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NEMA STANDARDS PUBLICATION NO. ICS 2

nema

Industrial Control Devices, Controllers and Assemblies

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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ICS 2-1988

ICS2

INDUSTRIAL CONTROL DEVICES, CONTROLLERS AND ASSEMBLIES

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TABLE OF CONTENTS

	Page
Foreword	i
Scope	iii
Part ICS 2-110 GENERAL STANDARDS FOR MANUAL AND MAGNETIC CONTROLLERS	
General Information and Features	1
Design Tests and Performance	2
Part ICS 2-120 CONTROL DEVICE CONNECTORS FOR COPPER CONDUCTORS	
General	4
Design Tests and Performance	4
Part ICS 2-125 CONTACTS FOR CONTROL CIRCUIT DEVICES	
Definitions	5
Ratings	5
Design Tests and Performance	7
Manufacturing	11
Application	12
Part ICS2-126 SEMICONDUCTOR SWITCHING ELEMENTS FOR CONTROL CIRCUIT DEVICES	
Definitions	13
Ratings	14
Design Tests and Performance	16
Application	18
Part ICS 2-210 AC GENERAL-PURPOSE MAGNETIC CONTACTORS, 600 VOLTS AND LESS, 50 AND 60 HERTZ	
Ratings	19
Design Tests and Performance	23
Application	23
Part ICS 2-211 MAGNETIC LIGHTING CONTACTORS	
Ratings	25
Design Tests and Performance	25
Part ICS 2-212 MAGNETIC CONTROL RELAYS	
Definitions	26
General Information and Features	26
Ratings	27
Design Tests and Performance	27
Application	28
Part ICS 2-213 RESISTORS AND RHEOSTATS	
General Information and Features	29
Ratings	31
Design Tests and Performance	32
Manufacturing	32
Application	33
Preventive Maintenance	35
Part ICS 2-214 AUTOTRANSFORMERS AND REACTORS	
General Information and Features	36
Design Tests and Performance	37
Manufacturing	37
Part ICS 2-215 FOOT SWITCHES	
Definitions	38
General Information and Features	38
Ratings	38
Design Tests and Performance	38
Application	39

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Part ICS 2-216 PUSHBUTTONS, SELECTOR SWITCHES, INDICATING LIGHTS AND PUSHBUTTON STATIONS

Definitions 40
General Information and Features 40
Ratings 41
Design Tests and Performance 41
Manufacturing 41
Application 43
Preventive Maintenance 43

Part ICS 2-218 TIME-DELAY RELAYS

Definitions 44
General Information and Features 45
Ratings 45
Design Tests and Performance 46
Application 47
Preventive Maintenance 47

Part ICS 2-219 DRY REED SWITCHES

Definitions 48
Ratings 48
Application 49

Part ICS 2-220 BRAKES

Definitions 50
General Information and Features 51
Ratings 52
Design Test and Performance 55
Manufacturing 55
Application 61

Part ICS 2-221 AUXILIARY CONTACTS

Ratings 63
Design Tests and Performance 63
Application 64
Preventive Maintenance 64

Part ICS 2-222 OVERLOAD RELAYS

Definitions 65
General Information and Features 67
Ratings 70
Design Tests and Performance 70
Manufacturing 75
Application 75

Part ICS 2-225 INDUSTRIAL LIMIT SWITCHES

Definitions 77
Ratings 80
Design Tests and Performance 81
Manufacturing 81
Application 81
Preventive Maintenance 87

Part ICS 2-226 PRESSURE OPERATED SWITCHES

Definitions 88
Electrical Ratings 89
Mechanical Ratings 89
Design Tests and Performance 89
Application 90
Preventive Maintenance 90

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Part ICS 2-227 TEMPERATURE OPERATED CONTROLLERS
Definitions . . . 91
Electrical Ratings . . . 92
Temperature Ratings . . . 92
Design Tests and Performance . . . 92
Manufacturing . . . 93
Application . . . 93
Preventive Maintenance . . . 94
Part ICS 2-228 LIQUID LEVEL SWITCHES
Definition . . . 95
Ratings . . . 95
Design Tests and Performance . . . 95
Application . . . 96
Preventive Maintenance . . . 96
Part ICS 2-229 PROXIMITY SWITCHES
Definitions . . . 97
Ratings . . . 104
Design Tests and Performance . . . 105
Application . . . 109
Preventive Maintenance . . . 111
Part ICS 2-302 MAINTENANCE OF MOTOR CONTROLLERS AFTER A FAULT CONDITION
General . . . 112
Procedures . . . 112
Part ICS 2-321 AC GENERAL-PURPOSE CLASS A MAGNETIC CONTROLLERS FOR INDUCTION MOTORS RATED IN HORSEPOWER 600 VOLTS AND LESS, 50 AND 60 HERTZ
General Information and Features . . . 114
Ratings . . . 121
Design Tests and Performance . . . 129
Manufacturing . . . 130
Application . . . 133
Part ICS 2-322 AC MOTOR CONTROL CENTERS
Definitions . . . 135
General Information and Features . . . 136
Ratings . . . 137
Design Tests and Performance . . . 138
Manufacturing . . . 141
Application . . . 142
Part ICS 2-324 AC GENERAL-PURPOSE MEDIUM-VOLTAGE CONTACTORS AND CLASS E CONTROLLERS, 50 AND 60 HERTZ
General Information and Features . . . 144
Ratings . . . 144
Design Tests and Performance . . . 146
Manufacturing . . . 154
Application . . . 155
Part ICS 2-325 AC GENERAL-PURPOSE CONTROLLERS FOR SYNCHRONOUS MOTORS
General Information and Features . . . 156
Ratings . . . 161
Part ICS 2-327 AC GENERAL-PURPOSE CLASS A MAGNETIC CONTROLLERS FOR INDUCTION MOTORS, RATED IN FULL-LOAD AND LOCKED-ROTOR CURRENT, 600 VOLTS AND LESS, 50 AND 60 HERTZ
General Information and Features . . . 162
Ratings . . . 162
Design Tests and Performance . . . 168
Manufacturing . . . 168
Application . . . 168

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Part ICS 2-328 AC GENERAL-PURPOSE CLASS A MANUALLY OPERATED AND MOTOR OPERATED CONTROLLERS FOR INDUCTION MOTORS RATED IN HORSEPOWER
Ratings 169
Manufacturing 171
Part ICS 2-329 AC GENERAL-PURPOSE CLASS A MANUALLY OPERATED FULL-VOLTAGE CONTROLLERS FOR SINGLE-SPEED INDUCTION MOTORS RATED IN FULL-LOAD AND LOCKED-ROTOR CURRENT FOR NONPLUGGING AND NONJOGGING DUTY
Ratings 172
Part ICS 2-331 DC GENERAL-PURPOSE CONSTANT-VOLTAGE CLASS B CONTROLLERS
General Information and Features 173
Ratings 174
Design Tests and Performance 175
Manufacturing 176
Application 176
Part ICS 2-447 AC AUTOMATIC TRANSFER SWITCHES
Definitions 177
General Information and Features 177
Ratings 178
Design Tests and Performance 179
Manufacturing 180
Application 183
Part ICS 2-448 AC AUTOMATIC COMBINATION OIL FIELD CONTROLLERS
Ratings 186
Manufacturing 186
Part ICS 2-449 AC AUTOMATIC COMBINATION IRRIGATION PUMP CONTROLLERS
Ratings 188
Manufacturing 188
Appendix A REFERENCED STANDARDS
Listing 190

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Foreword

This Standards Publication, together with the others listed below, supersedes and revises the indicated Standards Publications of the Industrial Control and Systems Section. Also included in these publications is the information separately printed as Standards Publication No. ICS 2.2-1983(R 1988), *Maintenance of Motor Controllers After a Fault Condition*. Standards Publication No. ICS 3.1-1983 (R1988), *Safety Standards for Construction and Guide for Selection, Installation and Operation of Adjustable-speed Drive Systems*, is a supplement to Standards Publication No. ICS 3 and is not included.

Since Standards Publication No. ICS 1 applies as a general standard and Standards Publication No. ICS 6 applies to enclosures used for control and systems apparatus, these two standards should be used in conjunction with each of the product standards.

Standards Publication No.	Supersedes
ICS 1-1988, *General Standards for Industrial Control and Systems*	ICS 1-1983, formerly Part 1 (white pages) of NEMA Standards Publication No. ICS-1970, *Industrial Controls and Systems*
ICS 2-1988, *Industrial Control Devices, Controllers, and Assemblies*	ICS 2-1983, formerly Part 2 (green pages) of NEMA Standards Publication No. ICS-1970, *Industrial Controls and Systems*
ICS 3-1988, *Industrial Systems*	ICS 3-1983 and ICS 3-1978, formerly Part 3 (yellow pages) of NEMA Standards Publication No. ICS-1970, *Industrial Controls and Systems*
ICS 4-1983 (R 1988), *Terminal Blocks for Industrial Control Equipment and Systems*	ICS 4-1977, formerly NEMA Standards Publication No. ICS 4-1968, *Terminal Blocks for Industrial Control Equipment and Systems*

In 1988, unrevised portions of all NEMA Standards Publications for Industrial Controls and Systems (the ICS series) were reaffirmed.

To continue to serve the best interests of users of Industrial Control and Systems equipment, the Industrial Control and Systems Section is actively cooperating with other standardization organizations in the development of simple and more universal metrology practices. In this publication, the U.S. customary units are gradually being supplemented by those of the modernized metric system known as the International Systems of Units (SI). This transition involves no changes in standard dimensions, tolerances, or performance specifications.

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This Standards Publication provides practical information concerning ratings, construction, test, performance and manufacture of industrial control equipment. These standards are used by the electrical industry to provide guidelines for the manufacture and proper application of reliable products and equipment and to promote the benefits of repetitive manufacturing and widespread product availability.

NEMA Standards represent the result of many years of research, investigation and experience by the members of NEMA, its predecessors, its Sections and Committees. They have been developed through continuing consultation among manufacturers, users and national engineering societies and have resulted in improved serviceability of electrical products with economies to manufacturers and users.

One of the primary purposes of this Standards Publication is to encourage the production of reliable control equipment which, in itself, functions in accordance with these accepted standards. Some portions of these standards, such as electrical spacings and interrupting ratings, have a direct bearing on safety; almost all of the items in this publication, when applied properly, contribute to safety in one way or another.

Properly constructed industrial control equipment is, however, only one factor in minimizing the hazards which may be associated with the use of electricity. The reduction of hazard involves the joint efforts of the various equipment manufacturers, the system designer, the installer and the user. Information is provided herein to assist users and others in the proper selection of control equipment.

The industrial control manufacturer has limited or no control over the following factors which are vital to a safe installation:

1. Environmental conditions.
2. System design.
3. Equipment selection and application.
4. Installation.
5. Operating practices.
6. Maintenance.

This publication is not intended to instruct the user of control equipment with regard to these factors except insofar as suitable equipment to meet needs can be recognized in this publication and some application guidance is given.

This Standards Publication is necessarily confined to defining the construction requirements for industrial control equipment and to providing recommendations for proper selection for use under normal or certain specific conditions. Since any piece of industrial control equipment can be installed, operated and maintained in such a manner that hazardous conditions may result, conformance with this publication does not by itself assure a safe installation. When, however, equipment conforming with these standards is properly selected and is installed in accordance with the *National Electrical Code* and properly maintained, the hazards to persons and property will be reduced.

NEMA Standards Publications are subject to periodic review. They are revised frequently to reflect user input and to meet changing conditions and technical progress. Users should secure the latest editions. See the postal return card attached to the front cover of the Standards Publication for the proper procedure to obtain revision service for your copy of the publication.

Proposed revisions to this Standards Publication should be submitted:

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Scope

The product scope of the Control Group of the Industrial Control and Systems Section, which is responsible for the development of this Standards Publication, includes general purpose mechanical, electromechanical and/or solid state (static) devices and controls which are principally used in industrial applications for the control of motors or other power utilization apparatus rated not more than 750 volts dc or 7,200 volts ac. The product scope specifically includes, but is not limited to, devices principally used for the following purposes:

a. to start, stop, protect, accelerate, decelerate, reverse, and/or control the speed of electric motors, or
b. to provide some mechanical movement through the action of magnets or solenoids.

Examples of devices falling within this product scope are as follows.

1. Manual, magnetic and solid state (static) starters and controllers.
2. Relays and contactors, magnetic and solid state (static).
3. Drum switches.
4. Overload devices intended primarily for the starting and running protection of electric motors, including inherent overload protective devices.
5. Rheostats and resistors.
6. Autotransformers and reactors of the type principally used in reduced voltage starters.
7. Control circuit and/or pilot devices including, but not limited to, timers, push-buttons, indicating and pilot lights, limit switches, pressure, vacuum, temperature and/or liquid-level switches, plugging switches, speed switches, solenoids and photo-electric relays. Specifically includes domestic water pump pressure switches.
8. AC and DC brakes, clutches, and electrical operators.
9. Resistance dimmers, autotransformer dimmers, reactor dimmers, and solid state (static) dimmer systems.
10. Solid state logic devices.
11. Machine tool and similar machine control panels.

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Organization Of Control Product Standards In Nema Standards Publication No. ICS 2

The standards pertaining to control apparatus in NEMA Standards Publication No. ICS 2 are subdivided as shown below.

Par. No.	Subdivision and Contents
.01 thru .04	DEFINITIONS – Complete sentence definitions of terms which supplement the *IEEE Standard Dictionary of Electrical and Electronics Terms* (ANSI/IEEE Standard 100) or assist in clarifying the product standard.
.05 thru .19	GENERAL INFORMATION AND FEATURES – Descriptions of the electrical, mechanical and operational features that the product includes, product classifications where they have been established, and any general information pertaining to the product which assists the user in selecting the proper apparatus.
.20 thru .39	RATINGS – Descriptions of the kinds of ratings applicable to the product and tables of standard ratings for the product where they have been established.
.40 thru .59	DESIGN TESTS AND PERFORMANCE – The performance required to pass each design test specified for the product.
.60 thru .79	MANUFACTURING – Marking, color coding and similar production requirements to be incorporated into the product as manufactured, as well as production test requirements where they have been established, i.e., the rules that the manufacturer follows in producing the product.
.80 thru .99	APPLICATION – Information and performance considerations of importance to those who specify or use the product.

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Part ICS 2-110
GENERAL STANDARD FOR MANUAL AND MAGNETIC CONTROLLERS

The standards in this part apply to all parts in this Standards Publication pertaining to power circuit devices unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

GENERAL INFORMATION AND FEATURES

2-110.05 CLASSIFICATION OF MANUAL AND MAGNETIC CONTROLLERS BY INTERRUPTING CAPABILITY

Controllers shall be designated as Class A, B, D, or E in accordance with their ability to interrupt currents.

The majority of controllers are designed for interrupting operating overloads only and, unless it is specifically stated that a controller is of another class, it may be assumed to be either Class A or Class B. For operating overload, see Parts 1-100 and 1-112 of NEMA Standards Publication No. ICS 1.

In general, manual controllers are limited to 600 volts or less. A controller may be a combination of manually and magnetically operated components.

Direct current controllers for service on voltages above 600 volts are not included in this standard. Also, direct current controllers capable of interrupting faults beyond operating overloads are not included.

.01 Class A Controllers

Class A controllers are alternating current air-break and oil-immersed manual or magnetic controllers for service on 600 volts or less. They are capable of interrupting operating overloads but not short circuits or faults beyond operating overloads. For standards applying to these controllers, see Parts ICS 2-321 and ICS 2-327.

.02 Class B Controllers

Class B controllers are direct current air-break manual or magnetic controllers for service on 600 volts or less. They are capable of interrupting operating overloads but not short circuits or faults beyond operating overloads. For standards applying to these controllers, see Part ICS 2-331.

.03 Class D Controllers

Class D controllers are direct current air-break manual or magnetic controllers for service on 600 volts or less. They are capable of interrupting operating overloads but not short circuits or faults beyond operating overloads.

.04 Class E Controllers

Class E controllers are alternating current air-break and oil-immersed magnetic controllers for service on voltages from 2200 to 6600 volts. They are capable of interrupting short circuits or faults beyond operating overloads. For standards applying to these controllers, see Part ICS 2-324.

NEMA Standard 7-12-1978.

2-110.06 SIZES OF TERMINALS FOR EXTERNAL POWER CONNECTIONS

Manual and magnetic controllers shall have terminals suitable for connection to external copper power wire, shown in Table 2-110-1, the insulation of which is rated either 60° or 75°C.

NEMA Standard 6-12-1985.

Table 2-110-1
TERMINALS

	Minimum Range of Wire Sizes*	
Size of Controller	For Wire Insulation Rated 60°C	For Wire Insulation Rated 75°C
00	14 AWG	14 AWG
0	14-10 AWG	14-10 AWG
1	14-8 AWG	14-8 AWG
1P	8-6 AWG	10-8 AWG
2	10-4 AWG	10-6 AWG
3	8-0 AWG	10-1 AWG
4		4-000 AWG
5		00 AWG-500 MCM
6		Two 00 AWG-Two 500 MCM
7		Three 00 AWG-Three 500 MCM
8		Four 00 AWG-Four 500 MCM
9**		

* For controller size 5 and larger, a combination of parallel conductors that provide ampacity equivalent to the wire sizes shown shall be permitted.

**Busbar or cable-connected, as specified between control manufacturer and user.

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Note: The maximum wire size shown is for a 40°C ambient based on the ampacity required for service limit current corresponding to the controller size. The minimum wire size shown is for 75°C insulation in a 30°C ambient and minimum motor full load current corresponding to horsepower.

Authorized Engineering Information 6-12-1985.

2-110.07 MECHANICAL INTERLOCKING OF MANUAL AND MAGNETIC CONTACTORS

Contactors which would cause a line-to-line fault if they are in the closed position at the same time shall be mechanically interlocked to prevent this condition.

NEMA Standard 1-6-1966.

2-110.08 ELECTRICAL INTERLOCKING OF MAGNETIC CONTACTORS

Two or more magnetic contactors which would cause a line-to-line fault if they were in the closed position at the same time shall be electrically interlocked by means of normally closed auxiliary contacts connected in series with their coils.

NEMA Standard 9-20-1972.

DESIGN TESTS AND PERFORMANCE

2-110.40 MAKE AND BREAK DESIGN TEST

The make and break design test for Class A manual and magnetic motor controllers shall be 10 times the rated motor full-load current (10 times MFLC is not a rating) for 10 operations in a single continuous test, without intervening maintenance or servicing, at a maximum rate of one per minute with a minimum "ON" time of 0.1 second per operation.

In performing the above test, a new motor controller shall be used with a motor or a simulated motor load consisting of resistors in series with air-core reactor(s) for each phase. The air-core reactors shall not be connected in parallel with any other resistors or reactors, except that the reactor(s) in each phase may be shunted by a resistor having a power loss of approximately 1 percent of the total power consumption of that phase. This test shall be made at rated voltage and a power factor of 40 to 50 percent.

NEMA Standard 9-15-1971.

2-110.41 RANGE OF OPERATING VOLTAGE TEST

a. Direct-current contactors shall withstand 110 percent of their rated voltage continuously without injury to the operating coils and shall close successfully at 80 percent of their rated voltage.

b. Alternating-current contactors shall withstand 110 percent of their rated voltage continuously without injury to the operating coils and shall close successfully at 85 percent of their rated voltage.

c. If the contactors of alternating-current controllers are operated from the secondary of control circuit transformers which have their primaries connected to the supply circuits of the controllers, the controller shall withstand 110 percent of its rated voltage without injury to the operating coils and shall operate successfully at 90 percent of the rated voltage of the supply circuits. (See Part ICS 1-109 of NEMA Standards Publication ICS 1.)

NEMA Standard 3-6-1985.

2-110.42 SHORT-TIME CAPABILITIES

.01 Short-Time Operating Capability

Short-time operating capability of a motor controller is the ability to withstand the thermal stresses due to starting and accelerating a motor to normal speed and those due to an operating overload.

.02 Short-Time Surge Capability

.02.1 Short-time surge capability of a motor controller (with contacts closed) is the ability to withstand the thermal and mechanical stress due to current surges, such as might result from restoration of power to the load following a momentary loss of power.

NEMA Standard 5-25-88.

.02.2 The I^2t value (Joule Integral) calculated from the surge capability test should not be used to estimate the performance of the contactor under short-circuit conditions.

Authorized Engineering Information 1-11-1983.

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.03 Short-time Capability Test

Separate tests shall be conducted to establish short-time operating capability and short-time surge capability. The test current shall be passed through the closed contacts for the specified period of time, and must be supplied at a voltage sufficient to maintain the current. At the end of the tests:

a. The motor controller must be capable of withstanding the dielectric tests described in Part 1-109 of NEMA Standards Publication No. ICS 1, and,

b. The contacts must be capable of being opened by normal operation.

NEMA Standard 1-11-1983.

.03.1 In the test covered in ICS 2-110.42, a separate source of power may be supplied to the coil of magnetically operated devices.

Authorized Engineering Information 1-11-1983.

2-110.43 TEMPERATURE RISE TEST OF COILS AND CURRENT-CARRYING PARTS

The temperature rise of the coils and current-carrying parts of contactors and controllers shall be measured simultaneously when tested in accordance with their ratings. The values shall not exceed those given in Part 1-109 of NEMA Standards Publication No. ICS 1.

NEMA Standard 11-16-1972.

2-110.80 APPLICATION OF TRANSFORMERS TO PROVIDE CONTROL CIRCUIT VOLTAGE TO MAGNETIC CONTROLLERS

Transformers used for this purpose are known as machine-tool transformers (Ref. ANSI/UL 506).

Authorized Engineering Information 3-6-1985.

.01 Transformers used with magnetic controllers shall meet the following requirements:

a. The rated primary voltage of the transformer shall be equal to the system voltage.

Exception: Transformers with a higher voltage rating than the system voltage shall be permitted to be used, but only if the following calculation results in a value of control voltage equal to the rated control voltage of the controller.

$$\text{System Voltage} \times \frac{\text{Rated Transformer Secondary Voltage}}{\text{Rated Transformer Primary Voltage}} = \text{Rated Control Circuit Voltage}$$

b. The rated secondary voltage of the transformer shall be equal to the rated control circuit voltage of the controller.

NEMA Standard 3-6-1985.

.02 The size and design of the transformer shall be such as to limit the amount the secondary voltage varies above and below the rated control circuit voltage under conditions of minimum and maximum currents as defined below.

a. *At Minimum Current* – With rated primary voltage and hertz applied, and with the sealed current of a single load, or the sealed or continuous current of the lightest load that may occur with a multiplicity of loads, the secondary voltage shall not be greater than 105 percent of the rated control circuit voltage.

This condition shall be satisfied if the open circuit secondary voltage of the transformer does not exceed 105 percent of rated secondary voltage, with rated primary voltage and hertz applied.

b. *At Maximum Current (Peak Inrush)* – The effective impedance of the transformer shall be such that, with rated voltage and hertz of the controller applied to the primary and with a load impedance corresponding to the power factor and maximum value of the load current connected to the secondary, the voltage at the secondary terminals shall be not less than 95 percent of the rated voltage of the operating coils.

This condition assures compliance with Part ICS 2-110 where individual contactors which close successfully at 85 percent of rated voltage applied directly to the contactor coil will, when operated from the secondary of a transformer, close successfully at 90 percent of rated transformer primary voltage.

NEMA Standard 3-5-1985.

2-110.100 PREVENTIVE MAINTENANCE GUIDE

See Part ICS 1-115 of NEMA Standards Publication ICS 1 for general maintenance instructions.

Authorized Engineering Information 5-25-1988.

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Part ICS 2-120
CONTROL DEVICE CONNECTORS FOR COPPER CONDUCTORS

The standards in this part apply to all other parts of this Standards Publication, unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

GENERAL

2-120.01 SCOPE

Part ICS 2-120 establishes performance and test values for non-insulated slotted head, screw-tightened pressure wire connectors provided as an integral part of equipment and intended for the field wiring of 14 AWG and smaller copper control circuit conductors.

NEMA Standard 8-20-1986.

The dimensions and performance requirements of quick connect terminals are given in NEMA Standards Publication No. DC 2, *Quick-Connect Terminals.*

Authorized Engineering Information 8-20-1986.

DESIGN TESTS AND PERFORMANCE

2-120.20 PURPOSE OF TESTS

The purpose of these tests is to verify the ability of the connector and the device to which it is attached to adequately retain and support a conductor(s).

Authorized Engineering Information 8-20-1986.

2-120.21 PERFORMANCE TESTS

The connectors shall be evaluated in accordance with UL 486E, *Equipment Wiring Terminals*, and shall meet the temperature rise requirements of Part ICS 1-109 of NEMA Standards Publication No. ICS 1 when torqued to a value of seven (7) pound-inches.

Other values of torque shall be permitted to be used for the evaluation provided the equipment is marked with the torque value.

Suggested Standard for Future Design 8-20-1986.

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Part ICS 2-125
CONTACTS FOR CONTROL CIRCUIT DEVICES

The standards in this part apply to all other parts of this Standards Publication unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

Part ICS 2-125 establishes ratings and test values for electrical contacts used in control circuit devices, regardless of the actuating means. Contact ratings and test values for other than control circuit duty are not included.

DEFINITIONS

2-125.01 CONTACT ARRANGEMENTS

Form "A" Contacts

A Form A contact arrangement is one which has single-pole single-throw normally open contacts. The function of this arrangement is to close a circuit when actuated.

NEMA Standard 11-12-1970.

Form "B" Contacts

A Form B contact arrangement is one which has single-pole single-throw normally closed contacts. The function of this arrangement is to open a circuit when actuated.

NEMA Standard 11-12-1970.

Form "C" Contacts

A Form C contact arrangement is one which has single-pole double-throw contacts with three terminals—one for normally open, one for normally closed, and one common. The function of this arrangement is to transfer a circuit when actuated.

NEMA Standard 11-12-1970.

Form "Z" Contacts

A Form Z contact arrangement is one which has single-pole double-throw contacts with four terminals, two for normally open and two for normally closed. The function of this arrangement is to open one circuit and close the other.

NEMA Standard 11-12-1970.

RATINGS

2-125.20 ALTERNATING-CURRENT CONTACTS

.01 Contact Rating Designations

In contact rating designations, the letter (not to be confused with the contact arrangement form letter shown in ICS 2-125.01) designates the continuous current-carrying thermal capability of the unit or assembly. The numerical suffix designates the maximum voltage design values of 600, 300 and 150 volts for suffixes 600, 300 and 150, respectively.

.02 Contact Ratings

The ratings and designations of contacts which make, break or carry alternating current shall be in accordance with Table 2-125-1 for 50 and 60 hertz.

For ratings at voltages between the maximum design value and 120 volts, the make and break ratings shall be obtained by dividing the voltampere rating by the application voltage. For voltages below 120 volts, the maximum make current shall be the same as that for 120 volts, and the maximum break current shall be obtained by dividing the break voltamperes by the application voltage but shall not exceed the continuous thermal current.

The maximum make values (current and voltamperes) are for the very short duration (30 milliseconds or less) involved in controlling an electromagnetic device. Make and break ratings apply for double-throw contacts only when both the normally open and normally closed contacts are connected to the same polarity.

The ratings given in Table 2-125-1 shall not be exceeded when applied to control-circuit devices.

NEMA Standard 7-14-1976.

CAUTION:

a. In most circumstances, the contacts of control-circuit devices are applied at values less than their make and break ratings. See ICS 2-125.80 and the parts of this publication relating to specific control circuit devices.
b. Contacts for control circuit devices covered by this standard may not be intended for use at very low voltages or currents and may not be suitable

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for such service. Seek the advice of the manufacturer for such applications.

c. Very low voltage or currents may be defined as being less than the value shown on a log-log graph chart by a line through one milliampere-350 volts, 50 milliamperes-28 volts, and one ampere-4 volts. See Figure 2-125-1.

Authorized Engineering Information 1-21-1987.

