS ENERGIZED PERMITTING MOVEMENT OF MACHINE ELEMENTS AT SELECTED FEED RATES.

D. PRESSING "SPINDLE STOP" PUSHBUTTON "3PB" STOPS SPINDLE AND FEEDS MOVEMENTS SIMULTANEOUSLY.

E. LUBRICATION OPERATION:

F. PRESSURE SWITCH "2PS" IS CLOSED.

1. TIMER "2TR" CLUTCH IS ENERGIZED WHEN MOTORS START.
2. CONTACT "2TR-1" CLOSES AND ENERGIZES TIMER MOTOR "MTR" STARTING LUBE TIMING PERIOD.
3. CONTACT "2TR-3" CLOSES AND ENERGIZES TIMER "3TR".

G. TIMER "2TR" TIMES OUT.

1. CONTACT "2TR-1" OPENS, DE-ENERGIZING TIMER MOTOR "MTR".
2. CONTACT "2TR-2" CLOSES, ENERGIZING "5 SOL".
3. CONTACT "2TR-3" DE-ENERGIZING TIMER "3TR".
4. LUBRICATION PRESSURE ACTUATES PRESSURE SWITCH "2PS", DE-ENERGIZING AND RESETTING TIMER "2TR". CONTACTS "2TR-1", "2TR-2" AND "2TR-3" OPEN.
5. CONTACT "2TR-2" OPENING, DE-ENERGIZES "5 SOL".

H. REDUCED LUBRICATION PRESSURE DE-ACTUATES PRESSURE SWITCH "2PS" AND SEQUENCE REPEATS.

SWITCH OPERATION

1LS (4) ACTUATED BY SPINDLE DIRECTION LEVER ENGAGED
1PS (11) OPERATED WHEN SPINDLE CLUTCH ENGAGED
2PS (13) OPERATED BY NORMAL LUBE PRESSURE
1FS (16) OPERATED BY ADEQUATE LUBE SUPPLY