2-125.21 DIRECT-CURRENT CONTACTS

.01 Contact Rating Designations

In contact rating designations, the letter (not to be confused with the contact arrangement form letter shown in ICS 2-125.01) designates the continuous current-carrying thermal capability of the unit or assembly. The numerical suffix designates the maximum voltage design values of 600, 300, and 150 volts for suffixes 600, 300, and 150, respectively.

.02 Contact Ratings

The ratings and designations of contacts which make, break or carry direct current shall be in accordance with Table 2-125-2.

For ratings at 300 volts or less, the make and break ratings shall be obtained by dividing the voltampere rating by the application voltage but shall not exceed the continuous thermal current.

Make and break ratings apply for double-throw contacts only when both the normally open and normally closed contacts are connected to the same polarity.

The ratings given in Table 2-125-2 shall not be exceeded when applied to control-circuit devices.

NEMA Standard 7-14-1976.

CAUTION:

a. In most circumstances the contacts of control-circuit devices are applied at values less than their make and break ratings. See ICS 2-125.80 and the parts of this publication relating to specific control circuit devices.

b. Contacts for control circuit devices covered by this standard may not be intended for use at very low voltages or currents and may not be suitable for such service. Seek the advice of the manufacturer for such applications.

c. Very low voltage or currents may be defined as being less than the values shown on a log-log graph chart by a line through one milliampere-350 volts, 50 milliamperes-28 volts and one ampere-4 volts. See Figure 2-125-1.

Authorized Engineering Information 1-21-1987.

Table 2-125-1
RATINGS AND TEST VALUES FOR AC CONTROL CIRCUIT CONTACTS AT 50 OR 60 HERTZ (See ICS 2-125.20.02)

Contact Rating Designation	Thermal Continuous Test Current, Amperes	Maximum Current, Amperes								Voltamperes	
		120 Volts		240 Volts		480 Volts		600 Volts			
		Make	Break	Make	Break	Make	Break	Make	Break	Make	Break
A150	10	60	6.00	...	...	...	...	...	...	7200	720
A300	10	60	6.00	30	3.00	...	...	...	...	7200	720
A600	10	60	6.00	30	3.00	15	1.50	12	1.20	7200	720
B150	5	30	3.00	...	...	...	...	...	...	3600	360
B300	5	30	3.00	15	1.50	...	...	...	...	3600	360
B600	5	30	3.00	15	1.50	7.5	0.75	6	0.60	3600	360
C150	2.5	15	1.5	...	...	...	...	...	...	1800	180
C300	2.5	15	1.5	7.5	0.75	...	...	...	...	1800	180
C600	2.5	15	1.5	7.5	0.75	3.75	0.375	3.00	0.30	1800	180
D150	1.0	3.60	0.60	...	...	...	...	...	...	432	72
D300	1.0	3.60	0.60	1.80	0.30	...	...	...	...	432	72
E150	0.5	1.80	0.30	...	...	...	...	...	...	216	36

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DESIGN TESTS AND PERFORMANCE

2-125.40 GENERAL

The following design tests shall be used to demonstrate conformance with these standards but are not contemplated in normal production. The device containing the contacts being tested shall be mounted in its enclosure as it is intended to be used in service. Adjacent poles shall be connected with opposite polarity for testing unless polarity restrictions are marked on the device.

Devices with letter designation A (not to be confused with the form letter shown in ICS 2-125.01) shall be tested with 14 AWG copper wire, designation B with 20 AWG copper wire, and designation C, D, and E with 22 AWG copper wire.

Devices with letter designation N shall be tested with 14 AWG copper wire, designation P with 20 AWG copper wire, and designations Q and R with 22 AWG copper wire.

NEMA Standard 7-12-1978.

2-125.41 TEMPERATURE RISE TESTING

When tested without making or breaking current, a device with a contact rating described in this Part ICS 2-125 shall be capable of carrying thermal continuous test current without exceeding the allowable temperature rises given in Part 1-109 of NEMA Standards Publication No. ICS 1. All poles of the same mode shall be wired in series with 8 feet of wire between poles (4 feet per terminal).

Devices with letter designation A (not to be confused with the form letter shown in ICS 2-125.01) shall be tested with 14 AWG copper wire, designation B with 20 AWG copper wire, and designations C, D and E with 22 AWG copper wire. All normally open poles shall be wired in series with 4 feet of wire between poles. All normally closed poles shall be similarly wired.

Devices with letter designation N shall be tested with 14 AWG copper wire, and designation P with 20 AWG copper wire. All poles of the same mode shall be wired in series with 4 feet of wire between poles.

NEMA Standard 7-12-1978.

Table 2-125-2
RATINGS AND TEST VALUES FOR DC CONTROL CIRCUIT CONTACTS
(See ICS 2-125.21.02)

Contact Rating Designation	Thermal Continuous Test Current, Amperes	Maximum Make or Break Current, Amperes			Make or Break at 300 Volts or Less, Voltamperes
		125 Volts	250 Volts	301 to 600 Volts	
N150	10	2.2	...	...	275
N300	10	2.2	1.1	...	275
N600	10	2.2	1.1	0.40	275
P150	5.0	1.1	...	...	138
P300	5.0	1.1	0.55	...	138
P600	5.0	1.1	0.55	0.20	138
Q150*	2.5	0.55	...	...	69
Q300*	2.5	0.55	0.27	...	69
Q600*	2.5	0.55	0.27	0.10	69
R150*	1.0	0.22	...	...	28
R300*	1.0	0.22	0.11	...	28

*These lines approved as Suggested Standard for Future Design 5-20-1974.

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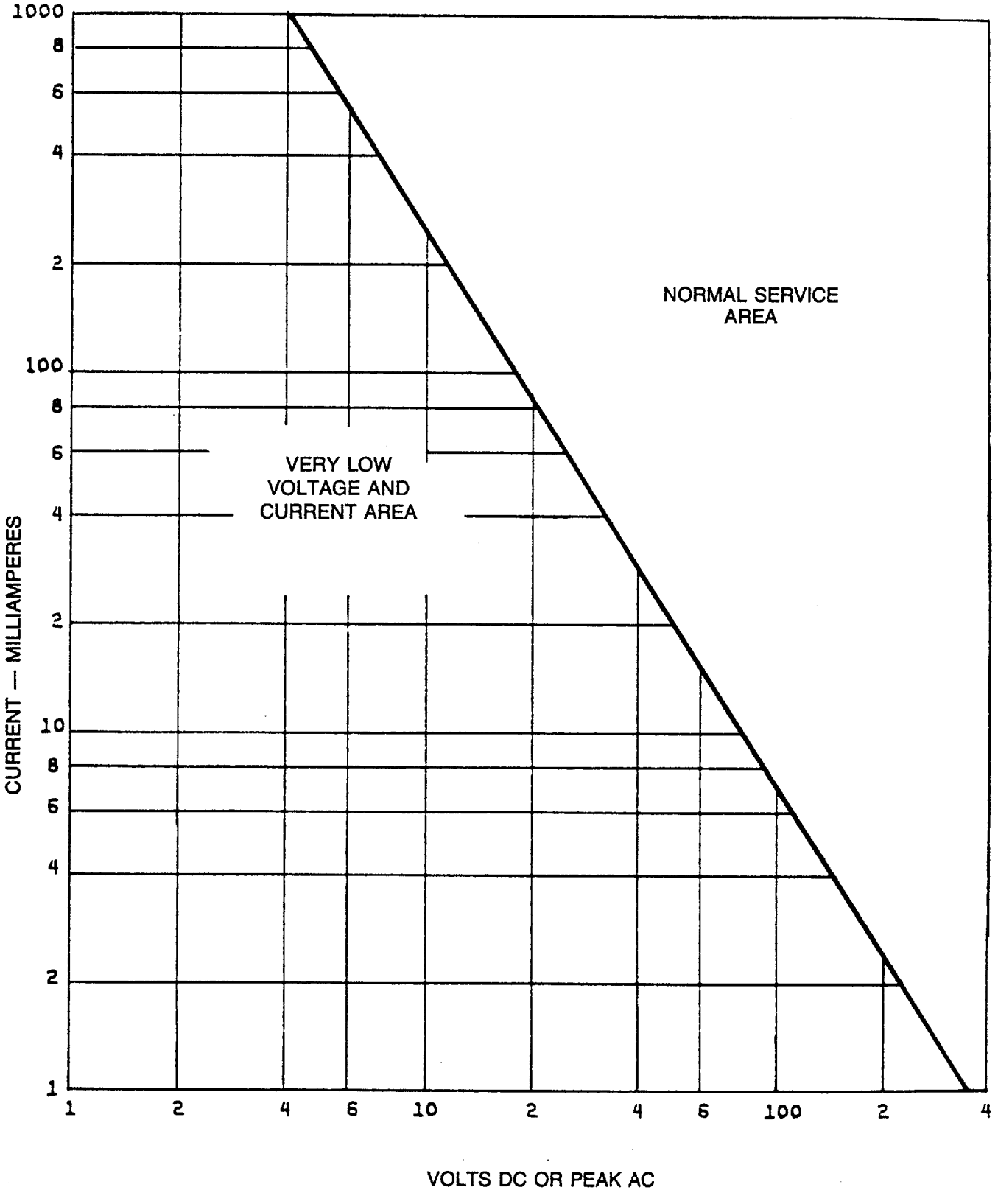


Figure 2-125-1
VERY LOW VOLTAGE AND CURRENT VALUES

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2-125.42 OVERLOAD TESTING OF AC AND DC CONTACTS

.01 Test Conditions

The overload test shall consist of 50 operations of making and breaking 110 percent of the maximum make and break amperes shown in Tables 2-125-1 and 2-125-2 at 110 percent of each applicable voltage. The fifty operations shall be evenly spaced and shall be performed at the rate of six operations per minute. The circuit controlled by the contacts shall be closed for approximately 1 second during each operation.

.02 Test Criteria

There shall be no electrical or mechanical failure of the device, nor any undue burning, pitting or welding of the contacts.

NEMA Standard 1-17-1974.

2-125.43 ENDURANCE TESTING OF AC AND DC CONTACTS

.01 Test Conditions

The endurance test shall be made on the same contacts which were used for the overload test. The test shall consist of 6000 operations of making and breaking the make and break amperes, respectively, specified in Tables 2-125-1 or 2-125-2 at each applicable voltage, except that contacts rated 301 volts to 600 volts shall be tested at 600 volts.

The first 12 operations shall be at maximum speed, and the contacts shall be operated by a manual control. The contacts on test do not break make current. The next 988 operations shall be at the rate of one operation per second. For these first 1000 operations, the on time shall be approximately equal to the off time.

The last 5000 operations shall be made at the rate of six operations per minute, and the circuit controlled by the device shall be closed for approximately 1 second during each operation.

Devices which have both normally open and normally closed contacts shall be tested in both modes, with adjacent poles at opposite polarities and in the pole configuration which represents the most severe case permitted by the instructions accompanying the device.

.02 Test Criteria

There shall be no electrical or mechanical failure of the device, nor any undue burning, pitting, or welding of the contacts.

NEMA Standard 1-17-1974.

2-125.44 TESTING OF AC CONTACTS FOR EMERGENCY CONDITIONS

Alternating-current contacts shall be capable of interrupting their rated make current or voltamperes in an emergency. The test to verify conformance shall be made on contacts which have completed the endurance test and shall consist of making and breaking a current equal to 100 percent of the make current shown in Table 2-125-1 at 100 percent of each applicable voltage. The test shall consist of six operations at the rate of six per minute with the contacts closed for approximately 1 second during each operation. There shall be no electrical or mechanical failure of the device.

NEMA Standard 11-12-1970.

2-125.45 TEST LOADS FOR AC CONTACTS

The test load shall have a lagging power factor of 0.35 or less. The loads shall consist of any combination of electromagnets which results in the make and break amperes shown in Table 2-125-1 and specified power factor, except that, if loads in parallel are used, all such parallel loads shall have the same coils, the same magnets and the same air gaps. A recommended test circuit is shown in Figure 2-125-2.

NEMA Standard 11-12-1970.

2-125.46 INDUCTIVE TEST LOADS FOR DC CONTACTS

.01 Construction

The following inductive test loads shall be used to approximate the loads imposed upon contacts used in direct-current control circuits.

The magnetic circuit shall be made up of two solid steel cores, 1.75 inches in diameter and 6.25 inches long, which are fastened by screws at each end to solid steel yokes 1 × 2½ × 6 inches on 4-inch centers (see Figure 2-125-3). The steel shall have a resistance of between 80 and 120 ohms per circular mil-foot. (Cold-finished low-carbon steels such as AISI 1010, 1015, 1018, or 1116 meet this requirement.) At one end of each core, a nonmagnetic spacer having a thickness adjustable to between 0.005 and 0.030 inch shall be interposed between the end of the core and the yoke. Nonmagnetic screws shall be used to hold the yoke at the end having the nonmagnetic spacer, and steel screws shall be used at the other end.

A coil having the winding characteristics shown in Table 2-125-3 shall surround one of the cores. The current in the coil, when energized at the test voltage, shall be adjusted to the value specified in the table by means of a series resistor.

The thickness of the spacer shall be adjusted so that the coil current will build up from the instant of energization to 95 percent of its full value ($T_{0.95}$) in 270 to 330 milliseconds. If the range of adjustment results in a 95 percent charge time less than 270 milliseconds, the yokes shall be increased in cross section. Conversely, if the range of adjustment results in a 95 percent charge

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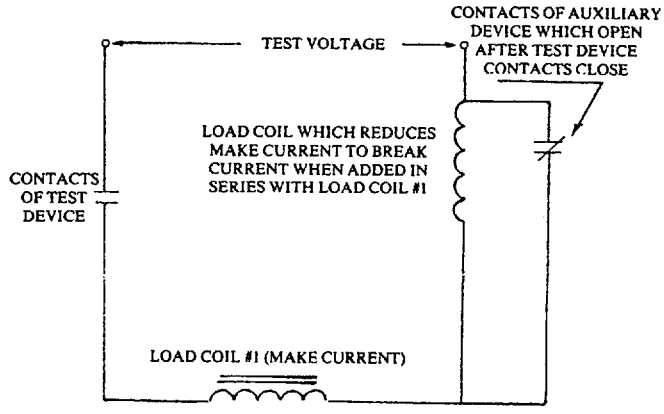


Figure 2-125-2
RECOMMENDED TEST CIRCUIT FOR CONTACTS

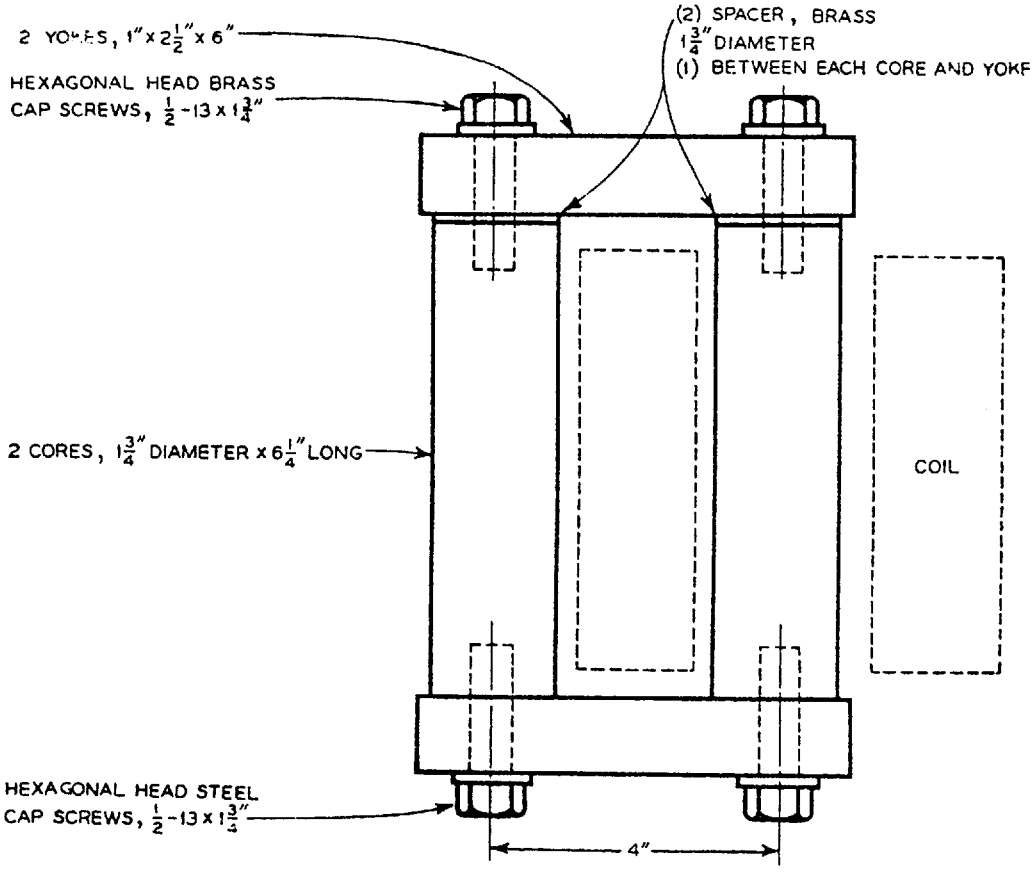


Figure 2-125-3
CONSTRUCTION OF LOAD FOR DC CONTACTS

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time greater than 330 milliseconds, the cross section of the yokes and/or cores shall be reduced.

NEMA Standard 1-17-1974.

.02 Explanation

The direct-current inductive loads found in control circuits are usually electromagnetically driven relays, contactors and solenoids rated 50 watts or less. The severity of these loads on the contacts of the control device is determined by the stored energy of the inductor which, in turn, is related to the average rate of rise of the current in the inductor or to the charging time of the inductor. It has been empirically determined that inductive loads up to 50 watts in size almost always have a charging time ($T_{0.95}$) to 95 percent of their full current value of 6 milliseconds per watt or less.

When the test load is intended to represent loads totalling more than 50 watts, the $T_{0.95}$ charging time of the test inductor shall be 270 to 330 milliseconds.

Test loads for coils of less than 50 watts may be designed on the basis of a 95 percent charging time ($T_{0.95}$) equal to 6 times the watts.

Authorized Engineering Information 1-17-1974.

TABLE-2-125-3
DC LOADS

Test Voltage, Volts	Coil Construction: Number of Turns	Coil Construction: Wire Size, AWG	Approximate Coil Resistance, Ohms	Series Resistor Limits Current to, Amperes	Voltamperes at Test Voltage	$T_{0.95}$,* Milliseconds (±10 %)
125	7000	20	74	1.1	138	300
250	14000	23	295	0.55	138	300
600	33400	27	1680	0.20	120	300

*$T_{0.95}$ = time to reach 95 percent of final current after application of test voltage to the load.

MANUFACTURING

2-125.60 COLOR CODING OF FACTORY-WIRED, CORD-CONNECTED CONTROL CIRCUIT DEVICES

The color coding used in multiconductor cables to identify the terminals associated with the contacts of a factory-wired, cord-connected control circuit device shall be in accordance with Table 2-125-4. When an insulated grounding conductor is supplied, it shall be green or green with one or more yellow stripes.

NEMA Standard 11-3-1983.

Table 2-125-4
CONDUCTOR COLOR IN MULTICONDUCTOR CABLE

Contact Arrangements (ICS 2-125.01)	When Insulated Grounding Conductor is Provided: Conductors	When Insulated Grounding Conductor is Provided: Color	When Insulated Grounding Conductor is NOT Provided: Conductors	When Insulated Grounding Conductor is NOT Provided: Color
A or B	3	Black, White, Green	2	Black, White
C	4	Black, White, Red,* Green	3	Black, White, Red*
Z or two A's or two B's	5	Black, White, Red, Orange, Green	4	Black, White, Red, Orange

*For Form C contact arrangements, red identifies the common terminal.

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APPLICATION

2-125.80 CONTACT LIFE

The life of control circuit contacts depends upon the magnitude and characteristics of the electrical load, inductance, duty cycle, mechanical properties of the device in which they are used, voltage fluctuations, environment, etc. When control circuit devices are operated at maximum rated load, the life of the contacts is usually less than that of the remainder of the device. If the application requires a large number of operations during the life of the contacts, the contacts must be applied at values much less than their maximum make and break ratings. See the parts of this publication relating the specific control circuit devices.

Authorized Engineering Information 11-12-1970.

2-125.81 POLARITY

Polarity, as applied to contacts and terminals (see Figure 2-125-4), is a term which is used to describe the relationship between the load and line connections to a multicircuit switch. When two or more sets of contacts are so connected in a circuit that a short circuit will not occur when all of the terminals of these contacts are made electrically common, these contacts are said to be connected to the same polarity.

When a short circuit will occur, these contacts are said to be of opposite polarity.

Authorized Engineering Information 9-20-1972.

2-125.82 POLARITY MARKING

When the contacts of a control circuit device are not suitable for use on opposite polarity, the manufacturer shall designate these contacts as being suitable for use only on the same polarity.

NEMA Standard 9-20-1972.

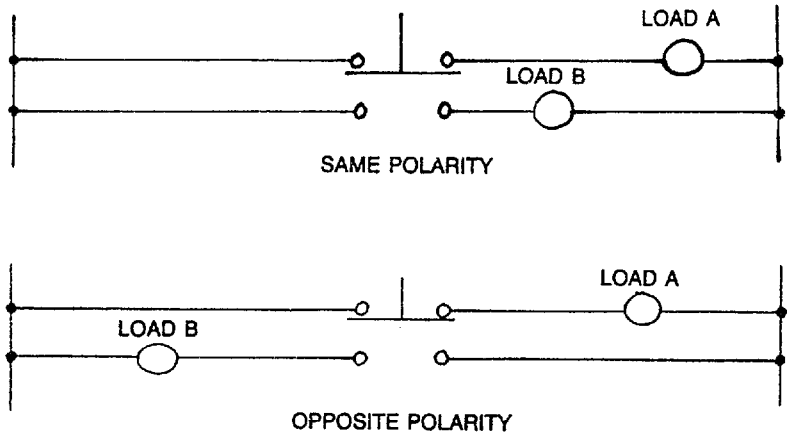


FIGURE 2-125-4
POLARITY

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Part ICS 2-126

SEMICONDUCTOR SWITCHING ELEMENTS FOR CONTROL CIRCUIT DEVICES

The Standards in this Part apply to all other Parts of this Standard Publication unless otherwise specified. The definitions and standards of NEMA Standards Publication ICS 1 also apply to this Part.

Part ICS 2-126 establishes ratings and test procedures for semiconductor switching elements for control circuit devices. Ratings for semiconductor devices other than control circuit switching element applications are not included.

DEFINITIONS

2-126.01 SWITCHING ELEMENT RATING PARAMETERS

RATED OPERATIONAL CURRENT (I_e)

A value I_e of current which determines the application of the switching element. It is assigned by the manufacturer and takes into account the rated operational voltage, the rated supply frequency, and the utilization category.

A switching element shall be permitted to be assigned a number of combinations of rated operational voltage and rated operational current. The rated operational current shall be stated in relation to the utilization category.

RATED MINIMUM OPERATIONAL CURRENT

The current that is necessary to maintain on-state conduction of the switching element.

RATED OPERATIONAL VOLTAGES (U_e)

A value U_e of voltage, assigned by the manufacturer, which, in combination with a rated operational current, determines the application of the switching element and to which the utilization categories are referred.

RATED INSULATION VOLTAGE (U_i)

The rated insulation voltage of an equipment is the value of voltage to which dielectric voltage test and creepage distances are referred.

For equipment not having a specified rated insulation voltage, the highest value of any rated voltages shall be considered to be the rated insulation voltage.

2-126.02 SWITCHING ELEMENT OPERATIONAL PARAMETERS

OFF-STATE CURRENT

The current which flows through the load when the device is in the off-state.

ON-STATE VOLTAGE DROP

The voltage measured across the semiconductor switching element in the on-state at a stated current.

CONDITIONS OF USE

The principal application of a control switch is the switching of loads as indicated for the various utilization categories in Table 2-126-1.

NORMAL CONDITIONS OF USE

The normal use of a control switch is to close, maintain, and open circuits which contain an electromagnet, the magnetic circuit which is open at the time when the coil current is made and closed when the coil current is broken.

ABNORMAL CONDITIONS OF USE

Abnormal conditions arise when an electromagnet, although energized, has failed to close, or when a transformer core is saturated.

A control switch is required to be able to break the current corresponding to such abnormal condition of use.

UTILIZATION CATEGORY

The utilization category of an equipment defines the intended application of a product.

Each utilization category is characterized by the values of currents, voltages, power-factors or time-constants, and other data specified in this standard.

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RATINGS

2-126.20 SWITCHING ELEMENT RATINGS

.01 The rating of a switching element shall include:

1. The utilization category,
2. The rating designation, and
3. The rated operational voltage, U_e.

.02 The utilization categories as given in Table 2-126-1 are considered standard. Any other types of application shall be based on agreement between manufacturer and user.

.03 Ratings of semiconductor control circuit switching elements shall be in accordance with Tables 2-126-2 (AC ratings) and 2-126-3 (DC ratings).

In the alphanumeric rating designations, the first letter, S, designates a semiconductor switching element. The second letter designates the rated operational current.

NEMA Standard 7-22-1987.

Semiconductor switching elements may have a rated operational current less than shown in Tables 2-126-2 and 2-126-3 for operation in higher ambient temperatures.

Authorized Engineering Information 7-22-1987.

Table 2-126-1
UTILIZATION CATEGORIES FOR SWITCHING ELEMENTS

Kind of Current	Category	Typical Applications
Alternating-Current	AC-12	Control of resistive loads and solid state loads with optical isolation.
	AC-13	Control of solid state loads with transformers isolation.
	AC-14	Control of small electromagnetic loads (max. 72 VA closed).
	AC-15	Control of electromagnetic loads (greater than 72 VA closed).
Direct- Current	DC-12	Control of resistive loads and solid state loads with optical isolation.
	DC-13	Control of electromagnets.
	DC-14	Control of electromagnet loads having economy resistors in circuit.

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Table 2-126-2
RATINGS FOR AC SEMICONDUCTOR CONTROL CIRCUIT SWITCHING ELEMENT AT 50 OR 60 HERTZ[1,2]

Switching Element Rating Designation	Rated Operational Current I_e (Amperes)[3]	Rated Make Current—Amperes				Rated Minimum Operational Current (Amperes)
		AC-15	AC-14	AC-13	AC-12	
SA	10	100	60	20	10	.1
SB	5	50	30	10	5	.1
SC	2	20	12	4	2	.1
SD	1	10	6	2	1	.05
SE	.5	5	3	1	.5	.02
SF	.25	2.5	1.5	.5	.25	.01
SG	.1	1	.6	.2	.1	.01

[1]Rated operational voltage shall be specified by the manufacturer as either:
a) Utilization voltage, with a tolerance range of +10−15%. Preferred utilization voltages are 24, 48, 120, and 240 VAC. Rated insulation voltage of devices specified in this manner shall be based on operational voltage.
b) Minimum and maximum voltage. Rated insulation voltage of devices specified in this manner shall be based on the maximum voltage.

[2]Maximum RMS on-state voltage drop and off-state RMS current shall be specified by the manufacturer. This maximum value shall include all combinations of operating current, voltage, and temperature.

[3]When the operational current rating is based on the use of a user furnished external heat sink or mounting means, the manufacturer shall clearly identify this requirement.

NEMA Standard 7-22-1987.

Table 2-126-3
RATINGS FOR DC SEMICONDUCTOR CONTROL CIRCUIT SWITCHING ELEMENTS[1,2]

Switching Element Rating Designation	Rated Operational Current I_e (Amperes)[3]	Rated Make Current—Amperes		
		DC-14	DC-13	DC-12
SN	10	100	10	10
SP	5	50	5	5
SQ	2	20	2	2
SR	1	10	1	1
SS	.5	5	.5	.5
ST	.25	2.5	.25	.25
SU	.1	1	.1	.1
SV	.05	.5	.05	.05

[1]Rated operational voltage shall be specified by the manufacturer as either:
a) Utilization voltage, with a tolerance range of +10−15%. Preferred utilization voltages are 24, 48, 125, 250 VDC. Rated insulation voltage of devices specified in this manner shall be based on rated operational voltage.
b) Minimum and maximum voltage. Rated insulation voltage of devices specified in this manner shall be based on the maximum voltage.

[2]Maximum on-state voltage drop and off-state current shall be specified by the manufacturer. This maximum value shall include all combinations of operating current, voltage, and temperature.

[3]When the operational current is based on the use of a user furnished external heat sink or mounting means, the manufacturer shall clearly identify this requirement.

NEMA Standard 7-22-1987.

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DESIGN TESTS AND PERFORMANCE

2-126.40 General

The following design (type) tests shall be used to demonstrate conformance with these standards. The device containing the switching element to be tested shall be mounted as intended to be used in service. If the device has more than one switching element, adjacent switching elements shall be wired with opposite polarity unless otherwise noted by the manufacturer.

NEMA Standard 7-22-1987.

2-126.41 Temperature Test

.01 Test Conditions

When tested without making or breaking current, a switching element shall be tested carrying its rated operational current. If the switching element rating is based on the use of a heat sink or mounting means, a suitable heat sink or mounting means as supplied or recommended by the manufacturer shall be used for these tests.

Switching elements designated with the prefix SA and SN shall be tested with AWG 14 copper wire, switching elements with prefix SB and SP, with AWG 20 copper wire and the balance with AWG 22 copper wire. The length of wire connected to each terminal shall be 1.2 meters (4 feet).

NEMA Standard 7-22-1987.

.02 Test Criteria

Busses, connecting straps, terminals, and insulating systems shall not exceed the allowable temperature rise specified in Part ICS 1-109 for these items.

NEMA Standard 7-22-1987.

2-126.42 Verification of Make and Break Capability

.01 The tests are intended to verify that the switching element is capable of performing its intended duty according to the utilization category, rating designation, and conditions of use.

NEMA Standard 7-22-1987.

.02 Normal Conditions of Use

A switching element shall be tested in accordance with Table 2-126-4.

The first 50 operations shall be run at $U/U_e = 1.1$ with the loads set to yield the specified load currents of I/I_e when $U/U_e = 1$. This is the overload segment of the test.

The next 6000 operations shall be run at $U/U_e = 1$ and shall make and break the test circuit as specified in Table 2-126-4. The test shall be performed in the following sequences.

1. The first 1000 operations shall be at the rate of 1 operation per second except the first 10 operations shall be manual operations made as rapidly as possible while making sure of the actual operation of the switching element.
2. When the construction of the device is such that rapid manual operation is not possible, the rate of operation shall be 6 operations per minute or as fast as the device will permit.
3. The remaining 5000 operations shall be at the rate of 6 operations per minute with the switching element conducting for the specified on-time.

NEMA Standard 7-22-1987.

.03 Abnormal Conditions of Use

The test shall be made on switching elements which have completed the normal conditions test and shall consist of making and breaking the values shown in Table 2-126-5. The test shall consist of 10 operations at the rate of 6 per minute with the switching element closed for 0.5 second during each operation.

NEMA Standard 7-22-1987.

.04 Test Loads for AC Switching Elements

The loads shall consist of any combination of electromagnets or air core loads and resistors which results in a minimum 2 cycle make current and rated operational current shown in Table 2-126-2. If loads in parallel are used, all such parallel loads shall be identical. An example of a test circuit is shown in Figure 2-126-1. The test load power factor shall be as specified in Tables 2-126-4 and 2-126-5.

NEMA Standard 7-22-1987.

.05 Test Loads for DC Switching Elements

The test load shall have a resistance to yield the final currents described in Table 2-126-3 and the rise times described in Tables 2-126-4 and 2-126-5. If loads in parallel are used, all such parallel loads shall be identical.

NEMA Standard 7-22-1987.

.06 Test Criteria

During the test, there shall be no electrical or mechanical failures. After the test, the switching element shall meet the dielectric requirements of ICS 2-110.

NEMA Standard 7-22-1987.

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Table 2-126-4
VERIFICATION OF MAKING AND BREAKING CAPABILITIES OF SWITCHING ELEMENTS UNDER NORMAL CONDITIONS OF USE

Utilization Category	MAKE				BREAK				Sequence, Number and Rate Of Operations for Make and Break Tests, Applicable to All Utilization Categories			
	I/I_e	U/U_e	$T_{0.95}$	Power Factor (Cos θ)	I/I_e	U/U_e	$T_{0.95}$	Power Factor (Cos θ)	Test Sequence	Opera.	Ops./Min.	On Time (Sec)[3]
AC-12	1	1	—	0.9	1	1	—	0.9	1	50	6	0.05
AC-13	2	1	—	0.65	1	1	—	0.65	2	10	Rapid Manual Operations	—
AC-14	6	1	—	0.3	1	1	—	0.3				
AC-15	10	1	—	0.3	1	1	—	0.3	3	990	60	0.05
DC-12	1	1	1 ms	—	1	1	1 ms	—				
DC-13	1	1	[6P] ms[2]	—	1	1	[6P] ms[2]	—	4	5,000	6	0.05
DC-14	10	1	15 ms	—	1	1	15 ms	—				

I_e = rated operational current

U_e = rated operational voltage

$T_{0.95}$ = time to reach 95% of the steady-state current in milliseconds

$P = U_e I_e$ = Steady-state power consumption, in watts

I = Test current, make or break

U = Test voltage, open circuit (before make)

NOTES:

[1]The first 50 operations shall be run at $U/U_e = 1.1$ with the loads set at U_e.

[2]The value of "[6P] ms" results from an empirical relationship which is found to represent moderate DC magnetic loads. The maximum time constant shall not exceed 60 ms.

[3]The I/I_e make current for AC switching elements shall be two cycles in duration. The remainder of the on-time shall be at the I/I_e break current. The duration of the on-time may have to be extended to provide time for switching the test circuit from make current to break current, or to permit the DC test current to reach the $T_{.095}$ value.

Table 2-126-5
VERIFICATION OF MAKING AND BREAKING CAPABILITIES OF SWITCHING ELEMENTS UNDER ABNORMAL CONDITIONS OF USE

Utilization Category	MAKE				BREAK				Number and Rate Of Operations for All Utilization Categories		
	I/I_e	U/U_e	$T_{0.95}$	Power Factor (Cos θ)	I/I_e	U/U_e	$T_{0.95}$	Power Factor (Cos θ)	No. of Operations	Opera. per Minute	On Time Seconds[3]
AC-12	—	—		—	—	—		—			
AC-13[2]	10	1.1		0.65	1.1	1.1		0.65			
AC-14	6	1.1		0.3	.6	1.1		0.3			
AC-15	10	1.1		0.3	10	1.1		0.3	10	6	.05
DC-12	—	—		—	—	—		—			
DC-13[2]	1.1	1.1	[6P] ms[1]		1.1	1.1	[6P] ms[1]				
DC-14	10	1.1	15 ms		10	1.1	15 ms				

I_e = rated operational current

U_e = rated operational voltage

$T_{0.95}$ = time to reach 95% of the steady-state current in milliseconds

$P = U_e I_e$ = Steady-state power consumption, in watts

I = Test current, make or break

U = Test voltage, open circuit (before make)

NOTES:

[1]The value of "[6P] ms results from an empirical relationship which is found to represent moderate DC magnetic loads. The maximum time constant shall not exceed 60 ms.

[2]An overload protection device specified by the manufacturer should be used to protect the semiconductor or switching element during this test.

[3]For AC-13 switching elements, the I/I_e make current shall be one-half cycle in duration. The duration of break current of the on-time may have to be extended to provide time for switching the test circuit from make current to break current, or to permit the DC test current to reach the $T_{0.95}$ value.

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APPLICATIONS

2-126.80 Application Considerations

Refer to ICS 1.1, *Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control,* with particular emphasis upon personnel safety for safety requirements when applying solid state devices.
NEMA Standard 7-22-1987.

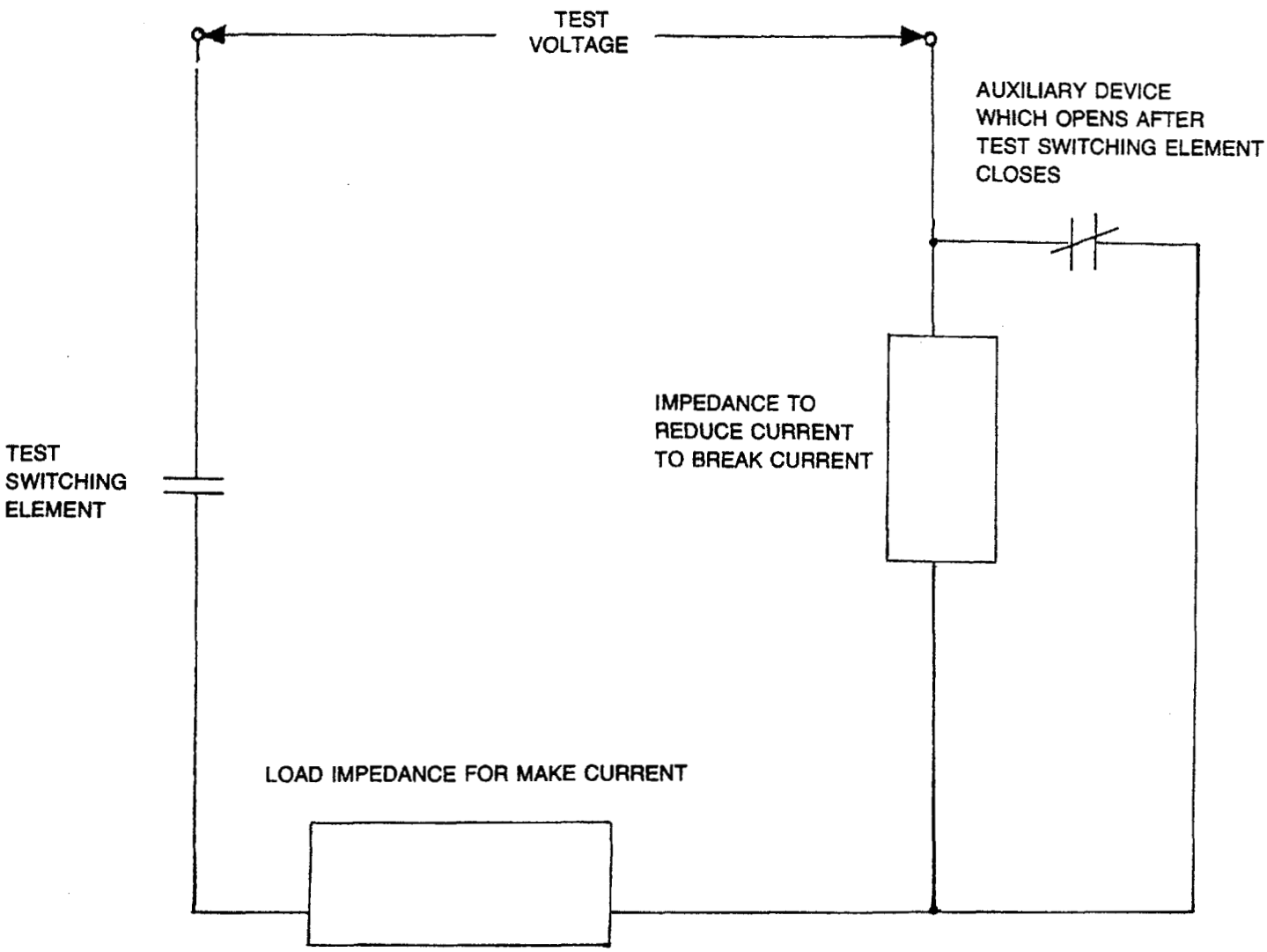


Figure 2-126-1
RECOMMENDED TEST CIRCUIT FOR AC SWITCHING ELEMENTS

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Part ICS 2-210

AC GENERAL-PURPOSE MAGNETIC CONTACTORS, 600 VOLTS AND LESS, 50 AND 60 HERTZ

Part ICS 2-210 applies to the contactor portion of the controllers covered by Parts ICS 2-321 and ICS 2-327. Part ICS 2-110 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

RATINGS

2-210.20 MOTOR LOAD APPLICATIONS

For motor load ratings and applications, see other parts of this publication, such as Parts ICS 2-321 and ICS 2-327.

Authorized Engineering Information 1-17-1974.

2-210.21 NONMOTOR LOAD APPLICATIONS—RATINGS OF THE CONTACTOR PORTION OF THE CONTROLLERS IN PARTS ICS 2-321 AND ICS 2-327

.01 For Applications Shown in Table 2-210-1

The ratings shall be in accordance with Table 2-210-1.

NEMA Standard 9-20-1978.

These ratings are based on the use of two poles to control the load for single phase (Figure 2-210-1) or three poles to control the load for three phases (Figure 2-210-2) up to 600 volts maximum.

For single-pole control of single-phase load with one line grounded (Figure 2-210-3), the maximum voltage rating is 300 volts.

Authorized Engineering Information 9-20-1978.

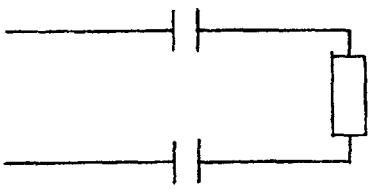


Fig. 2-210-1
SINGLE-PHASE LOAD

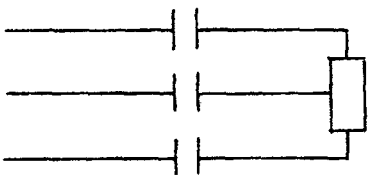


Fig. 2-210-2
THREE-PHASE LOAD

.02 For Capacitor Switching

Contactors are used to switch capacitors under three general conditions (see Figure 2-210-4).

a. In association with a motor for individual motor power factor correction.
b. To switch a single capacitor or single capacitor bank into and out of an electrical distribution system. See Tables 2-210-1 through 2-210-4.
c. To switch a single capacitor or single capacitor bank into and out of an electrical distribution system which has other capacitor banks already operating in the system. See Tables 2-210-1 through 2-210-4.

Authorized Engineering Information 9-20-1978.

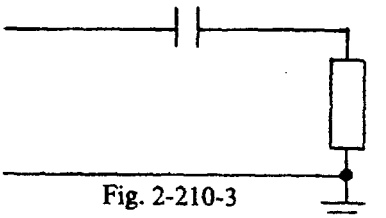


Fig. 2-210-3
SINGLE-PHASE LOAD—
ONE LINE GROUNDED

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Table 2-210-1
GENERAL-PURPOSE CONTACTOR RATINGS

Size of Contactor	Direct Load Switching RMS Ampere Rating: Continuous Carrying Current, RMS Amperes		Maximum Circuit-closing Inrush Current (Amps Peak Including Offset)	Tungsten Lamp Loads, 300 Volts Maximum†	Resistive Loads and Electric Discharge Lamp Loads‡		Transformer Primary Switching kVa Rating Open or Enclosed											
							Transformers Having Inrush Currents (Worst Case Peak) of Not More than 20 Times Peak of Continuous-current Rating								Transformers Having Inrush Currents (Worst Case Peak) of Over 20 Through 40 Times Peak of Continuous-current Rating							
							Single Phase Volts				Three Phase Volts				Single Phase Volts				Three Phase Volts			
	Enclosed*	Open	Open or Enclosed*	Open or Enclosed*	Enclosed*	Open	120	240	480	600	208	240	480	600	120	240	480	600	208	240	480	600
00	9	10	87	5	9	10																
0	18	20	140	10	18	20	0.6	1.2	2.4	3	1.8	2.1	4.2	5.2	0.3	0.6	1.2	1.5	0.9	1.0	2.1	2.6
1	27	30	288	15	27	30	1.2	2.4	4.9	6.2	3.6	4.3	8.5	11	0.6	1.2	2.5	3.1	1.8	2.1	4.3	5.3
2	45	50	483	30	45	50	2.1	4.1	8.3	10	6.3	7.2	14	18	1.0	2.1	4.2	5.2	3.1	3.6	7.2	8.9
3	90	100	947	60	90	100	4.1	8.1	16	20	12	14	28	35	2.0	4.1	8.1	10	6.1	7.0	14	18
4	135	150	1581	120	135	150	6.8	14	27	34	20	23	47	59	3.4	6.8	14	17	10	12	23	29
5	270	300	3163	240	270	300	14	27	54	68	41	47	94	117	6.8	14	27	34	20	24	47	59
6	540	600	6326	480	540	600	27	54	108	135	81	94	188	234	14	27	54	68	41	47	94	117
7	810	900	9470		810	900																
8	1215	1350	14205		1215	1350																
9	2250	2500	25380		2250	2500																

* Enclosed ratings apply in any type of enclosure.
† Tungsten lamp loads include infra-red lamps having tungsten filaments.
‡ Electric discharge lamps are those such as fluorescent, mercury vapor, etc.

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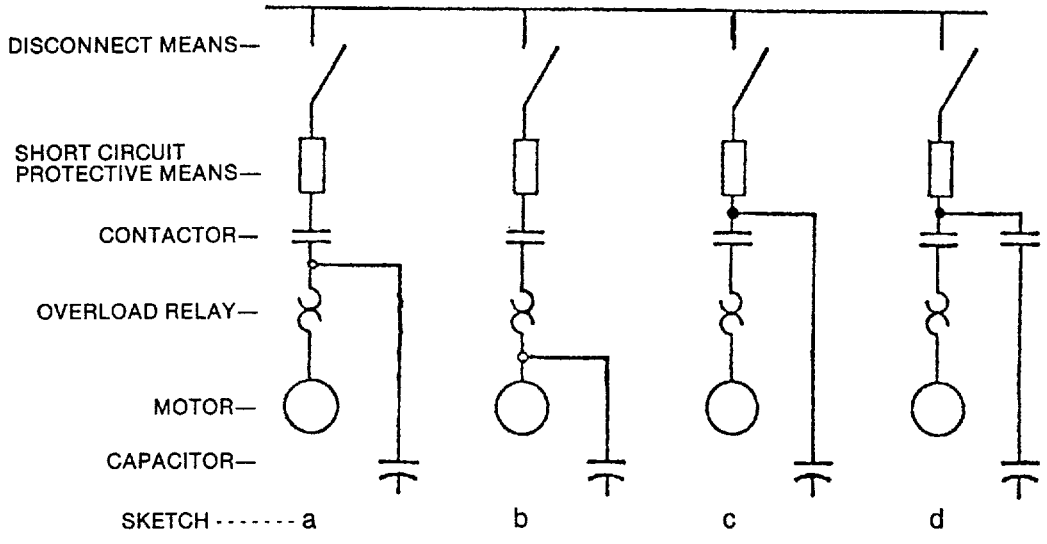


Fig. 2-210-4
METHODS OF CONNECTING POWER FACTOR CORRECTION CAPACITORS

Table 2-210-2
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 230 VOLTS 60 HZ

Size of Controller	Continuous Ratings RMS Amperes	Three-phase Rating of Capacitor · Maximum Size of Three-phase Capacitor in kVar for Available Current* in Amperes RMS Sym.					
		3000	5000	10,000	14,000	18,000	22,000
2	45	12	8	4	3	2	2
3	90	27	27	15	11	9	7
4	135	40	40	40	30	24	20
5	270	80	80	80	80	80	75
6	540	160	160	160	160	160	160
7	810	240	240	240	240	240	240
8	1215	360	360	360	360	360	360
9	2250	665	665	665	665	665	665

* Available at capacitor terminals.

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Table 2-210-3
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 460 VOLTS 60 HZ

Size of Controller	Continuous Ratings RMS Amperes	Three-phase Rating of Capacitor					
		Maximum Size of Three-phase Capacitor in kVar for Available Current* in Amperes RMS Sym.					
		3000	5000	10,000	14,000	18,000	22,000
2	45	25	16	8	6	4	4
3	90	53	53	31	23	18	15
4	135	80	80	80	61	49	41
5	270	160	160	160	160	160	149
6	540	320	320	320	320	320	320
7	810	480	480	480	480	480	480
8	1215	720	720	720	720	720	720
9	2250	1325	1325	1325	1325	1325	1325

* Available at capacitor terminals.

Table 2-210-4
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 575 VOLTS 60 HZ

Size of Controller	Continuous Ratings RMS Amperes	Three-phase Rating of Capacitor					
		Maximum Size of Three-phase Capacitor in kVar for Available Current* in Amperes RMS Sym.					
		3000	5000	10,000	14,000	18,000	22,000
2	45	31	20	10	7	6	5
3	90	67	67	39	29	23	19
4	135	100	100	100	77	61	51
5	270	200	200	200	200	200	189
6	540	400	400	400	400	400	400
7	810	600	600	600	600	600	600
8	1215	900	900	900	900	900	900
9	2250	1670	1670	1670	1670	1670	1670

*Available at capacitor terminals.

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The kilovar ratings of enclosed, three-phase, alternating-current, low-voltage contactors employed as magnetic switches for power capacitor load, when only one such load appears on the secondary of a distribution system, shall be as shown in Tables 2-210-2 through 2-210-4. See ICS 2-210.81 for application information.

NEMA Standard 9-20-1978.

When more than a capacitor load appears on the secondary of a distribution system, capacitors may be applied in accordance with Tables 2-210-2 through 2-210-4 provided the capacitor surge current does not exceed the maximum shown in Table 2-210-1 for contactor size.

NEMA Standards Publication No. CP 1 requires shunt capacitors to operate satisfactorily at 135 percent of rated kVar and notes that the actual kVar capacity of a shunt capacitor may be greater than rated kVar due to manufacturing tolerances and electrical system variations. The potentially higher inrush current of such capacitors should be considered in selecting contactor switching.

Contactors used in capacitor circuits where there is a high available fault current should be protected by suitable short-circuit protective means.

Authorized Engineering Information 9-20-1978.

DESIGN TESTS AND PERFORMANCE

The design tests of Part ICS 2-110 apply to Part ICS 2-210.

APPLICATION

2-210.80 APPLICATION GUIDE

The following load characteristics should be considered when selecting contactors for non-motor loads:

a. Maximum circuit-closing inrush current and duration.
b. Maximum circuit interrupting current, voltage, power factor, and wave form.
c. Frequency of operation and "ON" time.
d. Rms current based on averaging time of duty cycle if other than continuous duty.

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in these NEMA Standards. Manufacturers' recommendations should be obtained regarding specific applications.

A maintenance program and schedule should be established to meet the needs of each particular installation to assure minimum down time. The program should include, for example, tightening connections, inspecting for evidence of overheating, removing dust and dirt, and replacing contacts when worn or when the contact follow-up and pressure have been reduced to a level which might impair the operation of the equipment.

Authorized Engineering Information 1-17-1974.

2-210.81 CAPACITOR APPLICATIONS

.01 Motors with Power Factor Correction Capacitors

Capacitors used for power factor correction should be selected using the capacitor manufacturer's application data. Methods of connecting power factor correction capacitors are shown in Fig. 2-210-4.

When the capacitor is connected ahead of the overload relay (as shown in Fig. 2-210-4, sketch a, c, or d), the overload relay current elements should be selected using the full-load motor current and service factor values specified on the nameplate of the motor. When the capacitor is connected behind the overload relay (as shown in sketch b of Fig. 2-210-4), the overload relay manufacturer's instructions should be followed in selecting current elements, since the overload relay in this case will respond to the vector sum of the motor and capacitor currents.

Power factor correction capacitors should be switched by a separate contactor (Fig. 2-210-4, sketch d) under any of the following conditions:

a. High inertia load.
b. Open circuit transition reduced voltage starting.
c. Wye-delta motor.
d. Reversing or frequently jogged motor.
e. Multispeed motors.

(Also see NEMA Standards Publication No. MG 2, *Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators.*)

.02 Capacitor Bank Switching

When discharged, a capacitor has essentially zero impedance. For repetitive switching by contactors, sufficient impedance should be connected in series with the capacitor bank to limit the inrush current to not more than the maximum circuit closing inrush current from Table 2-210-1. In many installations, the impedance of connecting conductors may be sufficient for this purpose.

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When switching to connect an additional bank, the banks already on the line may be charged and can supply additional available short-circuit current which should be considered when selecting impedance to limit the current.

.03 Limiting Capacitor Surge Current

One method of limiting the surge current is to add inductance in the capacitor conductors. A simple air-core reactor may be made by forming a coil approximately 6 inches in diameter (ID), in each of the capacitor conductors, properly sized for the application. For systems voltages up to 250 volts, six turns have been found to be adequate; and for voltages up to 600 volts, eight turns have been found to be adequate.

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Part ICS 2-211

MAGNETIC LIGHTING CONTACTORS

Part ICS 2-211 applies to alternating-current contactors, rated 600 volts or less, designed for the control of tungsten lamp and electric discharge lighting loads. Part ICS 2-110 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

RATINGS

2-211.20 CONTACTOR RATINGS

The maximum continuous current rating, open or enclosed, when the load is connected directly to the load terminals of the contactor, shall be 30, 60, 75, 100, 150, 200, 225, 300, 400, or 600 amperes.

When magnetic lighting contactors are used as switching elements to control the primaries of transformers supplying lighting loads, and unless they are otherwise rated, the continuous current rating shall be reduced as follows.

a. For transformers having inrush currents (worst case peak) not more than 20 times the peak continuous current rating, derate to 50 percent.

b. For transformers having inrush currents (worst case peak) over 20 but not more than 40 times the peak continuous current rating, derate to 25 percent.

NEMA Standard 5-12-1975.

DESIGN TESTS AND PERFORMANCE

2-211.40 DESIGN TESTS

All of the test and performance requirements of Part ICS 2-110, except the make and break design test, shall apply to magnetic lighting contactors.

Magnetic lighting contactors shall be capable of meeting the requirements for the overload and endurance tests as given in the Underwriters Laboratories Inc. *Standard for Electric Industrial Control Equipment,* UL 508.

NEMA Standard 5-12-1975.

2-211.41 SHORT-TIME CAPABILITY

The short-time capability of a new (unused) magnetic lighting contactor shall be 15 times its continuous current rating for ½ second. See Part ICS 2-110 for test procedure.

NEMA Standard 1-11-1984.

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Part ICS 2-212

MAGNETIC CONTROL RELAYS

Part ICS 2-212 covers 50- and 60-hertz alternating-current and direct-current magnetic relays designed for control circuit usage. Part ICS 2-125 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

DEFINITIONS

2-212.01 RELAYS

ALTERNATING-CURRENT RELAY

An alternating-current relay is a relay which is designed to be actuated from an alternating-current source.

NEMA Standard 11-12-1970.

DIRECT-CURRENT RELAY

A direct-current relay is a relay which is designed to be actuated from a direct-current source.

NEMA Standard 11-12-1970.

2-212.02 RELAY CONTACT CONSTRUCTION

CONVERTIBLE CONTACT CONSTRUCTION

Convertible contact construction is one which can be changed from normally open to normally closed and vice versa in the field.

NEMA Standard 11-12-1970.

FIXED CONTACT CONSTRUCTION

Fixed contact construction is one which cannot be changed from normally opened to normally closed or vice versa in the field.

NEMA Standard 11-12-1970.

UNIVERSAL CONTACT CONSTRUCTION

Universal contact construction is a form of fixed contact construction in which the pole has both normally open and normally closed contacts but in which only one or the other mode may be used.

NEMA Standard 11-12-1970.

GENERAL INFORMATION AND FEATURES

2-212.05 CONTACT FORMS

Fixed, convertible, and universal contact constructions may be used for all of the contact forms described in Part ICS 2-125.

Authorized Engineering Information 11-12-1970.

2-212.06 CLASS DESIGNATIONS

The classes of relays shall be designated in terms of their contact ratings, by means of the letters and numerals given in Part ICS 2-125, in the following manner:

a. A letter (not to be confused with the form letter shown in ICS 2-125.01) which indicates the maximum continuous thermal test current as shown in Table 2-212-1.
b. A numeral following the letter which indicates the maximum voltage rating of 600, 300 or 150 volts.