FOR PANELS AND CONTROL STATION LAYOUT SEE SHEET 2
FOR HYDRAULIC DIAGRAM SEE _____
FOR LUBRICATION DIAGRAM SEE _____

LAST WIRE NUMBER USED 22
LAST RELAY NUMBER USED 1CR

SUPPLIER'S DWG. NO. _____
SUPPLIER'S NAME _____

PURCHASE ORDER NO. P.O. 91011

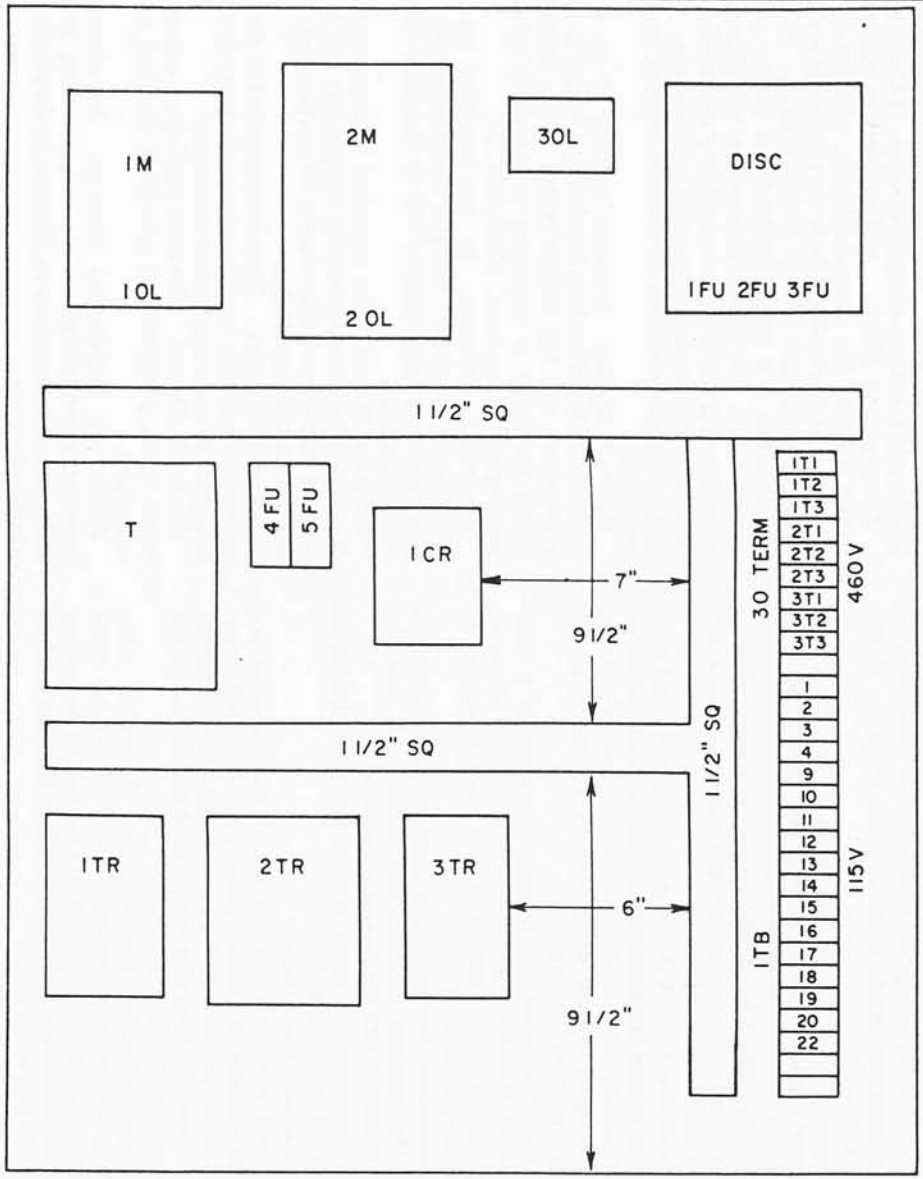
SERIAL NO. OF MACHINE TYP 121314

THESE DIAGRAMS USED FOR MACHINE NO. _____

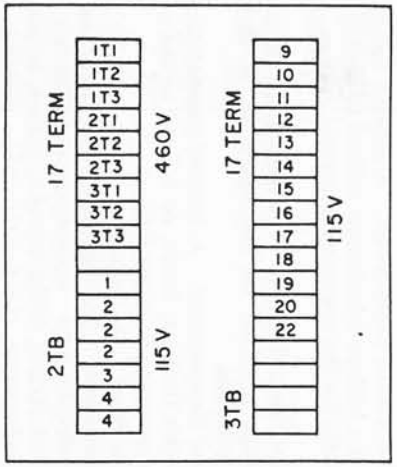
			FULL CATALOG DESCRIPTION OF ALL ITEMS
AMT.	SYM		DESCRIPTION
PART. NO. XY.100		SHEET 2	SHEETS / DWG. No. Purchaser's dwg. No.
DES. BY J.I.C	DET. BY W.T.	SAMPLE ELECTRICAL DIAGRAMS	
CHECKED BY R.S.	SAFETY OK P.N.		
DATE 8-2-66	SCALE	PLANT DIVISION	XYZ MACHINE CO.

(CONTINUED)

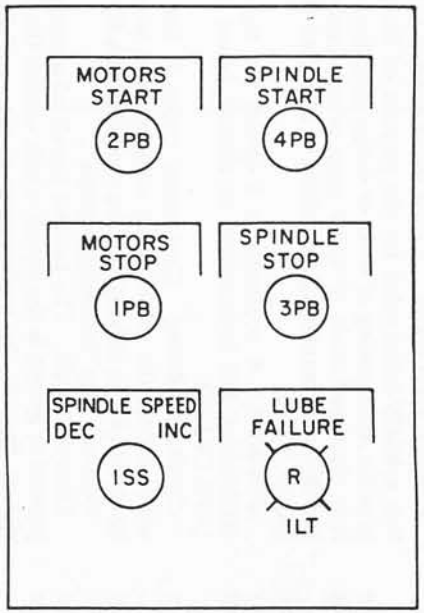
PANELS AND CONTROL STATION LAYOUT



MAIN CONTROL PANEL



MASTER TERMINAL BOX PANEL



CONTROL STATION

AMT.	SYM		DESCRIPTION

PART. NO. XY100		SHEET 2	SHEETS	DWG. No. Purchaser's dwg. No.
DES. BY J. I. C	DET. BY W. T.	TITLE **SAMPLE ELECTRICAL DIAGRAMS**		
CHECKED BY R. S.	SAFETY OK P. N.			
DATE 8-2-66	SCALE	PLANT DIVISION	XYZ MACHINE CO.	

Appendix C—Glossary of Terms

Actuator. The cam, arm or similar mechanical device used to trip limit switches.

Ambient Conditions. The condition of the atmosphere adjacent to the electrical apparatus. The specific reference may apply to temperature, contamination, humidity, etc.