NEMA Standard 11-3-1983.

Example – A relay designated A600 is a relay which has A600 contacts, is suitable for use at all alternating-current voltages through 600 volts, is built to the 600-volt spacing requirements given for Group A controls in Table 1-111-1 of NEMA Standards Publication No. ICS 1, and has a thermal continuous test current rating of 10 amperes and make and break ratings in accordance with Table 2-125-1.

Authorized Engineering Information 11-12-1970.

Table 2-212-1
CONTACT CLASS DESIGNATIONS

Letter Designation		Thermal Continuous Test Current, Amperes
Alternating Current	Direct Current	
A	N	10
B	P	5.0
C	Q	2.5
D	R	1.0
E		0.5

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RATINGS

2-212.20 CONTACT RATINGS

The contact ratings of control relays shall be in accordance with Part ICS 2-125. For applications, see ICS 2-212.80.

NEMA Standard 11-3-1983.

2-212.21 COIL RATINGS FOR CONTROL RELAYS

Control relays shall be equipped with coils having the ratings shown in Table 2-212-2. The coil shall have only one rating for any one frequency. See Part 1-112 of NEMA Standards Publication No. ICS 1.

NEMA Standard 3-12-1975.

TABLE 2-212-2
RATINGS OF COILS FOR CONTROL RELAYS

Alternating Current Volts		Direct Current Volts
50 Hertz	60 Hertz	
110	6	6
115	12	12
127	24	24
220	48	36
240	115 or 120*	48
380	200 or 208*	72
415	230 or 240*	115 or 120*
	265 or 277*	230 or 240*
	460 or 480*	550 or 600*
	575 or 600*	

*A coil may be rated for both voltages, e.g., 115–120.

DESIGN TESTS AND PERFORMANCE

2-212.40 TEMPERATURE RISE OF COILS, CONTACTS AND TERMINALS

The coils and contacts of a control relay, when operating at rated voltage and carrying continuous thermal test current, shall not exceed the temperature rises given in Part 1-109 of NEMA Standards Publication No. ICS 1. The temperature rise test on contacts shall be made on unused contacts carrying, but not making or breaking, current.

The field wiring terminals of a control relay, when operating at rated voltage and carrying continuous thermal test current, shall not exceed the temperature rise given in Part 1-109 of NEMA Standards Publication No. ICS 1, when wired and tested in accordance with ICS 2-125.41.

NEMA Standard 5-17-1971.

2-212.41 RANGE OF COIL OPERATING VOLTAGE

Alternating-current magnetic control relays shall withstand 110 percent of the rated voltage of the operating coil continuously without injury to the coil and shall close successfully at 85 percent of the rated coil voltage after being preheated to constant temperature at the rated coil voltage. If the rating of the operating coil is given as a voltage range, the relay shall withstand 110 percent of the higher voltage continuously without injury to the coil and shall close successfully at 85 percent of the lower voltage after being preheated to constant temperature at the lower voltage rating.

Direct-current magnetic control relays shall withstand 110 percent of the rated voltage of the operating coil continuously without injury to the coil and shall close successfully at 80 percent of the rated coil voltage after being preheated to constant temperature at the rated coil voltage. See Part 1-109 of NEMA Standards Publication No. ICS 1 for test procedure.

NEMA Standard 3-12-1975.

2-212.42 CONTACT PERFORMANCE

The contacts of a control relay shall be capable of passing the overload, endurance and emergency condition tests described in Part ICS 2-125.

NEMA Standard 11-12-1970.

2-212.43 DIELECTRIC TEST

A control relay shall be capable of withstanding the power frequency dielectric test described in Part 1-109 of NEMA Standards Publication No. ICS 1, when mounted as it is intended to be used in service.

NEMA Standard 11-12-1970.

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APPLICATION

2-212.80 APPLICATION GUIDE

The make and break ratings and test values shown in Tables 2-125-1 and 2-125-2 shall not be used as application ratings where the total number of operations is expected to substantially exceed the number specified in the test conditions described in Part ICS 2-125.

When the load is an alternating-current electromagnetically operated mechanical device whose coil current may be interrupted occasionally before the completion of its stroke, such as in jogging, the break current of the load shall be considered to be 50 percent of the make current of the load. The load limitations given in the following paragraph include provision for this situation.

NEMA Standard 11-12-1970.

When control relays are used in a typical automatically operated sequencing system, it is recommended that the load be less than 25 percent of the maximum make and break ratings given in Tables 2-125-1 and 2-125-2.

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in these NEMA Standards Publications. Manufacturers' recommendations should be obtained regarding specific applications.

2-212.81 OVERLAPPING CONTACTS

Because of manufacturing tolerances and the various characteristics of electrical loads, the normally open and normally closed contacts of a control relay may or may not be conducting current simultaneously during operation. If such overlap or non-overlap is essential, the manufacturer should be consulted.

Authorized Engineering Information 11-12-1970.

PREVENTIVE MAINTENANCE

2-212.90 PREVENTIVE MAINTENANCE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-88.

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Part ICS 2-213

RESISTORS AND RHEOSTATS

Part ICS 2-213 covers resistors and rheostats used in the power circuits of industrial control apparatus. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

GENERAL INFORMATION AND FEATURES

2-213.05 SERVICE CLASSIFICATION OF RESISTORS

Resistors shall be designated by class numbers in accordance with Tables 2-213-1 through 2-213-5.

Starting- and intermittent-duty resistors are primarily designed for use with motors which require an initial torque corresponding to the stated percent of full-load current on the first point and which require an average accelerating current (rms value) of 125 percent of full-load current.

With a secondary-resistor alternating-current controller, the figures given in the tables for the percent of full-load current on the first point, starting from rest, apply to rotor (secondary) current and to torque. The primary current will, in general, be a higher percentage of the full-load current.

Starting- and intermittent-duty primary resistors which are designed for use with squirrel-cage motors and which meet the test described in ICS 2-213.42 are included in the tables.

Table 2-213-1
CLASS NUMBERS OF RESISTORS FOR NONREVERSING SERVICE AND REVERSING NONPLUGGING SERVICE WITHOUT ARMATURE SHUNT OR DYNAMIC BRAKING

Approximate Percent of Full-load Current on First Point Starting from Rest	Class Numbers — Duty Cycles						
	5 Seconds On 75 Seconds Off	10 Seconds On 70 Seconds Off	15 Seconds On 75 Seconds Off	15 Seconds On 45 Seconds Off	15 Seconds On 30 Seconds Off	15 Seconds On 15 Seconds Off	Continuous Duty*
25	111	131	141	151	161	171	91
50	112	132	142	152	162	172	92
70	113	133	143	153	163	173	93
100	114	134	144	154	164	174	94
150	115	135	145	155	165	175	95
200 or over	116	136	146	156	166	176	96

* For speed-regulating duty, see Table 2-213-4.

When an armature shunt resistor is added, the class number shall include the suffix AS. For example, Class 155-AS is a resistor which includes an armature shunt and which will allow an initial inrush of 150 percent with the armature shunt open.

When a dynamic braking resistor is added, the class number shall include the suffix DB. For example, Class 155-DB.

Table 2-213-2
CLASS NUMBERS OF RESISTORS FOR REVERSING PLUGGING SERVICE WITHOUT ARMATURE SHUNT OR DYNAMIC BRAKING

Approximate Percent of Full-load Current on First Point Starting from Rest with All Resistance in Circuit	Class Numbers — Duty Cycles			
	15 Seconds On 45 Seconds Off	15 Seconds On 30 Seconds Off	15 Seconds On 15 Seconds Off	Continuous Duty
25	151P	161P	171P	91P
50	152P	162P	172P	92P
70	153P	163P	173P	93P
100	154P	164P	174P	94P

The class numbers apply to the complete resistor, but the duty cycles apply to the accelerating resistor only.

When an armature shunt resistor is added, the class number shall include the suffix AS. For example, Class 153P-AS is a plugging resistor which includes an armature shunt and which will allow an initial inrush of 70 percent with the armature shunt open.

When a dynamic braking resistor is added, the class number shall include the suffix DB. For example, Class 153P-DB.

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An adjustable-speed motor having a given horsepower rating, when started with full field, generally requires a resistor having a larger ohmic value than does a constant-speed motor of the same horsepower rating. For this reason, the current on the first point and the capacity of the complete resistor of the same NEMA classification for an adjustable-speed motor may be different from that for a constant-speed motor of the same horsepower.

A continuous-duty resistor shall be so designed that the controller may be operated continuously on any point when the load follows its normal speed-torque curve, except that it must not be operated continuously below the minimum speed specified.

Table 2-213-3
CLASS NUMBER OF RESISTORS FOR DYNAMIC LOWERING CRANE AND HOIST CONTROLLERS

Approximate Percent of Full-load Current on First Point Hoisting Starting from Rest without Armature Shunt	Class Numbers — Duty Cycles			
	15 Seconds On 45 Seconds Off	15 Seconds On 30 Seconds Off	15 Seconds On 15 Seconds Off	Continuous Duty
50	152DL	162DL	172DL	92DL
70	153DL	163DL	173DL	93DL

Table 2-213-4
CLASS NUMBERS OF RESISTORS FOR CONTINUOUS-DUTY SPEED-REGULATING SERVICES WITH DIRECT-CURRENT SHUNT MOTORS AND ALTERNATING-CURRENT WOUND-ROTOR MOTORS

Percent Speed Reduction	Class Numbers — Percent of Rated Motor Torque at Reduced Speed						
	40	50	60	70	80	90	100
5	405	505	605	705	805	905	1005
10	410	510	610	710	810	910	1010
15	415	515	615	715	815	915	1015
20	420	520	620	720	820	920	1020
25	425	525	625	725	825	925	1025
30	430	530	630	730	830	930	1030
35	435	535	635	735	835	935	1035
40	440	540	640	740	840	940	1040
45	445	545	645	745	845	945	1045
50	450	550	650	750	850	950	1050

(a) The stability of the motor speed obtained by simple rheostatic control is dependent upon the stability of the load on the motor. The degree of instability is directly proportional to the amount of speed reduction. Variations in load have a greater proportional effect on the speed when the load is light. For these reasons, Table 2-213-4 has not been carried beyond a speed reduction of 50 percent and a load torque of 40 percent.

(b) With a direct-current shunt motor, the percent of rated motor current which is obtained at the reduced speed is assumed to be the same as the percent of rated torque.

With a direct-current series motor operating at less than 100 percent current, the percent of torque is less than the percent of current.

With a wound-rotor motor and resistor in the motor circuit, the percent of rated rotor (secondary) current which is obtained at the reduced speed is assumed to be the same as the percent of rated torque.

(c) A speed-regulating resistor is so designed that it may be operated continuously at any point in the speed-regulating range when the load follows its normal speed-torque curve. When additional resistance is required to obtain the starting current specified, the additional portion of the resistor shall be designed for a duty cycle selected from Table 2-213-1. The resulting resistor may be completely specified by a compound number.

For example, 154/850 designates a resistor which is designed for starting and speed-regulating duty. The starting section is designed to allow 100 percent of full-load current on the first point, starting from rest, and a duty cycle of 15 seconds on and 45 seconds off. The regulating section is designed to give 50 percent speed reduction at 80 percent of rated torque and for continuous duty when the load follows its normal speed-torque curve.

(d) If the speed-regulating resistor alone is used, the approximate percent of rated current which will be obtained on the first point of the controller, starting from rest, may be determined from the equation:

$$\text{Percent current} = \frac{\text{Percent torque at reduced speed}}{\text{Percent speed reduction}} \times 100$$

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Separate dynamic braking resistors shall be designated by class numbers in accordance with Table 2-213-5. The resistors shall not exceed their rated temperature rise (starting from ambient temperature) when the drive is braked by dynamic braking, from maximum speed to standstill, three times in rapid succession with a load inertia which is equal to or less than the motor inertia.

NEMA Standard 7-15-1970.

If the load inertia and/or the number of stops exceeds that specified in the preceding paragraph, the resistor may be designated as "Similar to Class _____ except _____," spelling out the difference. In this case, the following data are required:

a. Motor horsepower and voltage rating.
b. Maximum motor speed.
c. Motor inertia.
d. The load inertia reflected to the motor shaft.

Authorized Engineering Information 7-15-1970.

2-213.06 CURRENT-CARRYING CAPACITY OF RESISTOR WIRES FOR WOUND-ROTOR MOTORS

The connecting wires between the rotor of a wound-rotor motor and its resistors shall have a minimum current-carrying capacity in accordance with Table 2-213-6.

NEMA Standard 1-29-1937.

2-213.07 CURRENT-CARRYING ABILITY

Continuous-duty resistors shall be capable of carrying continuously the current for which they are designed without exceeding the specified temperature rise. See ICS 2-213.40

NEMA Standard 3-20-1957.

RATINGS

2-213.20 RATINGS

Resistors shall be rated in ohms, amperes and class of service.

NEMA Standard 1-5-1977.

Table 2-213-5
CLASS NUMBERS OF DYNAMIC BRAKING RESISTORS

Peak Braking Current as a Percentage of Rated Full-load Current	Number of Steps		
	1	2	3
100	DB11	DB12	DB13
150	DB21	DB22	DB23
200	DB31	DB32	DB33
250	DB41	DB42	DB43
300 or over	DB51	DB52	DB53

Table 2-213-6
CONDUCTOR CAPACITY

Resistor Class Number (See ICS 2-213.05)	Minimum Current-carrying Capacity, Percent of Full-load Secondary Current
101 to 106, 111 to 116	35
131 to 136	45
141 to 146	55
151 to 156	65
161 to 166	75
171 to 176	85
91 to 96	110

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DESIGN TESTS AND PERFORMANCE

2-213.40 TEMPERATURE RISE OF RESISTORS

When a temperature rise test is made on a resistor, rheostat or dimmer at the current values, duty cycle and elapsed time specified, the temperature rise above the ambient temperature and the methods of temperature measurement shall be in accordance with the following.

a. For bare resistive conductors, the temperature rise shall not exceed 375°C as measured by a thermocouple in contact with the resistive conductor.
b. For resistor units, rheostats and wall-mounted rheostatic dimmers which have an embedded resistive conductor, the temperature rise shall not exceed 300°C as measured by a thermocouple in contact with the surface of the embedding material.
c. For rheostatic dimmers which have embedded resistive conductors and which are arranged for mounting on switchboards or in noncombustible frames, the temperature rise shall not exceed 350°C as measured by a thermocouple in contact with the surface of the embedding material.
d. The temperature rise of the issuing air shall not exceed 175°C as measured by a mercury thermometer at a distance of 1 inch from the enclosure.

NEMA Standard 3-13-1952.

2-213.41 TEMPERATURE RISE TEST—RESISTORS

When a temperature rise test is made on a starting- or intermittent-duty resistor without its motor, the resistor shall be connected to a voltage which will give the initial inrush current specified. In addition, the steps shall be cut out at equal intervals of time in the time-on period of the cycle specified, and the current shall be maintained at 125 percent of the full-load current for those steps through which 125 percent of full-load current can flow. The specified cycle shall be repeated for 1 hour.

When a temperature rise test is made on a continuous-duty resistor without its motor, any tested step shall be subjected to 100 percent of the current for which the resistor is designed, and this value of current shall be maintained until the maximum temperatures are reached.

When a temperature rise test is made on a rheostatic dimmer, it shall be made on a single plate which is operated at rated voltage and connected in series with lamps totalling the rated lamp load.

Single plates meeting this test will operate at safe temperatures when assembled into switchboard groups because of the diversity of loading of the various plates. The maximum temperature rise may be approximated by setting the lever so that the dimmer is dissipating maximum wattage.

NEMA Standard 8-10-1949.

2-213.42 TEMPERATURE RISE TEST—PRIMARY RESISTORS FOR SQUIRREL-CAGE MOTORS

When a temperature rise test is made on a general-purpose single-step primary starting resistor for a squirrel-cage motor, the resistor shall be tested with 300 percent of normal full-load current of the motor for which the resistor is designed, and the current shall be maintained for a duty cycle as indicated in the resistor classification. This cycle shall be repeated for 1 hour, after which period the temperature rise shall not exceed the limitations given in ICS 2-213.40.

NEMA Standard 3-17-1955.

MANUFACTURING

2-213.60 MARKING END CONNECTORS FOR RESISTOR UNITS

When a resistor consists of two or more units which are to be connected, the use of the letters "A" to "A," "B" to "B," etc., is recommended.

Authorized Engineering Information 11-12-1953.

2-213.61 DIRECTION OF ROTATION FOR RHEOSTATS

A rheostat which is connected in series with the shunt field of a motor shall increase the speed of the motor when the operating handle is turned in a clockwise direction, viewed from the operator's position.

A rheostat which is connected in series with the shunt field of a generator for the ultimate purpose of controlling the voltage of the generator shall increase the voltage of the generator when the operating handle is turned in a counterclockwise direction, viewed from the operator's position.

A rheostat, or rheostats, applied to an adjustable-voltage drive shall increase the speed of the motor when the generator rheostat or the motor rheostat is turned in a clockwise direction, viewed from the operator's position.

NEMA Standard 11-12-1953.

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APPLICATION

2-213.80 DERATING RESISTORS FOR ALTITUDE

For altitudes between 6600 feet (2000 meters) and 12000 feet (3500 meters):

a. Continuous-duty resistors shall be derated to 75 percent of their normal power rating, and

b. Intermittent and starting-duty resistors shall be applied on a duty cycle which is selected on the basis of the next higher "time-on" classification.

NEMA Standard 1-5-1977.

2-213.81 RESISTOR APPLICATION TABLE

Table 2-213-7 is intended as a guide in specifying and designing resistors. The classifications are those which experience has shown to be correct for the average installation. It is recognized that there will be exceptions. The table applies to resistors composed of wire-wound units or cast grids. It is also applicable to unbreakable resistors provided that the time-on period does not exceed the values given in ICS 2-213.05. The table gives the basic class number. Where plugging, dynamic braking, armature shunt or dynamic lowering functions are required, the appropriate suffix letters shown in Tables 2-213-2 and 2-213-3 should be added to the basic number.

Authorized Engineering Information 3-19-1958.

Table 2-213-7
APPLICATION GUIDE

Installation	Class No. of Resistor
Blowers–	
Centrifugal	133-93
Constant pressure	135-95
Brick Plants–	
Augers	135
Conveyors	135
Dry pans	135
Pug mills	135
By-product Coke Plants–	
Door machine	153
Leveler ram	153
Pusher bar	153
Valve reversing machines	153
Cement Mills–	
Conveyors	135
Crushers	145
Elevators	135
Rotary dryers	145-95
Grinders and pulverizers	135
Kilns	135-95

Table 2-213-7 (continued)
APPLICATION GUIDE

Installation	Class No. of Resistor
Coal and Ore Bridges–	
Bridge	153
Closing	162
Holding	162
Trolley	162, 163
Coal Mines–	
Car hauls	162
Conveyors	135-55
Cutters	135
Crushers	145
Fans	134-93
Hoists–	
Slope	172
Vertical	162
Jigs	135
Picking tables	135
Rotary car dumpers	153
Shaker screens	135
Compressors–	
Constant speed	135
Varying speed–	
Centrifugal	93
Plunger type	95
Concrete Mixers	135
Cranes–Service Classes A, B, and C*	
Hoist	152, 153
Bridge or Trolley with–	
Sleeve bearings	153
Roller bearings	152
Cranes–Service Classes D and E*	
Hoist	162, 163
Bridge or trolley with–	
Sleeve bearings	163
Roller bearings	162
Flour Mills–	
Line shafting	135
Food Plants–	
Butter churns	135
Dough mixers	135
Hoists–	
Winch	153
Mine slope	172
Mine vertical	162
Contractor's hoists	152
Larry Cars	153
Lift Bridges	152

*Definition per Crane Manufacturers Association of America's specification CMAA No. 70, Revised 1983.

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Table 2-213-7 (continued)
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Installation	Class No. of Resistor
Machine Tools –	
Bending rolls	163-164
Boring mills	135
Bulldozers	135
Drills	115
Gear cutters	115
Grinders	135
Hobbing machines	115
Lathes	115
Milling machines	115
Presses	135
Punches	135
Saws	115
Shapers	115
Metal Mining –	
Ball, rod and tube mills	135
Car dumpers – rotary	153
Converters – copper	154
Conveyors	135
Crushers	145
Tilting furnace	153
Paper Mills –	
Beaters	135
Calenders	154-92
Pipeworking –	
Cutting and threading	135
Expanding and flanging	135-95
Power Plants –	
Clinker grinders	135
Coal crushers	135
Conveyors –	
Belt	135
Screw	135
Pulverized fuel feeders	135
Pulverizers –	
Ball type	135
Centrifugal	134
Stokers	135-93
Pumps –	
Centrifugal	134-93
Plunger	135-95
Rubber Mills –	
Calenders	155
Crackers	135
Mixing mills	135
Washers	135
Steel Mills –	
Accumulators	153
Casting machines – pig	153

*Definition per Association of Iron & Steel Engineers A.I.S.E. Standard No.6, May 1, 1969.

Table 2-213-7 (continued)
APPLICATION GUIDE

Installation	Class No. of Resistor
Steel Mills (continued) –	
Charging machines –	
Bridge	153-163
Peel	153-163
Trolley	153-163
Coiling machines	135
Converters – metal	154
Conveyors	135-155
Cranes	*
Crushers	145
Furnace doors	155
Gas valves	155
Gas washers	155
Hot metal mixers	163
Ingot buggy	153
Kickoff	153
Levelers	153
Manipulator fingers	153-163
Pickling machine	153
Pilers – slab	153
Racks	153
Reelers	135
Saws – hot or cold	155
Screw downs	153-163
Shears	155
Shuffle bars	155
Side guards	153-163
Sizing rolls	155
Slab buggy	155
Soaking pit covers	155
Straighteners	153
Tables –	
Approach	153
Lift	153-163
Main roll	153-163
Roll	153
Shear approach	153-163
Transfer	153
Tilting furnace	153
Wire-stranding machine	153
Woodworking Plants –	
Boring machines	115
Lathe	115
Mortiser	115
Moulder	115
Planers	115
Power trimmer and mitre	115
Sanders	115
Saws	115
Shapers	115
Shingle machine	115

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PREVENTIVE MAINTENANCE

2-213.82 Preventive Maintenance Guide

See Part ICS 1-115 of NEMA Standards Publication ICS 1 for general maintenance instructions.

Authorized Engineering Information 5-25-1988.

2-213.83 Specific Maintenance Instructions

In order to assure proper equipment operation, a periodic maintenance program should be established. Maintenance instructions should be obtained from the manufacturer for incorporation into this program.

Disconnect all power sources to the resistors before attempting preventive maintenance. Resistors should be examined for evidence of overheating and all connections should be checked for proper tightness. Check to see that proper clearance is maintained to any combustible material near the resistor. The resistor mounting feet and/or any supporting structures should be checked for tightness of mounting hardware.

Authorized Engineering Information 5-25-1988.

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Part ICS 2-214

AUTOTRANSFORMERS AND REACTORS

Part ICS 2-214 covers alternating-current 50- and 60-hertz autotransformers and reactors of the type used to supply reduced voltage for motor controllers for motors which are rated 3000 horsepower or less. It does not cover the application of autotransformers and reactors to synchronous condensers and frequency changers since such autotransformers and reactors are, in general, quite large and usually require special taps. The autotransformers covered by Part ICS 2-214 are for applications where the windings are in the circuit only during the starting period.

The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

GENERAL INFORMATION AND FEATURES

2-214.05 SERVICE CLASSIFICATIONS

Autotransformers and reactors shall be classified as suitable for heavy-duty or medium-duty service in accordance with the following paragraphs.

.01 Heavy Duty

Heavy-duty service includes applications which require frequent starting or jogging, such as certain steel-mill drives and other special drives, including those having extremely high inertia.

.02 Medium Duty

Medium-duty service includes applications to motors which drive loads such as fans, pumps, compressors, line shafts, etc.

NEMA Standard 1-6-1966.

2-214.06 DUTY CYCLE CONDITIONS

Ratings for heavy-duty and medium-duty controllers shall be based on the following duty cycles and load conditions:

.01 Heavy Duty

ON	1 minute
OFF	1 minute
REPEAT	4 times (for a total of 5 cycles)
REST	2 hours
ON	1 minute
OFF	1 minute
REPEAT	4 times (for a total of 5 cycles)
TAP	lowest tap
LOAD	motor with rotor blocked or connected to equivalent inductive load

.02 Medium Duty – Manual Controllers, 300 Horsepower Or Less

ON	15 seconds
OFF	3 minutes, 45 seconds
REPEAT	3 times (for a total of 4 cycles)
REST	2 hours
ON	15 seconds
OFF	3 minutes, 45 seconds
REPEAT	3 times (for a total of 4 cycles)
TAP	65 percent
TAP CURRENT	300 percent of motor full-load current
POWER FACTOR	50 percent or less

.03 Medium Duty – Magnetic Controllers For Motors, 200 Horsepower Or Less

ON	15 seconds
OFF	3 minutes, 45 seconds
REPEAT	14 times (for a total of 15 cycles)
REST.	2 hours
ON	15 seconds
OFF	3 minutes, 45 seconds
REPEAT	14 times (for a total of 15 cycles)
TAP	65 percent
TAP CURRENT	300 percent of motor full-load current
POWER FACTOR	50 percent or less

.04 Medium Duty – Magnetic Controllers for Motors, More Than 200 Horsepower to 3000 Horsepower, Inclusive

ON	30 seconds
OFF	30 seconds
REPEAT	2 times (for a total of 3 cycles)
REST	1 hour
ON	30 seconds
OFF	30 seconds
REPEAT	2 times (for a total of 3 cycles)
TAP	65 percent
TAP CURRENT	300 percent of motor full-load current
POWER FACTOR	50 percent or less

NEMA Standard 5-17-1971.

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2-214.07 STARTING TAPS

.01 Autotransformers

Autotransformers shall have starting taps in accordance with Table 2-214-1. For heavy-duty service, the load conditions are governed by the particular application. For medium-duty service, the stalled motor current at full voltage shall be assumed to be 6 times the normal full-load current for the purpose of determining the tap voltage under load conditions. The load taken from the taps shall be an inductive load having a power factor of 0.5 or less.

.02 Reactors

Assuming the same load conditions as those given for autotransformers and with the motor stalled, reactors shall provide the motor terminal voltages shown in Table 2-214-1.

NEMA Standard 1-6-1966.

Table 2-214-1
TAPS AND MOTOR TERMINAL VOLTAGES

Service Classification	Horsepower Rating of Motors	Starting Taps, Motor Terminal Voltages (Approximate Percent of Line Voltage)
Medium duty	50 and less	65-80
	More than 50	50-65-80
Heavy duty	50 and less	65-80
	More than 50	50-65-80

DESIGN TESTS AND PERFORMANCE

2-214.40 TEMPERATURE RISE OF COILS

The temperature rise of autotransformer and reactor coils, when measured by the resistance method at the duty cycle given in ICS 2-214.06 and at specified normal voltage, shall not exceed the limits specified in Part 1-109 of NEMA Standards Publication No. ICS 1.

NEMA Standard 8-10-1949.

MANUFACTURING

2-214.60 MARKING

.01 Autotransformers

The taps and the coils shall be marked as follows: the end of the winding which is connected to the Y or delta point and which is the start of the winding shall be marked 0. The intermediate taps shall be marked with the approximate percentage of line voltage which will be delivered to the motor under the specified load conditions. The end connection which goes to the line shall be marked 100. For example, on transformers, motors rated more than 50 horsepower for medium duty shall be marked 0-50-65-80-100.

.02 Reactors

The start of the winding shall be marked 0, and the taps shall be marked 1, 2, 3, 4, etc. The nameplate or terminal board shall show the connections to be used for each of the specified voltages.

NEMA Standard 1-6-1966.