Ambient Temperature. Ambient temperature is the temperature of the surrounding cooling medium, such as gas or liquid, which comes into contact with the heated parts of the apparatus.

Ampacity. Current-carrying capacity expressed in amperes. (NEC-NFPA No. 70)

Anti-Plugging Protection. Anti-plugging protection is the effect of a control function or a device which operates to prevent application of counter-torque by the motor until the motor speed has been reduced to an acceptable value. (NEMA IC-1)

Apparatus. Control apparatus is a set of control devices used to accomplish the intended control functions. (ANS C42.25)

Auxiliary Contacts. Auxiliary contacts of a switching device are contacts in addition to the main-circuit contacts and function with the movement of the latter. (NEMA IC-1)

Auxiliary Device. Any electrical device other than motors and motor starters necessary to fully operate the machine or equipment.

Block Diagram. A block diagram is a diagram showing the relationship of separate sub-units (blocks) in the control system.

Bonding Conductor. A bonding conductor is one which serves to connect exposed metal surfaces together.

Branch Circuit. A branch circuit is that portion of a wiring system extending beyond the final overcurrent device protecting the circuit. (A device not approved for branch-circuit protection, such as a thermal cutout or motor overload protective device, is not considered as the overcurrent device protecting the circuit.) (NEC-NFPA No. 70)

Captive Screw. Screw-type fastener that is retained in some manner when unscrewed and cannot easily be separated from the part it secures.

Chassis. Sheet-metal box, frame, or simple plate on which electronic components and their associated circuitry can be mounted.

Circuit Breaker. A device designed to open and close a circuit by non-automatic means, and to open the circuit automatically on a predetermined overload of current, without injury to itself when properly applied within its rating. (NEC-NFPA No. 70)

Circuit Interrupter. A circuit interrupter is a non-automatic manually operated device designed to open, under abnormal conditions, a current-carrying circuit without injury to itself.

Combination Starter. A magnetic starter having a manually operated disconnecting means built into the same enclosure with the magnetic contactor.

Compartment. A space within the base, frame or column of the equipment.

Component. See "device".

Conduit, Flexible Metal. A flexible metal conduit is a flexible raceway of circular cross section specially constructed for the purpose of the pulling in or the withdrawing of wires or cables after the conduit and its fittings are in place. (ANS C42.95)

Conduit, Flexible Non-Metallic. A flexible non-metallic conduit is a flexible raceway of circular cross section specially constructed for the purpose of the pulling in or the withdrawing of wires or cables after the conduit and its fittings are in place.

Conduit, Rigid Metal. A rigid metal conduit is a raceway specially constructed for the purpose of the pulling in or the withdrawing of wires or cables after the conduit is in place and made of metal pipes of standard weight and thickness permitting the cutting of standard threads. (ANS C42.95)

Contactor. A contactor is a device for repeatedly establishing and interrupting an electric power circuit. (ANS C42.25)

Continuous Rating. Continuous rating is the rating which defines the substantially constant load which can be carried for an indefinitely long time. (NEMA IC-1)

Control. See "controller, electric".

Control Circuit. The control circuit of a control apparatus or system is the circuit which carries the electric signals directing the performance of the controller, but does not carry the main power circuit. (NEC-NFPA No. 70)

Control Circuit Transformer. A control circuit transformer is a voltage transformer utilized to supply a voltage suitable for the operation of control devices. (ANS C42.25)

Control Circuit Voltage. The control circuit voltage is the voltage provided for the operation of shunt coil magnetic devices.

Control Compartment. A control compartment is a space within the base, frame, or column of the machine used for mounting the control panel.

Control Panel. See "panel".

Control Station. See "operator's control station".

Controller, Electric. An electric controller is a device, or group of devices, which serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected. (ANS C42.25)

Device (Component). A control device is an individual device used to execute a control function. (ANS C42.25)

Disconnecting Means. A disconnecting means is a device whereby the current-carrying conductors of a circuit can be disconnected from their source of supply.

Disconnect Switch (Motor Circuit Switch). A motor circuit switch is a switch intended for use in a motor branch circuit. It is rated in horsepower, and it is capable of interrupting the maximum operating overload current of a motor of the same rating at the rated voltage. (ANS C42.25) (Also see NEMA IC-1 for definition of operating overload.)