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Part ICS 2-215

FOOT SWITCHES

Part ICS 2-215 covers foot switches used in the control circuits of industrial control apparatus. Part ICS 2-125 or ICS2-126 applies to this part unless otherwise specified.

The definitions and standards of NEMA Standards Publication Nos. 250, ICS 1, and ICS 6 also apply to this part.

DEFINITIONS

2-215.01 DEFINITIONS

FOOT SWITCH

A foot switch is a switch which is suitable for operation by an operator's foot.

NEMA Standard 8-20-1966.

GENERAL INFORMATION AND FEATURES

2-215.06 STANDARD-DUTY FOOT SWITCHES

Standard-duty foot switches shall have contact rating designations of B150, B300, B600, P150, P300 or P600 as shown in Part ICS2-125 under Table 2-125-1 for alternating current and Table 2-125-2 for direct current.

NEMA Standard 5-17-1971.

2-215.07 HEAVY-DUTY FOOT SWITCHES

Heavy-duty foot switches shall have contact rating designations of A150, A300, A600, N150, N300 or N600 as shown in Table 2-125-1 for alternating current and Table 2-125-2 for direct current.

NEMA Standard 5-17-1971.

RATINGS

2-215.20 CONTACT RATINGS

The contact ratings of foot switches used in control circuits shall be in accordance with Part ICS 2-125. For application, see ICS 2-215.80

NEMA Standard 5-17-1971.

2-215.21 SEMICONDUCTOR SWITCHING ELEMENT RATINGS

The ratings of foot switches having semiconductor switching elements for use in control circuits shall be in accordance with Part ICS 2-126 for the utilization category specified.

NEMA Standard 5-15-1989.

DESIGN TESTS AND PERFORMANCE

2-215.40 CONTACT PERFORMANCE

The contacts of foots switches, when new, shall:

a. Not exceed the temperature rise given in Part 1-109 of NEMA Standards Publication No. ICS 1 when carrying continuous thermal test current.

b. Be capable of passing the overload, endurance and emergency condition tests described in Part ICS 2-125.

NEMA Standard 5-17-1971.

2-215.41 SEMICONDUCTOR SWITCHING ELEMENT PERFORMANCE

Semiconductor switching elements shall meet the test and performance requirements of Part ICS 2-126 corresponding to their rating designation for the utilization category specified.

NEMA Standard 5-15-1989.

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APPLICATION

2-215.80 APPLICATION GUIDE FOR FOOT SWITCHES HAVING CONTACT SWITCHING ELEMENTS

The make and break ratings and test values shown in Tables 2-125-1 and 2-125-2 shall not be used as application ratings where the total number of operations is expected to substantially exceed the number specified in the test conditions described in Part ICS 2-125.

When the load is an alternating-current electromagnetically operated mechanical device whose coil current may be interrupted occasionally before completion of its stroke, such as in jogging, the break current of the load shall be considered to be 50 percent of the make current of the load.

NEMA Standard 3-17-1971.

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in this NEMA Standards Publication. Therefore, manufacturers' recommendations should be obtained regarding specific applications.

Authorized Engineering Information 1-27-1988.

2-215.81 OVERLAPPING CONTACTS

Because of manufacturing tolerances and the various characteristics of electrical loads, the normally open and normally closed contacts of a foot switch may or may not be conducting current simultaneously during operation. If such overlap or non-overlap is essential, the manufacturer should be consulted.

Authorized Engineering Information 5-17-1971.

2-215.82 APPLICATION GUIDE FOR FOOT SWITCHES HAVING SEMI-CONDUCTOR SWITCHING ELEMENTS

The utilization categories given in ICS 2-126 are considered standard.

NEMA Standard 5-15-1989.

Applications not covered by the utilization categories in ICS 2-126 should be based on agreement between the manufacturer and user.

Authorized Engineering 5-15-1989.

PREVENTIVE MAINTENANCE

2-215.90 PREVENTIVE MAINTENANCE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-1988.

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Part ICS 2-216

PUSHBUTTONS, SELECTOR SWITCHES, INDICATING LIGHTS AND PUSHBUTTON STATIONS

Part ICS 2-216 covers manually operated pushbuttons and related items which may be mounted in pushbutton stations and which are used primarily in the control circuit of industrial control apparatus. Part ICS 2-125 applies to this part unless otherwise specified.

The definitions and standards of NEMA Standards Publication Nos. 250, ICS 1 and ICS 6 also apply to this part.

DEFINITIONS

2-216.01 GENERAL DEFINITIONS

MASTER SWITCH

A master switch is a switch which dominates the operation of contactors, relays, or other remotely operated devices.

NEMA Standard 8-20-1966.

2-216.02 PUSHBUTTON DEFINITIONS

GUARDED PUSHBUTTON

A guarded pushbutton is a pushbutton so constructed that when properly mounted, the chance of inadvertent operation will be minimal. Recognized constructions are listed below.

a. *Recessed Pushbutton* — A pushbutton which has its surface for applied force below the surrounding surface in its initial and operated positions.
b. *Shrouded Pushbutton* — A pushbutton which has the relationship between the guard and the actuating means specified by the manufacturer.
c. *Shielded Pushbutton* — A pushbutton which requires some movement to operate which is essentially perpendicular to the movement required to enter the shield.
d. *Covered Pushbutton* — A pushbutton having an automatically returnable cover which must be displaced prior to operating the pushbutton.
e. *Lockable Pushbutton* — A pushbutton which includes provision for locking in specified positions.

NEMA Standard 3-8-1978.

PUSHBUTTON

A pushbutton switch (pushbutton) is a switch having a manually operable plunger, rocker or button for actuating the switch.

NEMA Standard 3-8-1978.

GENERAL INFORMATION AND FEATURES

2-216.05 STANDARD-DUTY PUSHBUTTON STATIONS

Standard-duty pushbutton stations shall consist of pushbuttons and/or selector switches, rated in accordance with ICS 2-216.21, and/or indicating lights in accordance with ICS 2-216.23, mounted in a suitable enclosure.

2-216.06 HEAVY-DUTY PUSHBUTTON STATIONS

Heavy-duty pushbutton stations shall consist of pushbuttons and/or selector switches rated in accordance with ICS 2-216.22, and/or indicating lights in accordance with ICS 2-216.23, mounted in a suitable enclosure.

NEMA Standard 3-17-1971.

2-216.07 ENVIRONMENTAL REQUIREMENTS

Pushbuttons, selector switches, indicating lights, and related items are considered dust tight, watertight and/or oil tight if, when properly mounted in a suitable enclosure, the assembly meets the applicable design test requirements of NEMA Standards Publication No. ICS 6, and 250.

NEMA Standard 3-17-1971.

2-216.08 SELECTOR SWITCHES

Standard-duty selector switches shall have either two or three positions.

Heavy-duty selector switches shall have two, three or more positions.

NEMA Standard 3-17-1971.

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RATINGS

2-216.20 CONTACT RATINGS

The contact ratings of manually operated pushbuttons and selector switches used in control circuits shall be in accordance with Part ICS 2-125. For application, see ICS 2-216.80.

NEMA Standard 3-17-1971.

2-216.21 STANDARD-DUTY PUSHBUTTONS AND SELECTOR SWITCHES

Standard-duty pushbuttons and selector switches shall have contact rating designations of B600, B300, B150, P600, P300 or P150 as shown in Table 2-125-1 for alternating current and Table 2-125-2 for direct current.

NEMA Standard 3-17-1971.

2-216.22 HEAVY-DUTY PUSHBUTTONS AND SELECTOR SWITCHES

Heavy-duty pushbuttons and selector switches shall have contact rating designations of A600, A300, A150, N600, N300 or N150 as shown in Table 2-125-1 for alternating current and Table 2-125-2 for direct current.

NEMA Standard 3-17-1971.

2-216.23 INDICATING LIGHTS

Indicating lights in pushbutton stations shall have any single voltage rating shown in Table 2-216-1.

NEMA Standard 3-17-1971.

Table 2-216-1
VOLTAGE RATINGS, VOLTS

Standard Duty		Heavy Duty	
60 Hertz Alternating Current	Direct Current	60 Hertz Alternating Current	Direct Current
120	120	6	6
240	240	12	12
		24	24
		120	120
		240	240
		480	
		600	

The voltage impressed on the lamp bulb may be less than that shown in the table depending on design details.

Authorized Engineering Information 3-17-1977.

DESIGN TESTS AND PERFORMANCE

2-216.40 CONTACT PERFORMANCE

The contacts of pushbuttons and selector switches, when new, shall:

a. Not exceed the temperature rise given in Part 1-109 of NEMA Standards Publication No. ICS 1 when carrying continuous thermal test current.

b. Be capable of passing the overload, endurance and emergency condition tests described in Part ICS 2-125.

NEMA Standard 3-17-1971.

MANUFACTURING

2-216.60 ARRANGEMENT OF ELEMENTS IN PUSHBUTTON STATIONS

On all single-row pushbutton stations, the stop button shall be located below or to the right of all other associated buttons, indicating lights and selector switches.

NEMA Standard 3-17-1971.

2-216.61 ARRANGEMENT OF PUSHBUTTON STATIONS FOR MULTI-SPEED MOTOR CONTROLLERS

Pushbutton stations used with multispeed motors shall be arranged as follows:

a. When mounted vertically, the lowest button shall be the stop button. The lowest-speed button shall be above the stop button, followed by those for consecutively higher speeds.

b. When mounted horizontally, the right-hand button shall be the stop button. The lowest-speed button shall be to the left of the stop button, followed by those for consecutively higher speeds.

NEMA Standard 8-10-1949.

2-216.62 COLOR CODING OF PUSHBUTTONS

The color of those pushbuttons which perform a stop function shall be red.

NEMA Standard 3-17-1971.

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2-216.63 LEGENDS FOR PUSHBUTTON STATIONS

.01 Standard-duty Pushbutton Station Legends

One Button	Two Button	Three Button
Start	Start-Stop	Foward-Reverse-Stop
Stop	Forward-Reverse Open-Close Up-Down	Open-Close-Stop Up-Down-Stop Fast-Slow-Stop

.02 Heavy-duty Pushbutton Station Legends

One Button	Two Button	Three Button
Start	Start-Stop	Start-Jog-Stop
Stop	Run-Stop	Run-Jog-Stop
Jog	Forward-Reverse	Forward-Reverse-Stop
Reset	Fast-Slow Open-Close Up-Down	Open-Close-Stop Fast-Slow-Stop Up-Down-Stop

NEMA Standard 3-17-1971.

2-216.64 DIRECTION OF OPERATION OF ROTARY SELECTOR SWITCHES

When a rotary selector switch is mounted in a pushbutton station or in the cover of an alternating-current magnetic nonreversing controller, the direction of rotation shall be such that the "hand" function is obtained in the counterclockwise direction of motion and the "automatic" function is obtained in the clockwise direction of motion. See Fig. 2-216-1.

NEMA Standard 1-21-1964.

2-216.65 DIRECTION OF OPERATION OF SELECTOR SWITCHES HAVING LEVERS WITH STRAIGHT-LINE MOTION

When a selector switch having a lever with straight-line motion is mounted in a pushbutton station or in the cover of an alternating-current magnetic nonreversing controller, the direction of motion shall be such that the "hand" function is obtained when the lever is moved to the left or moved downward and the "automatic" function is obtained when the lever is moved to the right or moved upward. See Fig. 2-216-2.

NEMA Standard 1-21-1964.

2-216.66 INDICATING LIGHTS

When a single indicating light is used to show the status of a single-speed nonreversing magnetic controller, the color shall be red, and the light shall be so connected that it is on when the controller is energized. When two indicating lights are used to show the status of a single-speed nonreversing magnetic controller, the second indicating light shall be green and the arrangement shall be such that the green light is on when the controller is de-energized.

NEMA Standard 3-17-1971.

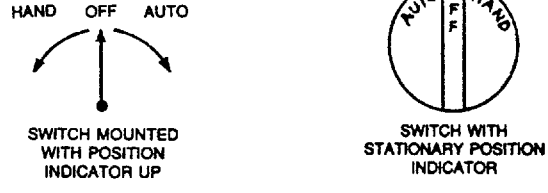


Fig. 2-216-1
ROTARY SELECTOR SWITCH OPERATION

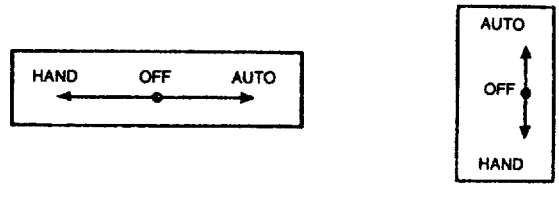


Fig. 2-216-2
LEVER SELECTOR SWITCH OPERATION

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APPLICATION

2-216.80 APPLICATION GUIDE

The make and break ratings and test values shown in Tables 2-125-1 and 2-125-2 shall not be used as application ratings where the total number of operations is expected to substantially exceed the number specified in the test conditions described in Part ICS 2-125.

When the load is an alternating-current electromagnetically operated mechanical device whose coil current may be interrupted occasionally before completion of its stroke, such as in jogging, the break current of the load shall be considered to be 50 percent of the make current of the load. The load limitations given in the following paragraph include provision for this situation.

NEMA Standard 3-17-1971.

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in this NEMA Standards Publication. Therefore, manufacturers' recommendations should be obtained regarding specific applications.

Authorized Engineering Information 1-27-1988.

2-216.81 OVERLAPPING CONTACTS

Because of manufacturing tolerances and the various characteristics of electrical loads, the normally open and normally closed contacts of a control relay may or may not be conducting current simultaneously during operation. If such overlap or non-overlap is essential, the manufacturer should be consulted.

Authorized Engineering Information 11-12-1970.

PREVENTIVE MAINTENANCE

2-216.90 PREVENTIVE MAINTENANCE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-1988.

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Part ICS 2-218

TIME-DELAY RELAYS

Part ICS 2-218 covers time-delay (timing) relays used primarily in control circuits of industrial control apparatus. Time delay may be achieved by pneumatic, oil dashpot, motor drive, magnetic or electronic circuitry means. The output may be achieved by contacts or solid-state circuitry.

Part ICS 2-125 or 2-126 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

DEFINITIONS

2-218.01 TIME-DELAY RELAY TYPES

ALTERNATING-CURRENT TIME-DELAY RELAY

An alternating-current time-delay relay is one which is designed to be actuated from an alternating-current source.

NEMA Standard 5-17-1971.

CLOCK TIMER

A clock timer is a type of repeat cycle timer whose timing intervals are based on time of day.

NEMA Standard 7-14-1982.

INTERVAL TIMING RELAY

An interval timing relay is a type of timing relay which changes the state of its timed contact(s) for predetermined time(s).

NEMA Standard 5-15-1989.

An interval timer may have more than one predetermined time interval.

Authorized Engineering Information 7-14-1982.

MAINTAINED INTERVAL TIMING RELAY

A maintained interval timing relay is a type of interval timing relay which requires that the initiating signal be maintained for a period not less than the preset timing interval of the timed contacts.

NEMA Standard 5-15-1989.

MOMENTARY INTERVAL TIMING RELAY

A momentary interval timing relay is a type of interval timing relay in which the timing interval of the timed contacts is independent of the duration of the initiating signal.

NEMA Standard 5-15-1989.

PNEUMATIC TIME-DELAY RELAY

A pneumatic time-delay relay is a timing relay which has its timing period controlled by the rate at which air moves through an adjustable or fixed orifice.

NEMA Standard 5-17-1971.

REPEAT CYCLE TIMER

A repeat timer is a type of interval timing relay that repeats its timing interval(s) periodically for as long as the timer remains energized.

NEMA Standard 7-14-1982.

SOLID-STATE TIME-DELAY RELAY

A solid-state time-delay relay is a timing relay which has its timing period controlled by a circuit using semiconductors. A solid-state time-delay relay may have a semiconductor or contact switching element.

NEMA Standard 5-15-1989.

TIME-DELAY (TIMING) RELAY

A time-delay or timing relay is a relay which has an assured time interval between energization and the action of the switching element, or between de-energization and the action of the switching element. The former are called "Time Delay after Energization (TDE)" or "On-delay" relays, and the latter are called "Time Delay after De-energization (TDD)" or "Off-delay" relays.

NEMA Standard 5-15-1989.

2-218.02 TIME-DELAY RELAY CHARACTERISTICS

INSTANTANEOUS SWITCHING ELEMENT (CONTACT OR SEMICONDUCTOR)

Instantaneous switching elements of a timing relay are the contact or semiconductor switching elements which operate at the time the relay is energized and de-energized. They are independent of the timed switching elements.

NEMA Standard 5-15-1971.

REPEAT ACCURACY DEVIATION

The repeat accuracy deviation of a time-delay relay is a measure of the maximum deviation in the time delay that will be experienced in successive operations at any particular time setting of the relay and for any particular operating voltage, frequency or current.

Repeat accuracy deviation is determined as one half of the total timing variation at any particular time setting, divided by the average of the maximum and minimum observed time periods for any 100 consecutive operations, expressed in terms of plus or minus percentage.

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Repeat accuracy is obtained from the following formula:

$$A_R = \pm 100 \frac{\frac{1}{2}(T_1 - T_2)}{\frac{1}{2}(T_1 + T_2)} = \pm 100 \frac{(T_1 - T_2)}{(T_1 + T_2)}$$

where –

A_R = Percent repeat accuracy deviation at any particular time setting.

T_1 = Maximum observed time.*

T_2 = Minimum observed time.*

* To be obtained over 100 consecutive operations; the time allowed for resetting shall not be less than the reset time.

NEMA Standard 5-17-1971.

TIMED SWITCHING ELEMENTS (CONTACT OR SEMICONDUCTOR)

Timed switching elements of a timing relay are those contact or semiconductor switching elements which operate immediately after the time delay.

NEMA Standard 5-15-1989.

GENERAL INFORMATION AND FEATURES

2-218.05 CONTACT DESIGNATIONS

The classes of time-delay relays with contact switching elements shall be designated in terms of their contact ratings, by means of the letter and numerals given in Part ICS 2-125, in the following manner:

a. A letter (not to be confused with the form letter shown in ICS 2-125.01) which indicates the maximum continuous thermal current as shown in Table 2-218-1.

b. A numeral following the letter which indicates the maximum voltage rating of 600, 300 or 150 volts.

NEMA Standard 5-15-1989.

EXAMPLE – A relay designated A600 is a relay which has A600 contacts, is suitable for use at all alternating-current voltages through 600 volts, is built to the 600-volt spacing requirements given for Group A controls in Table 1-111-1 of NEMA Standards Publication No. ICS 1, and has a continuous thermal test current rating of 10 amperes and make and break ratings in accordance with Table 2-125-1 in Part 2-125.

Authorized Engineering Information 5-17-1971.

Table 2-218-1
CONTACT CLASS DESIGNATIONS

Letter Designation		Thermal Continuous Test Current, Amperes
Alternating Current	Direct Current	
A	N	10
B	P	5.0
C	Q	2.5
D	R	1.0
E		0.5

RATINGS

2-218.20 CONTACT RATINGS

The contact ratings of timing relays with contact switching elements shall be in accordance with Part ICS 2-125. For application, see ICS 2-218.80.

NEMA Standard 5-15-1989.

2-218.21 COIL RATINGS OF MAGNETICALLY-OPERATED TIME-DELAY RELAYS

Magnetically-operated time-delay relays shall be equipped with coils having the ratings shown in Table 2-218-2. The coil shall have only one rating for any one frequency. See Part 1-112 of NEMA Standards Publication No. ICS 1.

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2-218.22 SEMICONDUCTOR SWITCHING ELEMENT RATINGS

The ratings of time-delay relays having semiconductor switching elements for use in control circuits shall be in accordance with Part ICS 2-126 for the utilization category specified.

NEMA Standard 5-15-1989.

Table 2-218-2
RATING OF COILS FOR TIME-DELAY RELAYS

Alternating Current, Volts		Direct Current,
50 Hertz	60 Hertz	Volts
110	6	6
115	12	12
127	24	24
220	48	36
240	115 or 120*	48
380	200 or 208*	72
415	230 or 240*	115 or 120*
	265 or 277*	230 or 240*
	460 or 480*	550 or 600*
	575 or 600*	

*A coil may be rated for both voltages, e.g., 115-120.

DESIGN TEST AND PERFORMANCE

2-218.40 TEMPERATURE RISE OF COILS AND OUTPUT CONTACTS

The coils and output contacts of a magnetically-operated time-delay relay, when operated at rated voltage and carrying rated current, shall not exceed the temperature rises given in Part 1-109 of NEMA Standards Publication No. ICS 1. The temperature rise test on contacts shall be made on unused contacts carrying, but not making or breaking, current.

NEMA Standard 5-17-1971.

2-218.41 TEMPERATURE RISE OF TERMINALS

The field wiring terminals of time-delay relays, when operating at rated voltage and carrying continuous thermal test current, shall not exceed the temperature rise given in Part 1-109 of NEMA Standards Publication No. ICS 1 when wired as shown in Table 2-218-3.

Table 2-218-3
CONDUCTOR SIZES FOR TESTING

Continuous Test Current Rating, Amperes	Copper Wire Size, AWG
5.1-10	14
2.6-5.0	20
2.5 and less	22

The terminals of all poles of the same mode shall be wired in series with 4 feet of wire between terminals.

NEMA Standard 3-12-1975.

2-218.42 RANGE OF COIL OPERATING VOLTAGE

Alternating-current magnetically-operated time-delay relays shall withstand 110 percent of the rated voltage of the operating coil continuously without injury to the coil and shall close successfully at 85 percent of the rated coil voltage after being preheated to constant temperature at the rated coil voltage. If the rating of the operating coil is given as a voltage range, the relay shall withstand 110 percent of the higher voltage continuously without injury to the coil and shall close successfully at 85 percent of the lower voltage after being preheated to constant temperature at the lower voltage rating.

Direct-current magnetically-operated time-delay relays shall withstand 110 percent of the rated voltage of the operating coil continuously without injury to the coil and shall close successfully at 80 percent of the rated coil voltage after being preheated to constant temperature at the rated coil voltage.

See Part 1-109 of NEMA Standards Publication No. ICS 1 for test procedure.

NEMA Standard 3-12-1975.

2-218.43 OUTPUT CONTACT PERFORMANCE

The output contacts of time-delay relays shall be capable of passing the overload, endurance and emergency condition tests described in Part ICS 2-125.

NEMA Standard 5-17-1971.

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2-218.44 DIELECTRIC TEST

A time-delay relay with output contacts shall be capable of withstanding the power frequency dielectric test described in Part 1-109 of NEMA Standards Publication No. ICS 1 when mounted as it is intended to be used in service.

A time-delay relay with a semiconductor output shall be capable of withstanding the power frequency dielectric test described in Part 1-109 of NEMA Standards Publication No. ICS 1, except that the test between the time-delay initiating circuit and the output circuit shall be omitted.

NEMA Standard 5-17-1971.

2-218.45 SEMICONDUCTOR SWITCHING ELEMENT PERFORMANCE

Semiconductor switching elements, when used as output for time-delay relays, shall meet the test and performance requirements of Part ICS 2-126 corresponding to their rating designation for the utilization category specified.

NEMA Standard 5-15-1989.

APPLICATION

2-218.80 APPLICATION GUIDE FOR TIME-DELAY RELAYS WITH CONTACT OUTPUT

The make and break ratings and test values shown in Tables 2-125-1 and 2-125-2 shall not be used as application ratings where the total number of operations is expected to substantially exceed the number specified in the test conditions described in Part ICS 2-125.

When the load is an alternating-current electromagnetically-operated mechanical device whose coil current may be interrupted occasionally before completion of its stroke, the break current of the load shall be considered to be 50 percent of the make current of the load. The load limitations given in the following paragraph include provision for this situation.

NEMA Standard 5-17-1971.

When timing relays are used in a typical automatically operated sequencing system, it is recommended that the load be less than 25 percent of the maximum make and break ratings given in Tables 2-125-1 and 2-125-2.

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in this NEMA Standards Publication. Therefore, manufacturers' recommendations should be obtained regarding specific applications.

Authorized Engineering Information 1-27-1988.

2-218.81 OVERLAPPING CONTACTS

Because of manufacturing tolerances and the various characteristics of electrical loads, the normally open and normally closed contacts of a timing relay may or may not be conducting current simultaneously during operation. If such overlap or non-overlap is essential, the manufacturer should be consulted.

Authorized Engineering Information 5-17-1971.

2-218.82 APPLICATION GUIDE FOR TIME-DELAY RELAYS HAVING SEMICONDUCTOR SWITCHING ELEMENTS

The utilization categories given in ICS 2-126 are considered standard.

NEMA Standard 5-15-1989.

Applications not covered by utilization categories in ICS 2-126 should be based on agreement between the manufacturer and user.

Consideration should be given to the degree of isolation necessary between the time delay initiating circuit and the output circuit when applying semiconductor time-delay relays.

Authorized Engineering Information 5-15-1989.

PREVENTIVE MAINTENANCE

2-218.90 PREVENTIVE MAINTENANCE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-1988.

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Part ICS 2-219

DRY REED SWITCHES

Part ICS 2-219 covers the rating and application of dry reed switches used in industrial control devices.
Part ICS 2-125 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

DEFINITIONS

2-219.01 DRY REED SWITCH DEFINITIONS

DRY REED SWITCH

A dry reed switch is a switching device comprised of two or more ferromagnetic reed-like contact-carrying arms which are sealed in a nonmagnetic capsule, usually a glass tube, without the presence of a liquid. The free end(s) are actuated by a change in a magnetic field, making or breaking electrical contact.

NEMA Standard 11-12-1970.

FAN-OUT

Fan-out is a rating given to one pole of a coil-operated switching device and represents the maximum number of coils of identical devices which can be controlled in parallel by that pole.

NEMA Standard 11-12-1970.

MERCURY-WETTED REED SWITCH

A mercury-wetted reed switch is similar to a dry reed switch except that the contacts are wetted by a film of mercury.

NEMA Standard 11-12-1970.

RATINGS

2-219.20 CONTACT CHARACTERISTICS

See Table 2-219-1 for contact characteristics of dry reed switches.

Authorized Engineering Information 11-12-1970.

Table 2-219-1
CONTACT CHARACTERISTICS

Characteristic	Contacts	
	Control-circuit Type	Logic Type
Nature of rating	Contacts rated for make, break and carry amperes at a specified voltage.	Contacts rated in volt-amperes, maximum voltage and maximum current.
Type of load	Contacts rated for an inductive load.	Contacts rated for a resistive load and, when coil operated, in number of coils which the device can operate (fanout).
Standard ratings	Contact ratings are shown in Part ICS 2-125.	Great variety of sizes and contact ratings available appears to make standardization difficult.

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APPLICATION

2-219.80 COMPONENT APPLICATIONS

Reed switches may be used as contact assemblies in relays, limit switches, pushbuttons, logic elements, etc.

Authorized Engineering Information 11-12-1970.

2-219.81 CONTROL-CIRCUIT-TYPE SWITCHES

Control-circuit-type dry reed switches have the advantage of providing relatively high speed operation and contact reliability even when exposed to environmental contamination.

Authorized Engineering Information 11-12-1970.

2-219.82 LOGIC-TYPE SWITCHES

Logic-type dry reed switches provide contact reliability at low values of voltage and current, and relatively high speed operation, even when exposed to environmental contamination. The contacts of coil-operated dry reed switches having a fan-out rating may be applied in logic circuits consisting of similar coil-operated dry reed switches. Logic-type dry reed switches used in other applications should be tested to verify their suitability, particularly when the load is nonresistive and arc suppression is required. Logic-type dry reed switches are often used as the interface device between solid-state and nonsolid-state devices.

Authorized Engineering Information 11-12-1970.

2-219.83 ARC SUPPRESSION

Contacts which operate inductive loads may require protection by arc suppression networks. These may be connected across either the load or the contacts. The network may consist of a resistor in series with either a capacitor or diode. (For alternating current, the diode should be a thyrector.) The effectiveness of the suppressor network should be checked by an oscilloscope to assure that transfer voltages do not exceed the voltage ratings of the contacts or, alternatively, the relay manufacturer should be consulted for recommendations.

Authorized Engineering Information 11-12-1970.

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Part ICS 2-220

BRAKES

Part ICS 2-220 covers electromagnetically released friction brakes, which are spring, hydraulic, permanent magnet, or electromagnetically set. Brakes may include provisions for manual release. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

DEFINITIONS

2-220.01 MANUAL RELEASE DEFINITIONS

MANUAL RELEASE

A manual release for an electromagnetic brake is a device by which the braking surfaces are manually disengaged without disturbing the torque adjustment.

NEMA Standard 8-20-1986.

MANUAL RELEASE WITH AUTOMATIC-RESET

A manual release with automatic-reset is a manual release which, when operated, will maintain the braking surfaces in disengagement but will automatically disengage the release mechanism as soon as electric power is again supplied.

NEMA Standard 8-20-1986.

MANUAL RELEASE WITH MANUAL-RESET

A manual release with manual-reset is a manual release which requires an additional manual action to disengage the release mechanism.

NEMA Standard 8-20-1986.

MANUAL RELEASE WHICH IS SELF-RESETTING

A manual release which is self-resetting is a manual release which is operative only while it is held manually in the release position.

NEMA Standard 8-20-1986.

2-220.02 SETTING MECHANISM

A setting mechanism is a spring, hydraulic, permanent magnet, or elecromagnetic actuator which provides a force that is transmitted to the braking surfaces through the brake linkages. Combinations of setting mechanisms shall be permitted to be used on the same brake when adjustable service braking and fixed parking braking are provided.

NEMA Standard 8-20-1986.

2-220.03 SELF-ADJUSTING

A self-adjusting brake is a brake which incorporates a mechanism which automatically compensates for lining wear by maintaining a predetermined position relationship between the braking surfaces.

NEMA Standard Standard 8-20-1986.

2-220.04 INDICATORS

.01 An adjustment indicator incorporates a method for indicating the condition of the brake with respect to its specified adjustment. It shows if readjustment is required as a result of wear of the braking surfaces or other parts and provides indication of proper brake adjustment.

.02 A wear indicator is a device which shows when lining replacement is required.

.03 An electrical release indicator is a brake mounted control circuit contact complying with Part ICS 2-125, that changes state when the brake setting mechanism has moved to the release position.

.04 A mechanical release indicator is a brake mounted visual indicator that changes state when the brake setting mechanism has moved to the release position.

NEMA Standard 8-20-1986.

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GENERAL INFORMATION AND FEATURES

2-220.05 MOUNTING ARRANGEMENTS FOR BRAKES

.01 Shoe Brakes (Bracket or Base-Mounted)

a. Type I—Floor-mounted Horizontal-shaft Brake

A floor-mounted horizontal-shaft brake is a brake which is arranged for floor mounting with the wheel located on a shaft which is approximately parallel to the floor and with the brake actuator located at the side of the brake wheel.

b. Type I-A—Floor-mounted Horizontal-shaft Brake

Type I-A is similar to Type I, except that the brake actuator is located either above or below the brake wheel.

c. Type II—Wall-mounted Horizontal-shaft Brake

A wall-mounted horizontal-shaft brake is a brake which is arranged for wall mounting with the wheel located on a shaft which is approximately parallel to the floor and to the wall and with the brake actuator located above or below the brake wheel.

d. Type III—Ceiling-mounted Horizontal-shaft Brake

A ceiling-mounted horizontal-shaft brake is a brake which is arranged for ceiling mounting with the wheel located on a shaft which is approximately parallel to the floor and with the brake actuator located at the side of the brake wheel.

e. Type IV—Wall-mounted Vertical-shaft Brake

A wall-mounted vertical-shaft brake is a brake which is arranged for wall mounting with the wheel located on a shaft which is approximately perpendicular to the floor and with the brake actuator located at the side of the brake wheel.

NEMA Standard 8-20-1986.

.02 Disc Brakes

a. Standard disc brakes shall be suitable for mounting to horizontal shaft motor frames as shown in MG 1-11.34 and MG 1-11.35 of the NEMA Standard for *Motors and Generators*, MG 1.

b. Mounting to other than horizontal-shaft motors is non-standard and shall be specified when required.

NEMA Standard 8-20-1986.

2-220.06 MANUAL RELEASE FOR BRAKES

Manual-release devices, when supplied, shall be one of the following types:

a. Manual release with automatic-reset.
b. Manual release with manual-reset.
c. Manual release which is self-resetting.

NEMA Standard 8-20-1986.

2-220.07 ENCLOSURES FOR BRAKES

Enclosures for brakes shall comply with NEMA Standards Publication No. ICS 6.

NEMA Standard 8-20-1986.

2-220.08 BRAKE TYPES

.01 Series brakes are used with DC series motors. The brake release coil is connected in series with the motor armature and field, motor, or both.

.02 Shunt brakes are used with either DC or AC motors and with the brake release coil arranged for connection across a motor or power source.

.03 Rectifier operated brakes are used with an AC power source and are provided with DC shunt release coils.

NEMA Standard 8-20-1986.

2-220.09 ENVIRONMENTAL REQUIREMENTS

.01 Brake coil terminal enclosures, if supplied, shall be suitable for the environment specified and shall be in accordance with NEMA Standards Publication No. ICS 6.

.02 Disc brakes employing Type 7D enclosures (when the brake hub is supported as it would be on the Type C motor face) for installation in hazardous locations shall conform to the Underwriters Laboratories Inc., Publication No. UL 674, *Electric Motors and Generators for Use in Hazardous Locations, Class I, Groups C and D, Class 2, Groups E, F, and G.*

NEMA Standard 8-20-1986.

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RATINGS

2-220.20 GENERAL PURPOSE SHOE BRAKE TORQUE RATINGS

The torque ratings of shoe brakes with series or shunt coils shall be as shown in Table 2-220-1.

NEMA Standard 11-12-1953.

Direct-current brakes with rectifiers, when applied on alternating-current circuits, may be given the direct-current 1-hour shunt torque ratings shown in the above table if used with one-hour coils. If used with continuous duty coils, continuous torque ratings may be given.

This table applies to brakes for application on other than the 600 frame, 800 frame, wound-rotor motors and AC frame AISE** mill motors and short time rated crane and hoist motors.

Authorized Engineering Information 8-20-1986.

2-220.21 TORQUE RATINGS OF DC OPERATED SHOE BRAKES FOR USE WITH THE 600 FRAME, 800 FRAME, WOUND-ROTOR MOTORS, AC FRAME AISE ** MILL MOTORS, AND SHORT TIME RATED CRANE AND HOIST MOTORS

The torque ratings of DC operated shoe brakes with series or shunt coils for use with the 600 frame, 800 frame, wound-rotor motors, AC frame AISE[1] mill motors, and short-time rated crane and hoist motors shall be as shown in Table 2-220-2.

NEMA Standard 8-20-1986.

Table 2-220-1
GENERAL PURPOSE SHOE BRAKE TORQUE RATINGS FOR USE WITH OTHER THAN 600 FRAME, 800 FRAME, WOUND ROTOR MOTORS AND AC FRAME AISE** MILL MOTORS, AND SHORT TIME RATED CRANE AND HOIST MOTORS

Direct-current-operated Brakes				50- and 60-hertz Alternating-current-operated Brakes	
Torque of Shunt Brake, Pound-feet		Torque of Series Brake, Pound-feet		Torque Ratings, Pound-feet	
Continuous*	1-hour*	1-hour*	½-hour*	Continuous*	1-hour or ½-hour*
3	—	—	—	1.5	—
10	15	—	—	3	—
25	35	—	—	10	15
50	75	—	—	25	35
70	90	60	90	50	75
150	200	135	200	125	160
400	525	350	525	325	400
675	900	600	900	600	800
1350	1800	1200	1800	1200	1600
2700	3600	2400	3600	2400	3200

*These refer to the continuous, 1-hour or ½-hour thermal ratings of the operator or coils.

**AISE refers to Association of Iron and Steel Engineers, Standards No. 1-1968, *DC Mill Motor Standard*, and 1-A-1964, *AC Mill Motor Standard*, available from AISE, Three Gateway Center, Suite 2350, Pittsburgh, PA 15222.

[1]Refers to AISE Standards 1 and 1-A.

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Table 2-220-2
TORQUE RATINGS OF DC OPERATED SHOE BRAKES FOR USE WITH 600 FRAME, 800 FRAME, WOUND-ROTOR MOTORS, AC FRAME AISE MILL MOTORS, AND SHORT TIME RATED CRANE AND HOIST MOTORS

Brake Size (Wheel Diameter	TORQUE RATINGS (LBS. - FT.)					
	SHUNT		SERIES		RECTIFIER OPERATED	
	Cont.* (8 Hour) Duty	1 Hour (50% Duty Cycle) or 8 Hour (100% Duty) Hi-Speed Forced	1 Hour* (50% Duty Cycle)	½ Hour* (30% Duty Cycle)	8 Hour (100% Duty) **	1 Hour (50% Duty Cycle) or 8 Hour (100% Duty) Hi-Speed Forced **
8″	75	100	65	100	75	100
10″	150	200	130	200	150	200
13″	400	550	365	550	400	550
16″	750	1000	650	1000	750	1000
19″	1500	2000	1300	2000	1500	2000
23″	3000	4000	2600	4000	3000	4000
30″	6750	9000	6000	9000	6750	9000

*Ratings shown for 8-hour, 1-hour and ½-hour are the thermal ratings of the coil. The duty cycles apply providing the on-time does not exceed 10 minutes.

The torque ratings apply at a worn lining condition defined as the point where the brake readjusts, or where adjustment is required as recommended by the brake manufacturer.

**See Paragraph ICS 2-220.08.03

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2-220.22 TORQUE RATINGS FOR DISC BRAKES

Torque ratings for alternating- and direct-current disc brakes, corresponding to motor frame sizes, shall be as shown in Table 2-220-3.

NEMA Standard 8-20-1986.

Brake designations A, B, C, and D refer to brake diameter. No attempt is made to identify a specific diameter. For each size of brake, there are various torque ratings available which may be obtained by varying the number of discs which, in turn, will vary the length of the brake.

Authorized Engineering Information 7-13-1960.

2-220.23 SHOE BRAKE COIL RATINGS OF THE BRAKE TYPES INDICATED IN PARAGRAPH ICS 2-220.21

Coil ratings are established based on the brake operating duty cycle and thermal capacity of the operating coil. Refer to the manufacturer for maximum current coil ratings.

Authorized Engineering Information 8-20-1986.

Table 2-220-3
TORQUE RATINGS FOR DISC BRAKES

BRAKE SIZE	MOTOR FRAME	BRAKE TORQUE, POUND-FEET
A	56C*, 143TC*, 182TCH*, 145TC*, 184TCH*	Static Torque Range—1 to 25 (1½, 3, 6, 10, 15, 20, 25 Typical Static Torque Increments)
B	182TC*, 184TC*, 213TC*, 215TC*, 254TC*, 256TC*	Static Torque Range—10 to 105 (10, 15, 25, 35, 50, 75, 105 Typical Static Torque Increments)
C	284TFC, 286TFC	Static Torque Range—25 to 175 (25, 35, 50, 70, 75, 105, 125, 175 Typical Static Torque Increments)
D	324TFC, 356TFC, 364TFC, 365TFC, 404TFC, 405TFC	Static Torque Range—75 to 550 (75, 90, 105, 125, 175, 230, 345, 460, 550 Typical Static Torque Increments)

*Certain brakes can be used on drive end, but when the face for mounting is at the end opposite the drive, the prefix F shall be used, making the suffix letter FC.

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DESIGN TESTS AND PERFORMANCE

2-220.40 RANGE OF OPERATING VOLTAGE AND CURRENT AT MAXIMUM RATED TORQUE

Direct-current brakes operated by series coils shall release at 40 percent or less of rated motor current and shall set at 10 percent or less of rated motor current.

Direct-current brakes operated by shunt coils shall release at 80 percent or less of rated voltage and shall operate satisfactorily at 110 percent of rated voltage.

Alternating-current brakes operated by shunt coils shall release at 85 percent of rated voltage and shall operate satisfactorily at 110 percent of rated voltage.

Under the voltage or current operating conditions described above, the brake shall be adjusted to worn lining condition defined as the point where the brake readjusts, or where adjustment is required, as recommended by the brake manufacturer.

A brake which is operated by a shunt coil shall operate successfully at its minimum voltage when the temperature of the brake coil is at the operating temperature obtainable in a 40°C ambient, at its normal operating rating.

NEMA Standard 8-20-1986.

2-220.41 TEMPERATURE RISE OF COILS

The operating coil of a shoe or disk brake shall not exceed the temperature rise specified in Part 1-109 of NEMA Standards Publication No. ICS 1 when operated at rated voltage and duty cycle.

NEMA Standard 11-12-1981.

Exception: When Class F coil insulation is incorporated, a temperature rise, determined by resistance of 115°C above an ambient of 40°C, shall be allowed.

NEMA Standard 11-12-1981.

2-220.42 BRAKING TORQUE

.01 A new shoe brake should equal or exceed the rated torque value in Tables 2-220-1 and 2-220-2 in both a dynamic and static mode and at operating temperatures of the braking surfaces as defined by the manufacturer, when installed, adjusted and aligned per the manufacturer's instructions. For exceptions, see Paragraph ICS 2-220.83.b.

.02 A new disc brake should have a static torque of not less than 90% of rated torque after following the manufacturer's recommended installation procedures. This brake should maintain a minimum of 90% of rated static torque at operating temperatures determined by the heat dissipation capabilities listed by the manufacturer.

Authorized Engineering Information 8-20-1986.

2-220.43 DIELECTRIC TEST

The operating coil shall withstand a power frequency dielectric test as shown in Paragraph ICS 1-109.21.

NEMA Standard 8-20-1986.

MANUFACTURING

2-220.60 DIMENSIONS OF DC OPERATED SHOE BRAKES FOR THE 600 FRAME, 800 FRAME, WOUND-ROTOR MOTORS, AC FRAME AISE* MILL MOTORS, AND SHORT TIME RATED CRANE AND HOIST MOTORS

The outline and mounting dimensions of DC operated shoe brakes for the 600 frame, 800 frame, Wound-rotor Motors, AC frame AISE* mill motors, and short time rated crane and hoist motors shall be as shown in Table 2-220-4. These brakes are floor mounted and are of open construction. The brake lining width is 1/4 inch less than dimension C. Brake mounting tolerances, both horizontal and vertical with respect to the motor, shall be as indicated in Table 2-220-4..

NEMA Standard 8-20-1986.

*Refers to AISE Standards 1 and 1-A.

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TABLE 2-220-4
DIMENSIONS OF DC OPERATED SHOE BRAKES FOR THE 600 FRAME, 800 FRAME, WOUND-ROTOR MOTORS AND AC FRAME AISE* MILL MOTORS AND SHORT TIME RATED CRANE AND HOIST MOTORS**

Wheel Size-Inches D	Motor Frame Size	Wheel Dimensions - Inches				Mounting Dimensions - Inches						
		C	E	F	O	A	B	H	J	Z***	K	L
8	254X	3¼	2½	1 13/16	2 11/16	3¼ ± .032	2 7/8 ± .032	11/16	7 ± .032	—	—	¾
	256X	"	2¾	2 3/16	3 5/16	"	"	"	"	—	—	¾
	284X	"	"	"	"	"	"	"	"	—	0	0
	286X	"	"	"	"	"	"	"	"	—	0	0
	324X	"	3	1 1/16	2 6/17	"	"	"	"	—	—	1
	326X	"	"	"	"	"	"	"	"	—	—	1
	364X	"	3 5/8	2	4	"	"	"	"	—	—	2
	365X	"	"	"	"	"	"	"	"	—	—	2
	2 602 802	"	3	2 5/8	"	"	"	"	"	8¼	5/8	—
	603 803	"	3½	2 1/8	"	"	"	"	"	9	1½	—
	604 804	"	"	"	"	"	"	"	"	9½	2	—
	606	"	4	1 5/8	"	"	"	"	"	9½	3	—
	AC1 AC2	"	3	2 5/8	"	"	"	"	"	9 5/8	0	0
	AC4	"	"	"	"	"	"	"	"	10 1/8	1	—
	AC8	"	4	1 5/8	"	"	"	"	"	10 5/8	2	—
10	284X	3¾	2 3/4	2 5/8	3¾	4 ± .032	3 1/8 ± .032	11/16	8 1/8 ± .032	—	—	1 3/8
	286X	"	"	"	"	"	"	"	"	—	—	1 3/8
	324X	"	"	"	"	"	"	"	"	—	—	3/8
	326X	"	3	2 1/8	3¼	"	"	"	"	—	—	3/8
	364X	"	3 5/8	1 7/8	3 5/8	"	"	"	"	—	5/8	—
	365X	"	"	"	"	"	"	"	"	—	5/8	—
	404X	"	3 7/8	1 7/8	3 7/8	"	"	"	"	—	1 5/8	—
	405X	"	"	"	"	"	"	"	"	—	1 5/8	—
	444X	"	4¼	1½	"	"	"	"	"	—	2 5/8	—
	445X	"	"	"	"	"	"	"	"	—	2 5/8	—
	602 802	"	3	3 1/8	4¼	"	"	"	"	8½	—	3/4
	603 803	"	3½	2 5/8	"	"	"	"	"	9¼	1/8	—
	604 804	"	"	"	"	"	"	"	"	9¾	5/8	—
	606 806	"	4	2 1/8	"	"	"	"	"	9¾	1 5/8	—
	608	"	4½	1 5/8	"	"	"	"	"	9 7/8	2 7/8	—
	AC1 AC2	"	3	3 1/8	"	"	"	"	"	9 7/8	—	1 3/8
	AC4	"	"	"	"	"	"	"	"	10 3/8	—	3/8
	AC8	"	4	2 1/8	"	"	"	"	"	10 7/8	5/8	—
	AC12	"	"	"	"	"	"	"	"	11 5/8	1 5/8	—

*Refers to AISE Standards 1 and 1-A.
**Per NEMA Standards Publication No. MG-1, Clauses MG 1-18.506, 18.519 and 18.520.
***Z dimension has not been established for wound-rotor motors. Refer to MG1-18.520.

(continued)

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TABLE 2-220-4 *(Continued)*

Wheel Size-Inches D	Motor Frame Size	Wheel Dimensions - Inches				Mounting Dimensions - Inches						
		C	E	F	O	A	B	H	J	Z***	K	L
13	324X	5¾	3	4 3/8	4½	5¾ ±.032	4½ ±.032	13/16	9 7/8 ±.045	—	—	1 7/8
	326X	"	"	"	"	"	"	"	"	—	—	1 7/8
	364X	"	3 5/8	4 5/16	5 1/16	"	"	"	"	—	—	7/8
	365X	"	"	"	"	"	"	"	"	—	—	7/8
	404X	"	3 7/8	3 3/8	4 3/8	"	"	"	"	—	1/8	—
	444X	"	"	"		"	"	"	"	—	1/8	—
	444X	"	4¼	2½	3 7/8	"	"	"	"	—	1 1/8	—
	445X	"	"	"	"	"	"	"	"	—	1 1/8	—
	603 803	"	3½	4 3/8	5	"	"	"	"	10	—	1 3/8
	604 804	"	"	"	"	"	"	"	"	10½	—	7/8
	606 806	"	4	3 7/8	5 3/8	"	"	"	"	10½	1/8	—
	608 808	"	4½	3¾	—	"	"	"	"	11	1 3/8	—
	610 810	"	"	"	"	"	"	"	"	11 5/8	2 3/8	—
	612 812	"	5	3¼	"	"	"	"	"	12 1/8	3½	—
	614 814	"	"	"	"	"	"	"	"	13 1/8	4 7/8	—
	AC8	"	4	3 7/8	5	"	"	"	"	11 5/8		7/8
	AC12	"	"	"	"	"	"	"	"	12 3/8	1/8	—
	AC18	"	4½	3 3/4	5 3/8	"	"	"	"	14 11/32	2 5/8	—
	AC25 AC30	"	5	3¼	"	"	"	"	"	15 13/16	4 5/8	—
16	404X	6¾	3 7/8	5 3/8	5 7/8	7½ ±.032	5 3/8 ±.032	1 1/16	12 1/8 ±.045	—	—	2 1/8
	405X	"	"	"	"	"	"	"	"	—	—	2 1/8
	444X	"	4¼	4½	5 3/8	"	"	"	"	—	—	1 1/8
	445X	"	"	"	"	"	"	"	"	—	—	1 1/8
	606 806	"	4	5 7/8	6½	"	"	"	"	12	—	2 1/8
	608 808	"	4½	5 3/8	"	"	"	"	"	12 1/8	—	7/8
	610 810	"	"	"	"	"	"	"	"	12¾	1/8	—
	612 812	"	5	4 7/8	"	"	"	"	"	13¼	1¼	—
	614 814	"	"	"	"	"	"	"	"	14¼	2 5/8	—
	616 816	"	5½	4 3/8	"	"	"	"	"	15½	3 7/8	—
	AC18	"	4½	5 3/8	"	"	"	"	"	15 15/32	3/8	—
	AC25 AC30	"	5	4 7/8	"	"	"	"	"	16 15/16	2 3/8	—
	AC40 AC50	"	"	"		"	"	"	"	18½	4 7/8	—
19	444X	8¾	4¼	5 9/16	5 7/16	9¼ ±.032	6½ ±.032	1 1/16	13¼ ±.062	—	—	2¼
	445X	"	"	"	"	"	"	"	"	—	—	2¼
	608 808	"	4½	7 3/8	7½	"	"	"	"	13 1/8	—	2
	610 810	"	"	"	"	"	"	"	"	13¾	—	1
	612 812	"	5	6 7/8	"	"	"	"	"	14¼	1/8	—
	614 814	"	"	"	"	"	"	"	"	15¼	1½	—
	616 816	"	5½	6 3/8	"	"	"	"	"	16½	2¾	—
	618 818	"	6	5 7/8	"	"	"	"	"	16	4½	—
	620	"	6¾	5 1/8	"	"	"	"	"	16	7 5/8	—
	AC25 AC30	"	5	6 7/8	"	"	"	"	"	17 15/16	1¼	—
	AC40 AC50	"		"		"	"	"	"	19½	3¾	—

(continued)

***Z dimension has not been established for wound-rotor motors. Refer to MG 1-18.520.

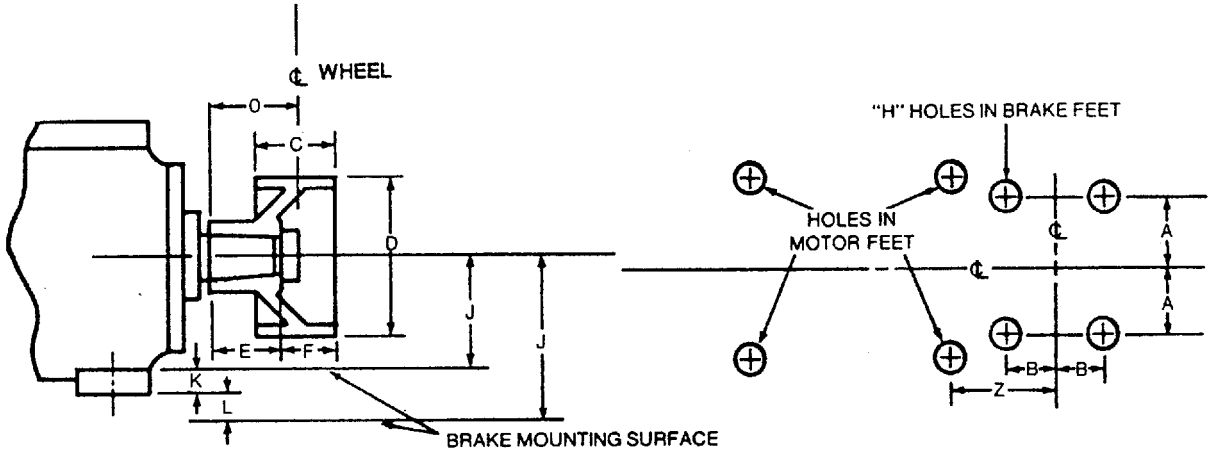
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TABLE 2-220-4 *(Continued)*

Wheel Size-Inches D	Motor Frame Size	Wheel Dimensions - Inches				Mounting Dimensions - Inches						
		C	E	F	O	A	B	H	J	Z***	K	L
23	612 812	11¼	5	8 7/8	8¼	11¾ ± .032	8 ± .032	1 5/16	15 7/8 ± .062	15	—	2½
	614 814	"	"	"	"	"	"	"	"	16	—	1 1/8
	616 816	"	5½	8 3/8	"	"	"	"	"	17¼	1/8	—
	618 818	"	6	8 3/8	8¾	"	"	"	"	17¼	1 7/8	—
	620	"	6¾	8 5/8	9¾	"	"	"	"	18¼	5	—
	622	"	7¼	8 1/8	"	"	"	"	"	17½	7 1/8	—
	624	"	9¼	6 1/8	"	"	"	"	"	18¼	8 1/8	—
	AC25 AC30	"	5	8 7/8	8¼	"	"	"	"	18 11/16	—	1 3/8
	AC40 AC50	"	"	"	"	"	"	"	"	20¼	1 1/8	—
30	616 816	14¼	5½	11 7/8	10¼	15 ± .032	9½ ± .032	1 9/16	20¾ ± .075	19¼	—	4¾
	618 818	"	6	11 3/8	"	"	"	"	"	18¾	—	3
	620	"	6¾	10 5/8	"	"	"	"	"	18¾	1/8	—
	622	"	7¼	10 5/8	10¾	"	"	"	"	18½	2¼	—
	624	"	9¼	8 5/8	"	"	"	"	"	19¼	3¼	—

***Z dimension has not been established for wound-rotor motors. Refer to MG 1-18.520.



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2-220.61 DEVICE MARKINGS

Brakes shall be marked with the following data:

a. Rated voltage, current, or both;
b. Torque;
c. Brake identification number;
d. Manufacturer's name or identification mark; and
e. Special mounting arrangements (disc brakes only).

NEMA Standard 8-20-1986.

2-220.62 BRAKE WHEEL UNBALANCE (MAXIMUM ALLOWABLE) FOR BRAKES

For the maximum allowable brake wheel unbalance, see Table 2-220-5.

Authorized Engineering Information 8-20-1986.

TABLE 2-220-5
MAXIMUM ALLOWABLE BRAKE WHEEL UNBALANCE

Wheel Diameter	Maximum Unbalance In Ounce-Inches
8	4
10	5
13	6
16	10
19	19
23	32
30	60

2-220.63 MOUNTING DIMENSIONS FOR DISC BRAKES FOR MOUNTING ON NEMA TYPE C FACE-MOUNTED ALTERNATING-CURRENT MOTORS

Dimensions for Type FC face mounting for brakes on the end opposite the drive of alternating-current motors are shown in Table 2-220-6.

The disc brake mounting surface shall have bolt holes suitable for tabulated FBF screw sizes in the motor face. Such holes shall be located on diametral lines 45 degrees from the vertical centerline of the brake.

Any hole or holes required by the disc brake for leads from the motor shall be provided within an available area defined by a circle having the diameter and radial location as shown. This provision shall not apply to disc brakes employing Type 7 enclosures. See ICS 6.

NEMA Standard 8-20-1986.

Standards for disc brake hub bore, keyway and permissible length of motor shaft extension have not been developed.

Authorized Engineering Information 8-20-1986.