Dynamic Braking. Dynamic braking of an electric drive is a system of braking in which the motor is used as a generator, and the kinetic energy of the motor and driven machinery is employed as actuating means of exerting a retarding force. (ANS C42.25)

Electrical Equipment. In this standard the term "Electrical Equipment" includes electro-magnetic, electronic and static apparatus as well as the more common electrical devices.

Electrical System. The organized arrangement of all electrical and electro-mechanical components and devices in a way that will properly control the particular machine tool or industrial equipment.

Electro-Mechanical. Electro-mechanical is the term applied to any device in which electrical energy is used to magnetically cause mechanical movement.

Electronic Control. The term applied to define electronic, static, precision and associated electrical control equipment.

Elementary (Schematic) Diagram. An elementary (schematic) wiring diagram is a diagram using symbols and a plan of connections to illustrate in simple form the scheme of control.

Enclosure. The case, box or structure surrounding the electrical equipment, which protects it from contamination. The degree of tightness is usually specified (e.g., NEMA Type 12). (See NEMA Standard IC-1 for various enclosure descriptions and ANS C42.95, Section 91, Qualifying Terms.)

External Control Devices. All control devices mounted external to the control panel.

Eyelet. Eyelets are used on printed circuit boards to make reliable electrical connections from one side of the board to the other side.

Fail-safe Operation. An electrical system so designed that the failure of any component in the system will prevent unsafe operation of the controlled equipment.

Feeder. A feeder is the circuit conductors between the service equipment, or the generator switchboard of an isolated plant, and the branch circuit overcurrent device. (NEC-NFPA No. 70)

Field Loss Relay. See "motor-field failure relay".

Grounded. Grounded means connected to earth or to some conducting body which serves in place of the earth. (NEC-NFPA No. 70)

Grounded Circuit. A grounded circuit is a circuit in which one conductor or point (usually the neutral or neutral point of transformer or generator windings) is intentionally grounded (earthed), either solidly or through a grounding device. (ANS C42.15)

Grounding Conductor. A grounding conductor is one which, under normal conditions, carries no current, but serves to connect exposed metal surfaces to an earth ground, to prevent hazards in case of breakdown between current-carrying parts and exposed surfaces. The conductor, if insulated, is colored green, with or without a yellow stripe.

Guarded. Covered, shielded, fenced, enclosed or otherwise protected by means of suitable covers or casings, barriers, rails or screens, mats or platforms to remove the likelihood of dangerous contact or approach by persons or objects to a point of danger. (ANS C42.95)

Inching. See "jogging".

Inrush Current. The inrush current of a solenoid or coil is the steady-state current taken from the line with the armature blocked in the rated maximum open position.

Isolating Transformer. See "insulating transformer".

Insulating (Isolating) Transformer. An insulating (or isolating) transformer is a transformer used to insulate one circuit from another. (ANS C42.15)

Interconnecting Wire. The term "interconnecting wire" refers to those connections between sub-assemblies, panels, chassis and remotely mounted devices and does not necessarily apply to internal connections of these units.

Interconnection Diagram. A diagram showing all terminal blocks in the complete system with each terminal identified.

Interlock. An interlock is a device actuated by the operation of some other device with which it is directly associated, to govern succeeding operations of the same or allied devices. Note: Interlocks may be either electrical or mechanical. (ANS C42.25)

Intermittent Duty. Intermittent duty is a requirement of service that demands operation for alternate intervals of (1) load and no-load; or (2) load and rest; or (3) load, no-load and rest; such alternate intervals being definitely specified. (NEMA IC-1)

Interrupting Capacity. Interrupting capacity is the highest current at rated voltage that the device can interrupt.

Jogging (Inching). Jogging is the quickly repeated closure of the circuit to start a motor from rest for the purpose of accomplishing small movements of the driven machine. (ANS C42.25)

Joint. A joint is a connection between two or more conductors. (ANS C42.95)

Large Enclosures. See E7.2 of these JIC Standards.

Latching Relay. A latching relay is one that can be mechanically latched in a given position manually, or when operated by one element, and released manually or by the operation of a second element. (ANS C42.20)

Legend Plates. Legend plates identify the function of operator controls, indicating lights, etc.

Limit Switch. A limit switch is a switch which is operated by some part or motion of a power-driven machine or equipment to alter the electric circuit associated with the machine or equipment. (ANS C42.25)

Locked-Rotor Current. The locked-rotor current of a motor is the steady-state current taken from the line with the rotor locked and with rated voltage (and rated frequency in the case of alternating-current motors) applied to the motor. (ANS C42.10)

Logic Control Panel Layout. The physical position or arrangement of the devices on a chassis or panel.

Logic Diagram. A logic diagram is a diagram showing the relationship of standard logic elements in a control system. No internal detail of the logic elements need be shown.

Magnetic Device. A magnetic device is a device actuated by electro-magnetic means.

Magnetic Starter. A magnetic starter is a starter actuated by electro-magnetic means.

Master Terminal Box. The main enclosure on the equipment containing terminal blocks for the purpose of terminating conductors from the control enclosure. (Normally associated with equipment requiring a separately mounted control enclosure.)

Motor-Circuit Switch. See "disconnect switch".

Motor Junction (Conduit) Box. An enclosure on a motor for the purpose of terminating a conduit run and joining motor to power conductors.

Motor-Field Failure Relay (Field Loss Relay). A motor-field failure relay is a relay which functions to disconnect the motor armature from the line in the event of loss of field excitation. (NEMA IC-1)

Nominal Voltage. Nominal voltage is the utilization voltage. See the appropriate NEMA Standard for device voltage ratings.

Normally Open and Normally Closed. The terms "normally open" and "normally closed", when applied to a magnetically operated switching device, such as a contactor or relay, or to the contacts thereof, signify the position taken when the operating magnet is de-energized. These terms apply only to non-latching types of devices. (NEMA IC-1)

Operating Floor. A floor or platform used by the operator under normal operating conditions.

Operating Overload. Operating overload is the overcurrent to which electric apparatus is subjected in the course of normal operating conditions that it may encounter. (ANS C42.25)

(Note 1: The maximum operating overload is considered to be six times normal full-load current for alternating-current industrial motors and control apparatus; four times normal full-load current for direct-current industrial motors and control apparatus used for reduced-voltage starting; and ten times normal full-load current for direct-current industrial motors and control used for full-voltage starting.)

(Note 2: It should be understood that these overloads are currents that may persist for a very short time only, usually a matter of seconds.)

Operator's Control Station (Pushbutton Station). A pushbutton station is a unit assembly of one or more externally operable pushbutton switches, sometimes in-

cluding other pilot devices such as indicating lights or selector switches, in a suitable enclosure. (ANS C42.25)

Outline Drawing. Drawing showing approximate over-all shape with no detail.

Overcurrent. Overcurrent in an electric circuit is that current which will cause an excessive or dangerous temperature in the conductor or conductor insulation.

Overcurrent Protective Device. A device operative on excessive current which causes and maintains the interruption of power in the circuit.

Overlapping Contacts. Overlapping contacts are combinations of two sets of contacts, actuated by a common means, each set closing in one of two positions, and so arranged that the contacts of one set open after the contacts of the other set have been closed. (NEMA IC-1)

Overload Relay. A device that provides overload protection for electrical equipment.

Panel. A subplate upon which the control devices are mounted inside the control compartment or enclosure.

Panel Layout. The physical position or arrangement of the components on a panel or chassis.

Pendant (Station). A pendant station is a pushbutton station suspended from overhead and connected by means of flexible cord or conduit, but supported by a separate cable.

Plugging. Plugging is a control function which provides braking by reversing the motor line voltage polarity or phase sequence so that the motor develops a counter-torque which exerts a retarding force. (NEMA IC-1)

Plug-In Device. Component or group of components and their circuitry which can be easily installed or removed from the equipment. Electrical connections are made by mating contacts.

Polarized Plug. A plug so arranged that it may be inserted in its receptacle only in a predetermined position.

Potting. Potting is a method of securing a component or group of components by encapsulation.

Precision Device. A precision device is a device that will operate within prescribed limits and will consistently repeat operations within those limits.

Pressure Connector. A conductor terminal applied with pressure so as to make the connection mechanically and electrically secure.

-Proof (used as a suffix). Apparatus is designated as splashproof, dustproof, etc., when so constructed, protected or treated that its successful operation is not interfered with when subjected to the specified material or condition.

Pushbutton Station. See "operator's control station".

Raceway. Any channel for holding wires, cables or busbars, which is designed expressly for, and used solely for, this purpose. (NEC-NFPA No. 70)

Readily Accessible. Capable of being reached quickly for operation, renewal, or inspection without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. (NEC-NFPA No. 70)

Relay. A relay is a device which is operative by a variation in the conditions of one electric circuit to effect the operation of other devices in the same or another electric circuit. (NEMA IC-1)

Schematic Diagram. See "elementary diagram".

Semiconductor. A device which can function either as a conductor or a non-conductor, depending on the polarity of the applied voltage such as a rectifier or transistor which has a variable conductance depending on the control signal applied.