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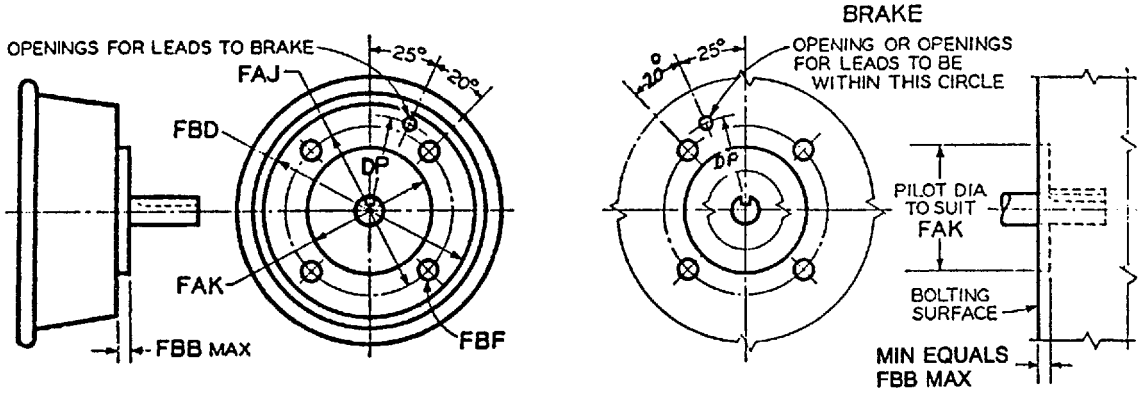
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TABLE 2-220-6
DIMENSIONS FOR TYPE FC FACE MOUNTING FOR BRAKES

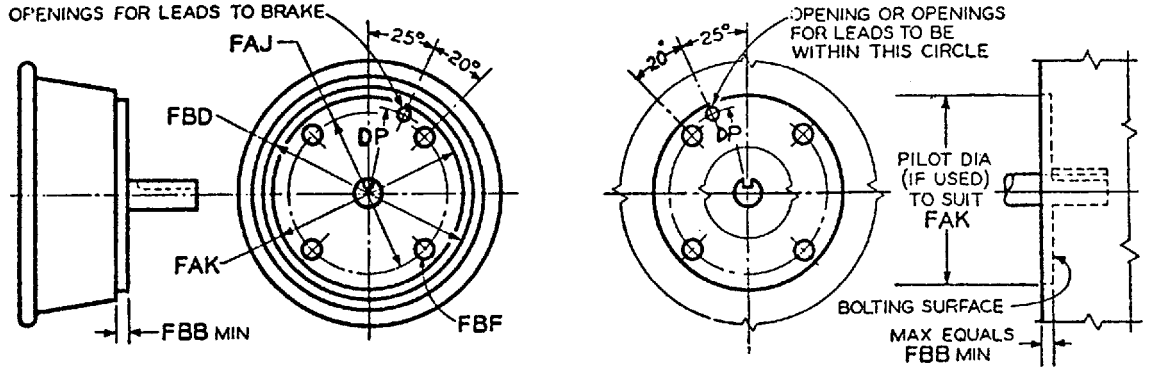
Type C Face Dimensions of Motor (See MG 1-11.36)								Brake Data		
		FBF Hole						Area for Leads		
Frame Designation	FAJ Bolt Circle	Number	Tap Size	Min Depth	FBD Outside Diameter of Face	FAK Outside Diameter of Pilot	FBB Depth of Pilot	Size	Diameter	DP (Radial Location)
*56C										
143TFC, 145TFC	5.875	4	3/8-16	0.56	6.50 Nom	4.50	0.16 Max	A	0.41	2.81
182TFC, 184TFC	5.875	4	3/8-16	0.56	6.50 Nom	4.50	0.16 Max	A	0.41	2.81
213TFC, 215TFC	7.250	4	1/2-13	0.75	9.00 Max	8.50	0.25 Min	B	0.62	3.81
254TFC, 256TFC	7.250	4	1/2-13	0.75	10.00 Max	8.50	0.25 Min	B	0.62	3.81
284TFC, 286TFC	9.000	4	1/2-13	0.75	11.25 Max	10.50	0.25 Min	C	0.62	4.50
324TFC, 326TFC	11.000	4	5/8-11	0.94	14.00 Max	12.50	0.25 Min	D	0.62	5.25

*Mounting dimensions not standardized.

MOTOR FRAMES 143TFC THROUGH 184TFC



MOTOR FRAMES 213TFC THROUGH 326TFC



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APPLICATIONS

2-220.80 BRAKE ENERGY DISSIPATION

.01 Starting from an operating temperature as defined by the manufacturer, a new shoe brake of the type indicated in ICS 2-220.21, should be capable of the one time emergency energy dissipation available from the manufacturer, without apparent damage to the brake or brake wheel.

Authorized Engineering Information 8-20-1986.

.02 The rate of energy dissipation allowable, under operating duty cycle conditions, in order not to exceed the normal operating temperature of the brake and brake wheel, can be obtained from the brake manufacturer if the manufacturer is provided with the brake size, number of brakes, maximum system Wk^2 running motor speed, accelerating time, running time, stopping time, off time, and ambient temperature for each duty cycle sequence.

Authorized Engineering Information 8-20-1986.

2-220.81 SHUNT BRAKE COIL CONTROL

.01 Shunt brakes provided with series resistors or with other voltage reduction control methods are used to enable the use of one-hour torque ratings on continuously energized brakes. They may also be used to obtain quicker setting and releasing than the standard brake.

.02 A control system including a suitable rectifier and series resistors or with other voltage reduction methods is used to enable the use of one-hour torque ratings on continuously energized brakes. They may also be used to obtain quicker setting and releasing than the standard brake.

Authorized Engineering Information 8-20-1986.

2-220.82 TECHNICAL DATA

See Table 2-220-7 for brakes indicated in Paragraph ICS 2-220.21.

NEMA Standard 8-20-1986.

2-220.83 SPECIAL PRECAUTIONS

a. Consult with the manufacturer for any special precautions required when mounting brakes in positions other than floor or horizontal-shaft mounted, since certain modifications may be required for proper operation of the brake.
b. Since the brake torque may vary due to conditions such as moisture on the friction surfaces, rusty wheels or discs, lining glaze, alignment of linings and brake wheels or discs, and other variables, allowance for these variations should be considered during application and use.
c. One hundred percent contact of braking surfaces is not required. Refer to the manufacturer for recommendations.

Authorized Engineering Information 8-20-1986.

2-220.84 UNUSUAL ENVIRONMENTAL CONDITIONS

Consult with the manufacturer for any special precautions or modifications required when any of the following conditions exist.

a. Airborne magnetic particles
b. Ambient temperatures above 40°C or below 0°C
c. High shock or vibration
d. Airborne oil, salt, corrosives, abrasives or water
e. Exposure to radiation
f. Other unusual environmental conditions.

Authorized Engineering Information 8-20-1986.

2-220.85 BRAKE MOUNTING TOLERANCES

For shoe brakes indicated in ICS 2-220.21 see Table 2-220-4 for mounting tolerances, with respect to the motor, required for the proper operation of the brake.

Authorized Engineering Information 8-20-1986.

TABLE 2-220-7
TECHNICAL DATA TABLE

Wheel Dia. (Inches)	Max Rpm	Min. Wheel Dia. (Inches)	Lining Thickness (Inches)**	
			*** Riveted	Bonded
8	5000	7.94	.010	.016
10	4000	9.92	.010	.020
13	3300	12.90	.010	.026
16	2600	15.87	.015	.032
19	2300	18.87	.015	.038
23	1900	22.87	.015	.046
30	1600	29.87	.015	.060

* Minimum after remachining
** Minimum permissible prior to replacement
***Above rivet head at maximum wear point

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2-220.86 BRAKE WHEEL OVERHEATING

For brakes indicated in ICS 2-220.20, ICS 2-220.21, and ICS 2-220.22, the brake will overheat if the thermal rating of the brake is exceeded, or if the linings are rubbing due to improper adjustments or mechanical or electrical failure, resulting in the brake not releasing.

Expansion of overheated braking surfaces may take up the brake operating clearance and may result in rapid deterioration of the braking surfaces. Overheating of the braking surfaces may also result in fade (reduction of braking torque).

Authorized Engineering Information 8-20-1986.

2-220.87 BRAKE OPERATING TIME

Brake release and set times are different for each manufacturer and can be obtained by contacting the manufacturer. These operating times can be provided based on rated operating conditions or as described in ICS 2-220.40.

Authorized Engineering Information 8-20-1986.

2-220.88 USER TESTING

The user should establish a schedule to test for the following.

a. The brake operates properly.
b. The brake can stop and hold the rated load.

Authorized Engineering Information 8-20-1986.

2-220.89 PREVENTIVE MAINTENANCE GUIDE

See Part ICS 1-115, of NEMA Standards Publication ICS 1, for general maintenance instructions.

Authorized Engineering Information 5-25-1988.

2-220.90 SPECIFIC MAINTENANCE INSTRUCTIONS

In order to assure proper equipment operation, a periodic maintenance program should be established. Maintenance instructions should be obtained from the manufacturer for incorporation into this program.

Brakes should be inspected to see that magnet gaps and torque spring settings are correct. The brake should be operated to verify that the brake linings are being released from the wheel or disc. Linings should be examined to determine if new linings are needed. Electrical connections and mechanical joints should be inspected for proper tightness, in particular, the hardware securing the wheel to the motor shaft and the brake mounting bolts. Dirt and dust should be removed from the brake with particular attention being given to the armature gap which tends to collect magnetic particles. The brake wheel or disc should be examined for unusual scoring, overheating, cracking, or wear, to determine the need for replacement. The condition of bearings and bushing should be checked along with the overall mechanical and electrical integrity of the complete braking system.

Authorized Engineering Information 5-25-1988.

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Part ICS 2-221

AUXILIARY CONTACTS

Part ICS 2-221 covers auxiliary contacts of controllers and disconnect devices used in the control circuits of industrial control apparatus. These auxiliary contacts are electromechanical. For semiconductor control circuit output ratings, see Part ICS 2-126. Part ICS 2-125 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

RATINGS

2-221.20 CONTACT RATINGS

The contact ratings of auxiliary contacts used in control circuits shall be in accordance with Part ICS 2-125. For applications, see ICS 2-221.80.

NEMA Standard 9-20-1972.

2-221.21 STANDARD-DUTY AUXILIARY CONTACTS

Standard-duty auxiliary contacts shall have contact rating designations of B150, B300, B600, P150, P300 or P600 as shown in Table 2-125-1 for alternating current and Table 2-125-2 for direct current.

NEMA Standard 9-20-1972.

2-221.22 HEAVY-DUTY AUXILIARY CONTACTS

Heavy-duty auxiliary contacts shall have contact rating designations of A150, A300, A600, N150, N300 or N600 as shown in Table 2-125-1 for alternating current and Table 2-125-2 for direct current.

NEMA Standard 9-20-1972.

DESIGN TESTS AND PERFORMANCE

2-221.40 CONTACT PERFORMANCE

Auxiliary contacts, when new, shall be capable of passing the temperature rise, overload, endurance and emergency condition tests described in Part ICS 2-125.

NEMA Standard 9-20-1972.

2-221.41 TEMPERATURE RISE OF TERMINALS

The field wiring terminals of auxiliary contacts carrying continuous thermal test current shall not exceed the temperature rise given in Part 1-109 of NEMA Standards Publication No. ICS 1 when wired as according to Table 2-221-1.

Table 2-221-1
CONDUCTORS FOR TESTING

Continuous Thermal Test Current, Amperes	Size of Copper Wire, AWG
5.1-10.0	14
2.6-5.0	20
2.5 and less	22

The terminals of all poles of the same mode shall be wired in series with 4 feet of wire between terminals.

Suggested Standard for Future Design 9-20-1972.

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APPLICATION

2-221.80 APPLICATION GUIDE

The make and break ratings and test values shown in Tables 2-125-1 and 2-125-2 shall not be used as application ratings where the total number of operations is expected to substantially exceed the number specified in the test conditions described in Part ICS 2-125.

When the load is an alternating-current electromagnetically operated mechanical device whose coil current may be interrupted occasionally before completion of its stroke, such as in jogging, the break current of the load shall be considered to be 50 percent of the make current of the load.

NEMA Standard 9-20-1972.

Because of the endless variety of application conditions in terms of the electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in this NEMA Standards Publication. Therefore, manufacturers' recommendations should be obtained regarding specific applications.

Authorized Engineering Information 1-27-1988.

2-221.81 OVERLAPPING CONTACTS

Because of manufacturing tolerances and the various characteristics of electrical loads, the normally open and normally closed contacts of auxiliary contact assemblies may or may not be conducting current simultaneously during operation. If such overlap or non-overlap is essential, the manufacturer should be consulted.

Because of manufacturing tolerances and the various characteristics of electrical loads, the auxiliary contacts of a controller or a disconnect device may open and close before or after the power contacts open and close. If it is essential that auxiliary contacts operate in some fixed relationship to the power contacts of a controller or a disconnect device, the manufacturer should be consulted.

Authorized Engineering Information 9-20-1972.

PREVENTIVE MAINTENANCE

2-221.90 PREVENTIVE MAINTENANCE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-1988.

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Part ICS 2-222

OVERLOAD RELAYS

Part ICS 2-222 covers overload relays that monitor line current. They may be mounted separately or combined with contactors (electric controllers) used in industrial control applications.

Parts ICS 2-125 and 2-126 apply to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

DEFINITIONS

2-222.01 DEFINITIONS

ALGORITHM

A prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps, for example, a full statement of an arithmetic procedure for evaluating sine x to a stated precision. (From IEEE Standard 100, *IEEE Standard Dictionary of Electrical and Electronics Terms*.)*

NEMA Standard 1-15-1986.

AMBIENT TEMPERATURE COMPENSATED (OVERLOAD RELAY)

A qualifying term applied to an overload relay to indicate that its ultimate current remains essentially unchanged over a designated range of ambient temperatures.

NEMA Standard 1-15-1986.

AMBIENT TEMPERATURE SENSITIVITY (OVERLOAD RELAY)

An expression of performance which defines the variations in its ultimate current over a designated range of ambient temperature.

NEMA Standard 1-15-1986.

CURRENT ELEMENT (OVERLOAD RELAY)

The part of an overload relay that determines the value of current which causes the relay to operate (trip). Current elements of thermal overload relays are referred to as heater elements.

NEMA Standard 1-15-1986.

CURRENT RATING (OVERLOAD RELAY)

The minimum value of continuously applied current which is expected to cause all like relays to operate (trip) under designated conditions. This value, for an individual relay, may be equal to or exceed its ultimate current under these conditions.

NEMA Standard 1-15-1986.

HEATER ELEMENT (THERMAL OVERLOAD RELAY)

The part of a thermal overload relay that is intended to produce heat when conducting current. Heater elements are sometimes referred to as heaters, thermal units, current elements, or heating elements.

NEMA Standard 1-15-1986.

INDUCTION-DISC RELAY

A protective device that includes a rotating disc in which currents are induced by permanent magnets and electromagnets in such a manner that the rotation of the disc to operate contacts is related to a selected inverse time function.

NEMA Standard 1-15-1986.

INSTANTANEOUS TRIP

A qualifying term indicating that no delay is purposely introduced in the tripping action of the relay.

NEMA Standard 1-15-1986.

INTEGRATED MOTOR MONITOR

A single solid-state device that provides a multiplicity of motor monitoring functions, one of which is overload protection, by sensing current components and using an algorithm to determine when it should provide a signal to alarm and/or trip.

NEMA Standard 1-15-1986.

INTERFACE EIA STANDARD RS 232 – A or B or C

A standardized method adopted by the Electronic Industries Association to insure uniformity of interface between data communication equipment and data processing terminal equipment. The standard interface has been generally accepted by a great majority of the manufacturers of data transmission and business equipment. (From IEEE Standard 100,)

NEMA Standard 1-15-1986.

*See Appendix A.

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INVERSE TIME

A qualifying term indicating that a delay is purposely introduced in the tripping action of the relay. The delay decreases as the magnitude of the current increases.

NEMA Standard 1-15-1986.

LIMIT OF SELF PROTECTION

The maximum current value that an overload relay can respond to without sustaining damage that will impair its function.

NEMA Standard 1-15-1986.

OPERATING MEMORY

A characteristic of an overload relay that considers the cumulative heating effect in the motor circuit resulting from motor operation or overload, and the cooling effect after the motor circuit is de-energized.

NEMA Standard 1-15-1986.

OPERATING MEMORY, NON-VOLATILE

An operating memory that is not lost if power to the relay is interrupted for a short period of time (See ICS 2-222.47, Operating Memory Verification Test for an Inverse-Time Overload Relay).

NEMA Standard 1-15-1986.

OVERCURRENT

Any current in excess of the rated continuous current of equipment or the ampacity of a conductor. It may result from motor starting, overload, short circuit or ground fault.

NEMA Standard 1-15-1986.

OVERLOAD

Operation of equipment in an electrically undamaged circuit in excess or normal, full-load rating, or of a conductor in excess of rated ampacity which, if persisting for a sufficient length of time, would cause damage or overheating. A fault, such as a short circuit or ground fault or a loss of phase, is not an overload.

NEMA Standard 1-15-1986.

OVERLOAD RELAY

An overcurrent relay which operates (trips) at a predetermined value of over-current to provide a signal or to cause disconnection of the load from the power supply, or both.

An overload relay is intended to protect the motor branch circuit conductors, the motor control apparatus and the motor(s) against overcurrent. It may not necessarily protect itself.

NEMA Standard 1-15-1986.

OVERLOAD RELAY CLASS

A classification of an overload relay time-current characteristic by means of a number which designates the maximum time in seconds at which it will operate (trip) when carrying a current equal to 600 percent of its current rating.

NEMA Standard 1-15-1986.

RESET, AUTOMATIC

A term used to describe an overload relay having an integral function that independently causes the overload relay to be reset.

NEMA Standard 1-15-1986.

RESET, MANUAL

A term used to describe an overload relay that requires deliberate human actuation in order to be reset.

NEMA Standard 1-15-1986.

SOLID-STATE OVERLOAD RELAY

An overload relay which senses overcurrent and performs a control function by means of a semiconductor circuit. A solid-state overload relay may have a semiconductor or a contact output.

NEMA Standard 1-15-1986.

THERMAL OVERLOAD RELAY

An overload relay that operates (trips) by means of a thermally responsive system.

NEMA Standard 1-15-1986.

TIME-CURRENT CHARACTERISTIC

An expression of performance which defines the operating time of an overload relay at various multiples of its current rating.

NEMA Standard 1-15-1986.

TRIP FREE

A qualifying term applied to an overload relay to indicate that its operation is independent of and non-voidable by the manual reset means.

NEMA Standard 1-15-1986.

ULTIMATE CURRENT

The minimum value of continuously applied current that will cause an overload relay to operate (trip).

NEMA Standard 1-15-1986.

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GENERAL INFORMATION AND FEATURES

2-222.02 LINE CURRENT HEATING EFFECT

Overload protection devices that respond to the heating effect of the motor line current include thermal and solid-state overload relays. Thermal overload relays use the motor line current to produce heat within themselves at a designed rate to simulate load and conductor heating. Solid-state overload relays of this type monitor motor line currents and determine with semiconductor circuits the heating effect of these currents on the load and conductors.

All thermal overload relays have an operating memory, i.e., they respond as if they remember that the load they are protecting has been operating at some rate and may not be cold when returned to service after an overload. Solid-state overload relays may have an equivalent operating memory. The operating function can be provided in various ways, such as by charging a capacitor or altering the count in a register of a microprocessor.

Overcurrents of short duration, such as those that occur during motor starting, are expected and do not cause excessive heating or damage to the motor, motor branch circuit conductors, or motor control equipment if they do not occur too frequently.

Authorized Engineering Information 1-15-1986.

2-222.03 INVERSE-TIME OVERLOAD RELAY CATEGORIES

Inverse-time overload relays are categorized by their ability to consider the cumulative heating effect in the motor circuit as a result of motor operation or overload. This characteristic, called operating memory, may be either volatile or non-volatile.

CATEGORY	CAPABILITY
A	Has non-volatile operating memory
B	Has volatile operating memory
C	Has no operating memory

NEMA Standard 1-15-1986.

2-222.04 LINE CURRENT MAGNITUDE

Protection devices that respond to the magnitude of the line current include magnetic, induction-disc, and solid-state relays, and jam detection relays. Such overload relays may be instantaneous or inverse time.

Instantaneous overcurrent relays ("jam" relays) are used in applications in which the overcurrent represents a load condition requiring instant removal of the motor from the line. The time and/or current to operate the relay must be such that normal overcurrents, such as during normal motor starting, do not cause nuisance tripping. This function may also be accomplished by disabling the "jam" relay during start-up.

Magnetic overload relays may also be inverse-time where the movement of the plunger attracted by a magnetic field is slowed by dashpot action. Solid-state overload relays may also have circuitry to obtain an inverse-time function.

Induction-disc relays provide adjustable inverse-time functions by varying the position or effect of the permanent magnets and/or electromagnets on the induction disc which must rotate to cause the relay to trip. (Ref. ANSI C37.90, *Standard Relays & Relay Systems Associated with Electrical Power Apparatus*)

Authorized Engineering Information 1-15-1986.

2-222.05 LINE CURRENT RELATIONSHIP IN POLYPHASE CIRCUITS

Both thermal and solid-state overload relays may respond to the relationship of line currents in each phase. This relationship may include phase loss, phase unbalance and phase angle functions. The response characteristics of overload relays to this relationship are not included in this standard.

Authorized Engineering Information 1-15-1986.

2-222.06 OVERLOAD RELAY TIME-CURRENT CHARACTERISTICS

The time-current characteristics of inverse-time overload relays in a 40°C ambient temperature are preferably expressed as the maximum operating times in seconds under the designated conditions associated with the current rating, at current values corresponding to multiples of the current rating. Curves such as minimum operating times may also be shown. All curves shall be identified. The time-current curve shall not be shown beyond the limit of self protection.

The preferred method for displaying these performance curves shall be time in seconds as ordinate and multiples of current rating as abscissa, plotted on a full logarithmic coordinate format as shown in the example in Figure 2-222-1.

NEMA Standard 1-15-1986.

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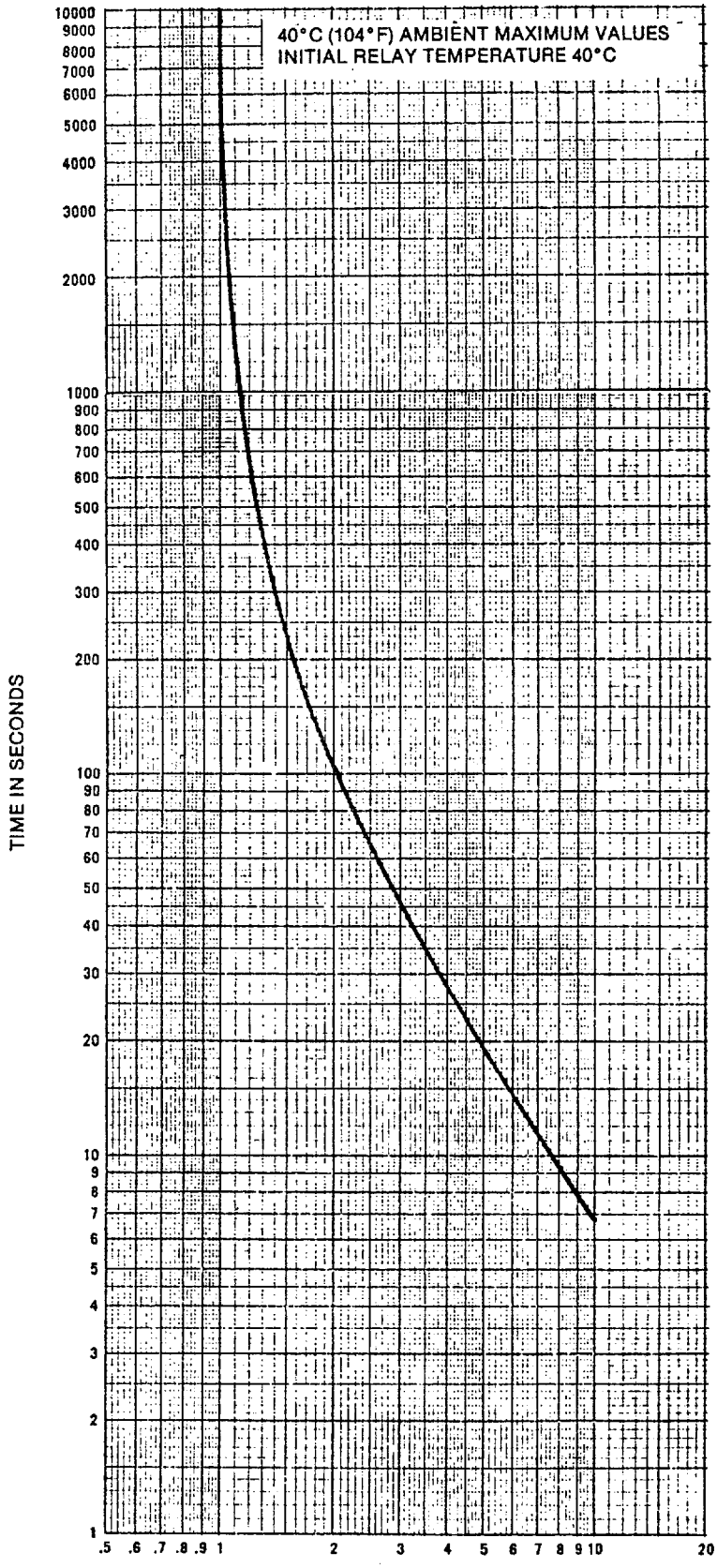


Figure 2-222-1
OVERLOAD RELAY TIME-CURRENT CHARACTERISTICS—EXAMPLE

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When the current setting is adjustable, these performance curves should be given for each end of the adjustment range. If the time characteristics are adjustable, they should also be given for each end of the adjustment range.

Authorized Engineering Information 1-15-1986.

2-222.07 OVERLOAD RELAY CLASS DESIGNATIONS

When an inverse-time overload relay is described by time-current characteristics, it shall be designated by a class number indicating the maximum time in seconds at which it will operate (trip) when carrying a current equal to 600% of its current rating. The class number applies with balanced overcurrent in all active phases. A Class 20 relay will operate (trip) in 20 seconds or less, a Class 30 relay will operate in 30 seconds or less, and a Class 10 relay will operate in 10 seconds or less.

NEMA Standard 1-15-1986.

A Class 15 relay will operate (trip) in 15 seconds or less.

Suggested Standard for Future Design 1-15-1986.

Class 10, 20 and 30 overload relays are normally applied to motors rated in horsepower. Class 15 overload relays are primarily for use with motors designed in accordance with the NEMA *Guide for the Development of Metric Standards for Motors and Generators*. Other Classes may be required for protection of solid-state contactors and motors with limited thermal capability.

Authorized Engineering Information 1-15-1986.

2-222.08 OVERLOAD RELAY LIMIT OF SELF PROTECTION

The limit of self protection of an overload relay at a 40°C ambient temperature shall be expressed by the assigned whole-number multiple of its current rating.

NEMA Standard 1-15-1986.

An overload relay should not be subjected to these current levels frequently.

Authorized Engineering Information 1-15-1986.

2-222.09 OVERLOAD RELAY AMBIENT TEMPERATURE SENSITIVITY

The ambient temperature sensitivity of an overload relay shall be expressed as the percent change in ultimate current per 10°C change of ambient temperature, between 25°C and 50°C.

NEMA Standard 1-15-1986.

The range of ambient temperature qualifying the percent change may be outside the application limits for continuous-duty operation and is only intended to provide the information necessary to predict the performance that can be expected under intermittent or abnormal operating conditions.

The ambient temperature sensitivity value may be applied to the current rating to determine the approximate ultimate current at other ambient temperatures.

Authorized Engineering Information 1-15-1986.

2-222.10 TRIP INDICATION

An overload relay may include a means to show that it is tripped.

Authorized Engineering Information 1-15-1986.

2-222.11 RESETTING

An overload relay shall be capable of being reset. Resetting may be accomplished automatically or manually. Overload relays shall be of the trip-free type.

NEMA Standard 1-15-1986.

If an overload relay is constructed so that it cannot be reset by the momentary removal and reapplication of power, instructions for power application should be included.