Sequence of Operation. A written detailed description of the order in which electrical devices and other parts of the equipment should function.

Shielded Cable. Shielded cable is single or multiple conductor cable surrounded by a separate conductor (the "shield") intended to minimize the effects of adjacent electrical circuits.

Short-Time Rating. The short-time rating is the rating that defines the load which can be carried for a short and definitely specified time; the machine, apparatus or device being at approximately room temperature at the time the load is applied. (NEMA IC-1)

Small Enclosure. See E7.2 of these JIC Standards.

Solenoid. A solenoid magnet (solenoid) is an electromagnet having an energized coil approximately cylindrical in form and an armature whose motion is reciprocating within and along the axis of the coil. (ANS C42.25)

Starter. A starter is an electric controller for accelerating a motor from rest to normal speed. (Note: A device designed for starting a motor in either direction of rotation includes the additional function of reversing and should be designated a controller.) (NEMA IC-1)

Static Device. As associated with electronic and other control or information handling circuits, the term "static" refers to devices with switching functions that have no moving parts.

Stepping Relay (Switches). A multi-position relay in which moving wiper contacts mate with successive sets of fixed contacts in a series of steps, moving from one step to the next in successive operations of the relay. (ANS C83.16)

Sub-Assembly. A sub-assembly is an assembly of electrical or electronic components mounted on a panel or chassis which forms a functional unit by itself.

Subplate. A rigid metal panel on which control devices can be mounted and wired.

Swingout Panel. A panel which is hinge-mounted in such a manner that the back of the panel may be made accessible from the front of the enclosure.

Symbol. A sign, mark or drawing agreed upon to represent an electrical device or component part thereof.

Temperature Control. A control device responsive to temperature.

Terminal. A point of connection in an electrical circuit.

Terminal Block. A terminal block is an insulating base or slab equipped with one or more terminal connectors for the purpose of making electrical connections thereto. (NEMA IC-1)

Tie Point. A distributing point in circuit wiring, other than a terminal connection, where junctions of leads are made.

-Tight (used as a suffix). Apparatus is designated as watertight, dust-tight, etc., when so constructed that the enclosing case will exclude the specified material. (ANS C42.95)

Undervoltage Protection. Undervoltage or low-voltage protection is the effect of a device operative on the reduction or failure of voltage, to cause and maintain the interruption of power to the main circuit. (ANS C42.25)

Vault-Type Hardware. See E7.6 of these JIC Standards.

Wire-Wrapping. Wire-wrapping is a technique used to terminate conductors.

Wireway. Wireways are sheet metal troughs with hinged covers for housing and protecting electrical conductors and cable and in which conductors are laid in place after the wireway has been installed as a complete system.

Wobble Stick. A wobble stick is a rod extending from a pendant station to operate the "Stop" contacts and will function when pushed in any direction.

Appendix D—Device Designations

The device designations given below are intended for use on diagrams in connection with the corresponding graphical symbols to indicate the function of the particular device. These device designations are based on the assignment of a standard letter or letters to the fundamental function that is performed by a component or device. Suitable prefix numbers (1, 2, 3, 4, etc.) and suffix letters (A, B, C, D, etc.) may be added to the basic designation to differentiate between devices performing similar functions.

The assignment of a designation to a device on a specific equipment is governed by the function of that device on that particular equipment and not by the type or nature of the device or its possible use for other functions in other equipment. The same type of device may perform different functions on different equipments or even on the same equipment and, consequently, may be identified by different designations.

Designation	Device
A	Accelerating Contactor or Relay
ABE	Alarm or Annunciator Bell
ABU	Alarm or Annunciator Buzzer
AH	Alarm or Annunciator Horn
AM	Ammeter
AT	Autotransformer
B	Brake Relay
CAP	Capacitor
CB	Circuit Breaker
CH	Chassis or Frame (not necessarily grounded)
CI	Circuit Interrupter
CON	Contactor
COS	Cable Operated (Emergency) Switch
CR	Control Relay
CRA	Control Relay, Automatic
CRE	Control Relay, Electronically Energized
CRH	Control Relay, Manual
CRL	Control Relay, Latch
CRM	Control Relay, Master
CRU	Control Relay, Unlatch
CS	Cam Switch
CT	Current Transformer
CTR	Counter
D	Diode
DAS	Diode Arc Suppressor
DB	Dynamic Braking Contactor or Relay
DISC	Disconnect Switch
DT	Tunnel Diode
DVC	Varicap Diode
DZ	Zener Diode
F	Forward
FA	Field Accelerating Contactor or Relay
FB	Fuse Block
FD	Field Decelerating Contactor or Relay
FF	Full Field Contactor or Relay
FL	Field Loss Contactor or Relay
FLD	Field
FLS	Flow Switch
FS	Float Switch
FTB	Fusible Terminal Block
FTS	Foot Switch
FU	Fuse
FW	Field Weakening
GRD	Ground
HTR	Heating Element
INST	Instrument
IOL	Instantaneous Overload
LO	Lock-Out Coil (located in plugging switch)
LS	Limit Switch
LT	Pilot Light
LVT	Linear Variable Differential Transformer
M	Motor Starter
MAX	Magnetic Amplifier Winding
MB	Magnetic Brake
MC	Magnetic Clutch
MCS	Motor Circuit Switch
MF	Motor Starter—Forward
MR	Motor Starter—Reverse
MSH	Meter Shunt
MTR	Motor
NLT	Neon Light
OL	Overload Relay
PB	Pushbutton
PC	Printed Circuit
PL	Plug
PLS	Plugging Switch
POT	Potentiometer
PRS	Proximity Switch
PS	Pressure Switch
PSC	Photosensitive Cell
Q	Transistor
QBN	Binistor
QFE	Transistor, Field-Effect
QSB	Transistor, Surface-Barrier
QT	Transistor, Tetrode
QTG	Trigistor
QTM	Thermistor
QTN	Trinistor
QU	Transistor, Unijunction
QVR	Varistor
R	Reverse
REC	Rectifier
RECP	Receptacle
RES	Resistor
RH	Rheostat
RSS	Rotary Selector Switch
S	Switch
SCR	Silicon Controlled Rectifier
SOC	Socket
SOL	Solenoid
SS	Selector Switch
ST	Saturable Transformer
SX	Saturable Core & Reactor
SYN	Synchro or Resolver
T	Transformer
TACH	Tachometer Generator
TAS	Temperature-Actuated Switch
TB	Terminal Block
T/C	Thermocouple
TCS	Thermocouple Switch
TGS	Toggle Switch
TR	Time Delay Relay
TRE	Timer Relay, Electronically-Energized
TVM	Tachometer Indicator
V	Electronic Tube
VAT	Variable Autotransformer
VM	Voltmeter
VS	Vacuum Switch
WLT	Work Light
WM	Wattmeter
X	Reactor

Appendix E—References to Other Codes and Standards

1. American Society for Testing Materials (ASTM)
   260 South Broad Street, Philadelphia, Pennsylvania 19107
   A. D2219, D2220, Insulation for Wire and Cable
   B. B8, B174, Conductors
2. American National Standards Institute, Inc. (ANSI)
   1430 Broadway, New York, New York 10018
   Formerly American Standards Association (ASA) and United States of America Standards Institute (USASI)
   A. Y32.2, Graphic Symbols for Electrical and Electronics Diagrams
   B. C19.1, Industrial Control Apparatus
   C. C80.1, Rigid Steel Conduit
   D. C6.1, Terminal Marking for Electrical Apparatus
   E. C50, Rotating Electrical Machinery
3. British Standards Institution (BSI)
   British Standards House, 2 Park Street, London, W1
   A. BS2771, Electrical Equipment of Machine Tools
4. State of California
   Printing Division, Documents Section, Sacremento, California 95814
   A. California State Electrical Safety Orders
5. Canadian Standards Association (CSA)
   National Research Building, Ottawa 2, Ontario
   A. Canadian Electrical Code
6. Electronic Industries Association (EIA)
   2001 Eye Street, NW, Washington, D.C. 20006
   A. RS-281, Construction Standards—Numerical Machine Tool Control
7. National Electrical Manufacturers Association (NEMA)
   155 East 44th Street, New York, New York 10017
   A. IC-1, Industrial Control
   B. KS-1, Enclosed Switches
   C. AB-1, Molded Case Circuit Breakers
   D. FU-1, Low-Voltage Cartridge Fuses
   E. ST-1, Specialty Transformers
   F. MG-1, Motors and Generators
8. National Fire Protection Association (NFPA)
   60 Batterymarch Street, Boston, Massachusetts 02110
   A. NFPA No. 70, National Electrical Code (NEC)
   B. NFPA No. 79, Electrical Standard for Metal-Working Machine Tools
9. Superintendent of Documents
   Government Printing Office, Washington, D.C. 20401
   A. MIL-I-7798A, Insulation Tape, Electrical, Pressure-Sensitive Adhesive, Plastic
10. Underwriters' Laboratories, Inc. (UL)
    207 East Ohio Street, Chicago, Illinois 60611
    A. UL 508, Industrial Control Equipment
    B. UL 496, Edison-Base Lampholders
    C. UL 758, Provisional Requirements for Machine-Tool Wires and Cables
    D. UL 83, Thermoplastic-Insulated Wires
    E. UL 62, Flexible Cord and Fixture Wire
    F. UL 486, Wire Connectors and Soldering Lugs
    G. UL 514, Outlet Boxes and Fittings

. . . . about Joint Industrial Council

Because of the wide-spread interest in the work of the Joint Industrial Council, and the wide acceptance of the standards written by its committees, many persons have asked about the organization and how it developed. To aid those persons not too familiar with the JIC and its operations, the following background material is included.

Decades ago line shafting was replaced as a machine-tool drive in favor of individual motor drives. At first this meant adding one or two individual motors, starters, and pushbuttons to the various machines, but it was not long before the control systems became much more involved. As the older machine-tool designs were updated and new machine designs were engineered, the various ideas of machine-tool engineers and user engineers were freely applied. The situation soon became confusing, if not chaotic, because no two companies agreed completely on the control application criteria; quite often the ideas and interests of the various groups were in direct conflict. Soon individual user companies began to write their own electrical standards in order to obtain equipment which best suited their needs. A multiplicity of these standards were in force in the late 1930's. A machine-tool builder had to analyze each job to determine which specifications might apply to the product on which he was asked to quote.

In the late 1930's the National Machine Tool Builders' Association formed a committee to study and act on the problem of industry-wide electrical standards for machine-tool applications. After collating all of the various companies' standards available to them, and after discussions with many of the machine users, the committee published a "Machine Tool Electrical Standard" on September 5, 1941. In 1942 this standard, was adopted as an American Standard, partially sponsored by the War Production Board. Because of the rapid advances in control circuitry, a revision of the standard soon became necessary. In September 1945, a second issue of the standard, called "Machine Tool Electrical Standards — For General Industrial Use Including Automative Standards," was completed. This issue recognized for the first time some of the requirements of the mass-production industries.

However, according to many automotive-plant engineers, the standard was not suitable for use in the mass-production industries, and a group was formed to consider standards written solely for that purpose. This became the Joint Industry Conference. Although the NMTBA standards stressed safety to personnel, uninterrupted production, and long life of equipment, the JIC group wanted stronger emphasis on the maintainability of the equipment and even such things as the huge inventory of necessary replacement parts. The first of the JIC standards, the electrical, appeared in 1948. Soon the JIC also considered hydraulic and pneumatic elements.

After 1948, the NMTBA and JIC electrical standards continued to be revised and reissued every three to five years, on a somewhat alternating basis, until 1960.

However, the procedure and informality of JIC were not conducive to writing good standards. There was no over-all governing body, no widely recognized mailing address, no group to whom requests for interpretation could be sent. After the last issue of the electrical standards in 1957, the JIC began to quietly fall apart with the withdrawal of some of the large users.

JIC standards were widely recognized and used in the United States and were also used extensively overseas. Many who did not participate in the writing of the standards used them, and their machine-tool specifications were being written to include references to the JIC standards for electrical, hydraulic, or pneumatic applications.

Since there had been wide interest and wide use of the JIC standards over the years, attempts were made in 1961 and 1962 to revive the standardizing activity. In September of 1963 a new group was tentatively formed under the name of the Joint Industrial Council. It was expected to take over all of the activities of the earlier JIC. An organizational structure was set up in such a manner as to minimize or eliminate the weaknesses of the earlier organization. Following close scrutiny by the legal departments of the large user companies and trade associations interested, a constitution and bylaws were finally adopted by letter ballot in March 1965.

The best explanation of the objectives of the JIC is contained in the preamble to the constitution:

> "The Joint Industrial Council is formed in order to provide direction, coordination and continuity of effort in the development, advancement and referral to the American National Standards Institute, Inc. of standards which will encourage the safe and reliable application of controls to machines and equipment used in industrial applications.
>
> "JIC is an organization, membership in which is open to interested and affected companies, associations and organizations who desire to participate in the fulfillment of the objectives. Qualified specialists from outside JIC membership may be called into any meeting, at any level, at the discretion of the body involved.