Authorized Engineering Information 1-15-1986.

2-222.12 INTERFACE WITH DATA COMMUNICATION EQUIPMENT

Where solid-state overload relays or an integrated motor monitor include the ability to transmit data point-to-point to a remote terminal or associated equipment, the data transmission shall be in accordance with the Electronic Industries Association (EIA) interface Standards RS-232 and RS-422.

Suggested Standard for Future Design 1-15-1986.

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RATINGS

2-222.20 OVERLOAD RELAY CURRENT RATING

The current rating of an overload relay shall be expressed in amperes at an ambient temperature of 40°C.

An overload relay may have different current ratings when used as an open-type device, or when mounted in an enclosure, or when used in combination with other equipment within a similar enclosure. The ambient temperature of 40°C for current rating assignment of enclosed devices shall refer to the measured temperature of the air which surrounds the enclosure.

NEMA Standard 1-15-1986.

2-222.21 MECHANICAL CONTROL-CIRCUIT CONTACT RATINGS

The rating of the contacts of an overload relay which operates in a control circuit shall be in accordance with Table 2-125-1 for the alternating-current ratings and Table 2-125-2 for direct-current ratings.

NEMA Standard 1-15-1986.

2-222.22 SOLID-STATE CONTROL CIRCUIT RATINGS

Over load relays with semiconductor control circuit switching elements shall be rated in accordance with Table 2-126-2 for alternating-current applications and in accordance with Table 2-126-3 for direct-current applications.

Suggested Standard for Future Design 1-15-1986.

DESIGN TESTS AND PERFORMANCE

2-222.40 VERIFICATION TEST FOR OVERLOAD RELAY CURRENT RATING AND TIME-CURRENT CHARACTERISTICS

.01 Test Conditions

a. Tests shall be conducted in an ambient temperature of 40°C ±1°C. The overload relay shall be allowed to reach thermal equilibrium with the specified ambient temperature before proceeding with each test.

b. Tests shall be conducted in a manner which simulates the intended service conditions. This includes the designated conditions for the assignment of the current rating, that is, whether the relay is a separate device or a part of a motor controller, and whether it is open or enclosed.

c. Relays designated as "ambient temperature compensated" shall be tested in ambient temperatures of 25°C and 50°C, as well as 40°C.

d. The power source shall be single phase 60 hertz with means for maintaining a sine wave current of an essentially constant rms value, unless the relay must be tested using another power system.

e. Current measurements shall be accurate within 1 percent of the measured value.

.02 Test Connections

a. *Conductors for Relays Marked for Full-load Current* – Conductors for the external wiring to the overload relay (or associated equipment), considered to be user connections, shall have a minimum length of 4 feet per terminal. The wire shall be of the smallest size having an ampacity of at least 125 percent of the maximum motor full-load current listing for the overload relay, the overload relay setting, or the overload relay current element. The wire shall be selected from the 75°C column of Table 310-16 of *National Electric Code*, unless otherwise specified by the manufacturer.

b. *Conductors for Relays Marked with Current Rating* – Conductors for the external wiring to the overload relay (or associated equipment), considered to be user connections, shall have a minimum length of 4 feet per terminal. The wire shall be the smallest size having an ampacity at least equal to the current rating of the relay, the overload relay setting, or the overload relay current element. The wire shall be selected from the 75°C column of Table 310-16 of *National Electrical Code*, unless otherwise specified by the manufacturer.

c. *Schematic Diagram* – The wiring for three-phase devices shall be in accordance with the typical schematic diagram shown in Figure 2-222-3 for three-phase test sources and as shown in Figure 2-222-2 for single-phase and direct-current sources. The wiring for single phase devices shall be in accordance with the manufacturer's instructions.

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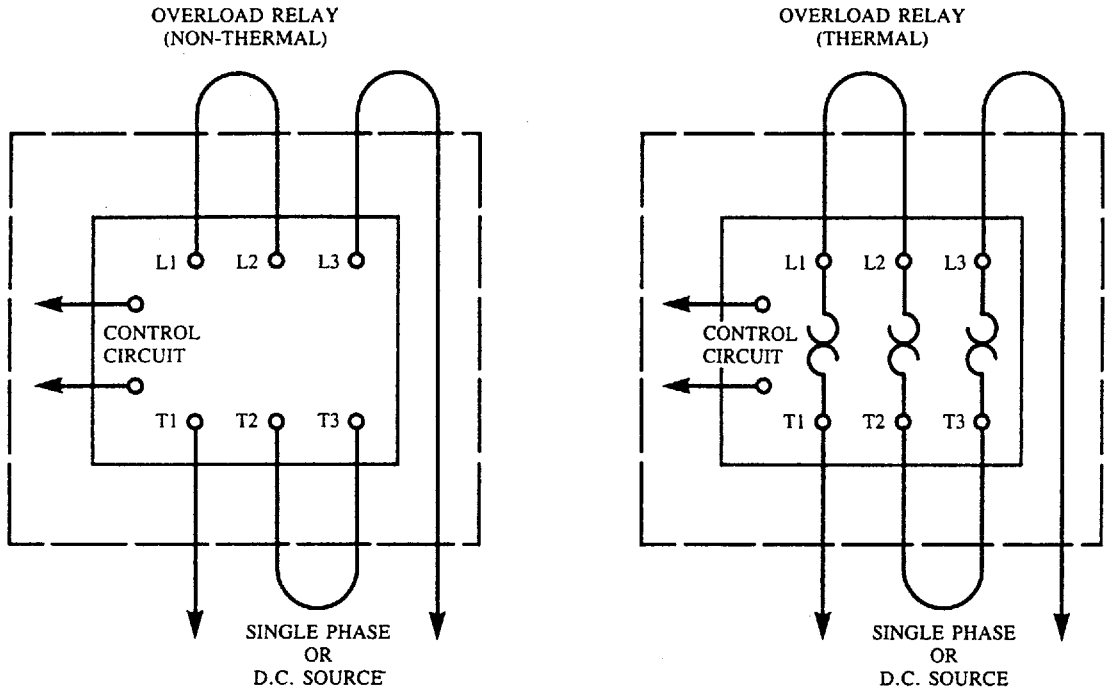


Figure 2-222-2
SCHEMATIC DIAGRAM OF THREE PHASE OVERLOAD RELAY
TEST CONNECTIONS FOR SINGLE PHASE AND D.C. TEST SOURCES

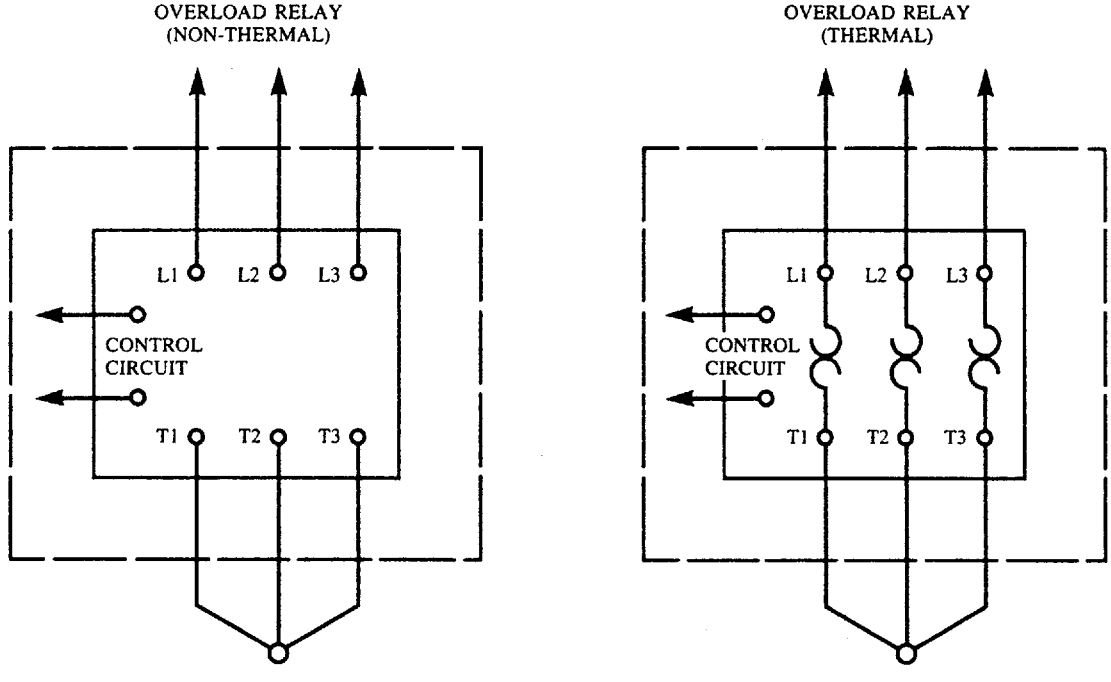


Figure 2-222-3
SCHEMATIC DIAGRAM OF THREE PHASE OVERLOAD RELAY
TEST CONNECTIONS FOR THREE PHASE SOURCE

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d. *Control Circuit* – To avoid possible damage to the relay, it is recommended that the test circuit be arranged so as to assure the disconnection of the current source when the overload relay operates (trips). (This subparagraph is approved as Authorized Engineering Information.)

.03 Test Procedure

a. A single-pole relay or a three-pole relay connected as a single-pole relay shall be tested at 100, 200 and 600 percent of the relay current rating.

b. Three single-pole relays, each with its own current element and trip mechanism, or a three-pole relay with three current elements and a single trip mechanism, intended for three-phase circuits, shall be tested at:
   1. 100 percent of the relay's current rating with three current elements connected,
   2. 200 percent of the relay's current rating with two current elements connected,
   3. 600 percent of the relay's current rating with two current elements connected, and
   4. 600 percent of the relay's current rating with three current elements connected.

c. An adjustable relay with interchangeable current elements and means for adjustment in percent of its current rating shall be set at the 100 percent mark on the adjustment scale and subjected to the test described in a. or b., depending on the intended application and number of relays involved. In addition, an adjustable relay shall be tested at its high and low adjustment points, such as the 120 and 80 percent marks, at 200 percent of its current rating to determine that the time of operation will be longer and shorter, respectively, than the operating time when the relay is subjected to the same test with the adjustment set at the 100 percent mark on the adjustment scale.

d. An adjustable relay arranged to cover several current ratings (trip currents) shall be tested at 100, 200 and 600 percent at its minimum, midpoint and maximum current ratings.

.04 Performance

When tested as described above, an overload relay shall perform as shown in Table 2-222-1.

NEMA Standard 1-15-1986.

2-222.41 VERIFICATION TEST FOR LIMIT OF SELF PROTECTION

.01 Test Conditions

The test conditions shall be the same as those specified in ICS 2-222.40.01 except that ambient-temperature-compensated relays may be tested at 40°C only.

.02 Test Procedure

A single test shall be conducted for the limit of self protection assigned to an overload relay.

The magnitude of the test current (self-protection limit current) is determined by multiplying the current rating of the overload relay by the multiplier assigned as its limit of self protection.

Table 2-222-1
OVERLOAD RELAY PERFORMANCE REQUIREMENTS

Test Current as Percent of Overload Relay Rating	Quantity of Poles Connected		Maximum Trip Times			
	3 Pole Relays	1 Pole Relays	Class 10	Class 15	Class 20	Class 30
100%	3	1	----------ULTIMATELY*----------			
200%	2	1	----------8 MINUTES----------			
600%	2 and 3	1	10 Sec.	15 Sec.	20 Sec.	30 Sec.

* Experience indicates that two to four hours is generally sufficient to verify this value. Systems which have large masses may require additional time.

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03. Test Connections

Test connections shall be the same as those specified in ICS 2-222.40.02.

The test circuit shall be arranged to assure that tripping of the load relay will immediately cause the relay to be disconnected from the current source.

.04 Performance

When tested at its self-protection limit current, an overload relay shall operate (trip) without sustaining damage that will impair its performance. An overload relay which has been subjected to this test shall be considered to conform to the requirements of this standard if it can subsequently be shown that it meets the requirements of the design test for current rating described in ICS 2-222.40.

NEMA Standard 1-15-1986.

2-222.42 VERIFICATION TEST FOR OVERLOAD RELAY AMBIENT TEMPERATURE SENSITIVITY

.01 Test Conditions

Test conditions shall be the same as those specified in ICS 2-222.40.01, except that tests shall be conducted at 40°C and other specified ambient temperatures.

.02 Test Connections

Test connections shall be the same as those specified in ICS 2-222.40.02.

.03 Test Procedure

The ultimate currents shall be determined at the ambient temperatures under consideration.

.04 Performance

When the ultimate currents are determined in this manner, the ambient temperature sensitivity of the overload relay shall not exceed the designated value.

NEMA Standard 1-15-1986.

2-222.43 OVERLOAD RELAY SHORT-TIME CAPABILITY

A new overload relay shall be capable of meeting the short-time operating and short-time surge capability requirements for controllers shown in Part ICS 2-321.

Suggested Standard for Future Design 1-15-1986.

2-222.44 CONTROL-CIRCUIT OUTPUT

The contacts or solid-state switching element of an overload relay shall perform in accordance with Part ICS 2-125, or Part ICS 2-126, respectively.

NEMA Standard 1-15-1986.

2-222.45 ELECTRICAL NOISE TEST FOR SOLID-STATE DEVICES

Solid-state overload relays and integrated multi-function motor monitors using semiconductor elements for sensing or switching shall not malfunction when subjected to the electrical noise test procedures of Part ICS 1-109.

NEMA Standard 1-15-1986.

2-222.46 IMPULSE WITHSTAND TEST FOR SOLID-STATE DEVICES

Solid-state overload relays and integrated multi-function motor monitors using semiconductor elements for sensing or switching shall not malfunction during and after being subjected to the impulse withstand test procedures of Part ICS 1-111A for installation (overvoltage) category III applied to the power circuit, and for installation (overvoltage) category II or I applied to the control circuit and power supply terminals.

Suggested Standard for Future Design 1-15-1986.

2-222.47 OPERATING MEMORY TEST FOR AN INVERSE-TIME OVERLOAD RELAY

An inverse-time overload relay that includes an operating memory shall be tested to verify the existence of a memory by applying 600 percent of rated current through all active phases, as shown in Figure 2-222-3 until it operates (trips). Reset as soon as possible. The time to trip and time to reset shall be recorded. The 600 percent current shall be reapplied and the time to trip recorded. The control power (if so equipped) shall be removed for 1.5 minutes after tripping, reapplied, and then the relay reset as soon as possible. The 600 percent current control power shall be applied for the third time and the time to trip recorded.

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Operating Memory Test Procedures

Test No.	Percent Rated Current	Trip Time	Procedure Following Trip
1	600	.T1 (Sec)	Reset as soon as possible.
2	600	.T2 (Sec)	Remove Control Power for 1.5 Minutes. Reapply Control Power. Reset as soon as possible.
3	600	.T3 (Sec)	----------

If, in Test No. 2, T2, the trip time is not greater than 85 percent of the trip time of Test No. 1, T1, the relay is considered to have an operating memory.

If, in test No. 3, T3, the trip time is not greater than 85 percent of the trip time in Test No. 1, T1, the relay is considered to have a non-volatile operating memory.

Suggested Standard for Future Design 1-15-1986.

2-222.48 SOLID STATE OVERLOAD RELAYS WITH EXTERNAL CONTROL POWER SOURCE

If an overload relay uses an external control power source, the relay shall open the normally closed contacts if the control power is removed.

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MANUFACTURING

2-222.60 IDENTIFICATION OF OVERLOAD RELAYS USING INTERCHANGEABLE CURRENT ELEMENTS

Interchangeable current elements shall bear identification which is visible after the apparatus is installed and wired. Information relating the identification to the complete device shall be furnished and shall include:

a. The current rating or the assigned motor full-load current or range of currents and frequency, when applicable.
b. Instructions for converting assigned motor full-load current to the relay current rating.
c. Maximum available fault current and recommendations for fault-current protection where such protection is not included with the equipment and where the requirements are more restrictive than those of the *National Electrical Code.*
d. Overload relay class if other than Class 20.
e. Overload relay category if other than Category A.
f. Range of adjustment if adjustment is provided.
g. Control circuit output ratings.
h. Power supply requirements (volts, amperes, hertz) when applicable.
i. Power conductor insulation temperature rating and size, expressed in one of two methods:
    1. By minimum insulation temperature rating (e.g., 75°C) and conductor size for each current element.
    2. By minimum insulation temperature rating and instructions permitting the use of conductors with a higher temperature rating, provided that the conductor size is selected on the basis of the ampacity of conductors with the minimum insulation temperature rating. For example, if 75°C is the minimum conductor insulation rating specified, 90°C conductors may be used, provided that the conductor size is selected from the 75°C column of Table 310-16 of the *National Electrical Code.*
j. Tightening torque for user connections.

NEMA Standard 1-15-1986.

2-222.61 IDENTIFICATION OF OVERLOAD RELAYS USING FIXED OR NON-INTERCHANGEABLE CURRENT ELEMENTS

An overload relay with fixed or noninterchangeable current elements shall meet the requirements of paragraph ICS 2-222.60 except that the identification of the current element may be marked on the overload relay.

Authorized Engineering Information 1-15-1986.

2-222.62 SELECTABLE FUNCTIONS AND SETTINGS

Where an overload relay provides functions or settings to be selected or adjusted by the user (e.g., overload relay class, phase unbalance, motor current, reset mode, etc.), these functions or settings shall be visible from the front when the overload relay or integrated motor monitor is mounted in its normal operating position.

Suggested Standard for Future Design 1-15-1986.

APPLICATION

2-222.80 CURRENT RATING AND TIME-CURRENT CHARACTERISTICS

The current rating and time-current characteristics of an overload relay should be coordinated with the components of a branch circuit selected in accordance with the *National Electrical Code.*

Authorized Engineering Information 1-15-1986.

2-222.81 LIMIT OF SELF PROTECTION

The current corresponding to the limit of self protection of an overload relay should be greater than the locked-rotor current of the motor which it is intended to protect.

Authorized Engineering Information 1-15-1986.

2-222.82 AMBIENT TEMPERATURE SENSITIVITY

The ambient temperature sensitivity provides the means to modify the selection of overload relays to accommodate a difference in ambient temperatures between the overload relay and motor that may exist on some applications.

Authorized Engineering Information 1-15-1986.

2-222.83 CAUTIONS ON THE USE OF AUTOMATIC RESET

Automatic reset of overload relays is a convenience in many installations and a necessity in some. However, the use of automatic reset should be considered only if:

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(a) the motor circuit will remain open when the overload relay contacts reclose, or (b) automatic restarting will not create a hazard.

An automatic-reset overload relay does not necessarily provide protection against overheating of a motor and its branch circuit components from a persisting overload condition that causes repetitive tripping and resetting of the relay. It may be necessary to provide means for delaying motor restarting or limiting the number of trip-reset cycles.

Authorized Engineering Information 1-15-1986.

2-222.84 POLYPHASE MOTORS UNDER SINGLE-PHASE OPERATING CONDITIONS

Overload protection which is provided by overcurrent units having current elements in each phase of a polyphase motor and which provides protection under polyphase operating overloads may not provide the same degree of protection when the same motor is operating under single-phase conditions.

Authorized Engineering Information 1-15-1986.

2-222.85 COORDINATION WITH FAULT-CURRENT PROTECTION

.01 Fault-current Protection

An overload relay should be protected against fault-currents by a device of a type and rating in accordance with ICS 222.60.c.

.02 Limit of Self Protection

At the current value corresponding to the self-protection limit of the overload relay, the fault-clearing time of the branch circuit protective device should not exceed the operating (trip) time of the overload relay. When this comparison is based on mean values, a margin for safety should be allowed to account for possible variations in operating (trip) times.

.03 Operating Overloads

At operating overloads it is desirable for the overload relay to operate (trip) before the branch circuit protective device can open the circuit. It may not be possible to obtain this degree of coordination with all types of branch circuit overcurrent devices.

Authorized Engineering Information 1-15-1986.

2-222.86 APPLICATION WITH CURRENT TRANSFORMERS

The current rating and the performance characteristics of an interconnected current transformer and overload relay combination will not necessarily be the same as those of the overload relay alone and shall be determined in the primary circuit of the current transformer.

NEMA Standard 1-15-1986.

2-222.87 CONTROL-CIRCUIT CONTACT RATING

The control-circuit contact rating of an overload relay should be related to the performance characteristics of the component(s) used in the particular control-circuit arrangement.

Authorized Engineering Information 1-15-1986.

2-222.88 OVERLOAD RELAY LIMITATIONS

Most devices offered to protect motors from overheating are designed to monitor line currents from a fixed frequency supply. Motors operating on a variable frequency supply voltage can be overheated by internal currents and loss of cooling at low speeds without appearing to be drawing excessive line current. Conventional overload relays should not be used in variable frequency motor branch circuits unless appropriate compensating steps are taken.

2-222.100 PREVENTIVE MAINTENANCE GUIDE

See Part ICS 1-115, of NEMA Standards Publication ICS 1, for general maintenance instructions.

Authorized Engineering Information 5-25-88.

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Part ICS 2-225

INDUSTRIAL LIMIT SWITCHES

Part ICS 2-225 covers limit switches used primarily in the control circuits of industrial control apparatus.
Part ICS 2-125 or ICS 2-126 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication Nos. 250, ICS 1 and ICS 6 also apply to this part.

DEFINITIONS

2-225.01 GENERAL DEFINITIONS

ACTUATING POINT

Actuating point is the point on an actuator at which operating force is normally applied.

NEMA Standard 6-24-1957.

ACTUATOR

An actuator is the mechanism of the switch or enclosure which, when moved as intended, will operate the contacts.

NEMA Standard 6-24-1957.

AUXILIARY ACTUATOR

An auxiliary actuator is a mechanism which may be attached to a switch to modify its characteristics.

NEMA Standard 6-24-1957.

BASIC SWITCH

A basic switch is a snap-acting switch of either the open type, skeleton type, or the type encased within an envelope. A basic switch is normally used within a protective enclosure or is used as a component.

NEMA Standard 6-24-1957.

BREAK DISTANCE

Break distance of a switch is the effective open-gap distance between the stationary and movable contacts.

NEMA Standard 6-24-1957.

CONTACT FORCE

Contact force is the force exerted by the moving contact on a stationary contact.

NEMA Standard 6-24-1957.

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 electrical circuit associated with the machine or equipment.

NEMA Standard 8-20-1966.

LIMIT SWITCH ENCLOSURE

A limit switch enclosure is a supplemental protection means for the basic switch but does not necessarily form an integral part thereof.

NEMA Standard 5-17-1971.

MAINTAINED CONTACT LIMIT SWITCH (RESET SWITCH)

A maintained contact limit switch is a switch which remains in a given condition until actuated to another condition, which is also maintained until further actuation. See Figure 2-225-3, Figure 2-225-4 and ICS 2-225.03.

NEMA Standard 5-17-1971.

MOMENTARY CONTACT LIMIT SWITCH

A momentary contact limit switch is a switch which returns from the operated condition to its normal circuit condition when the actuating force is removed. See Figure 2-225-1, Figure 2-225-2, and ICS 2-225.02.

NEMA Standard 5-17-1971.

OPERATED CONTACT POSITION

Operated contact position of a switch is the position to which the contacts move when the actuator is traveled to or beyond the actuator operating position.

NEMA Standard 6-24-1957.

OPERATING FORCE

Operating force is that straight-line force in the designated direction applied to the actuator to cause the switch contacts to snap to the operated contact position.

NEMA Standard 6-24-1957.

OPERATING POSITION

Operating position is the position of the actuator at which the contacts snap to the operated contact position.

NEMA Standard 6-24-1957.

OPERATING TORQUE

Operating torque is that torque which must be applied to the actuator to cause the moving contact to snap to the operated contact position.

NEMA Standard 6-24-1957.

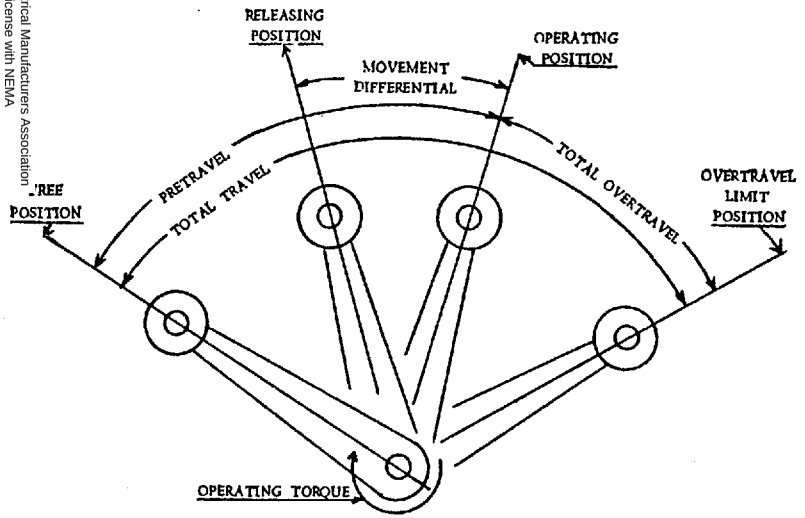
OVERTRAVEL

Overtravel is the movement of the actuator beyond the operating position.

NEMA Standard 6-24-1957.

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NOTE—Free position can be on the right with all positions, travels and torques reversed.

Fig. 2-225-1
MOMENTARY CONTACT LEVER-OPERATED LIMIT SWITCH

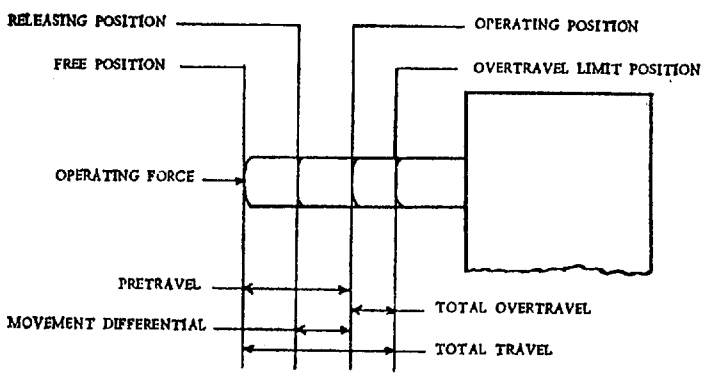
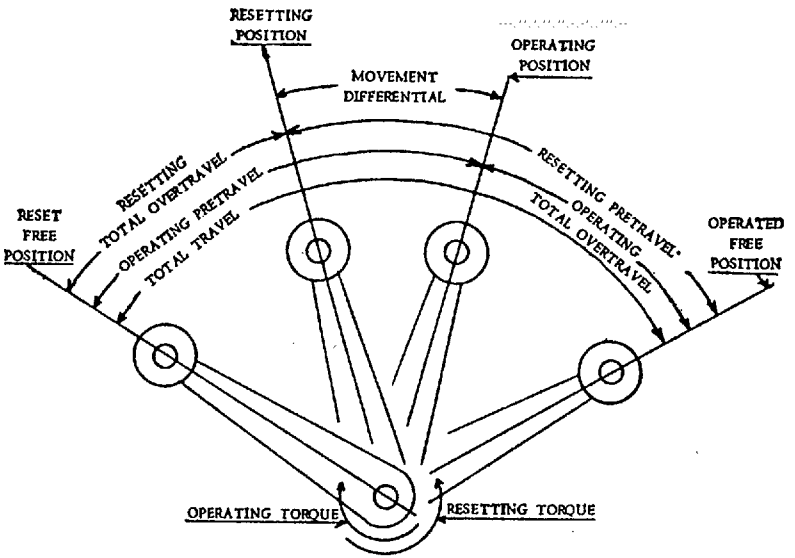


Fig. 2-225-2
MOMENTARY CONTACT PLUNGER-OPERATED LIMIT SWITCH



NOTE—All positions, travels and torques can be reversed.

Fig. 2-225-3
MAINTAINED CONTACT LEVER-OPERATED LIMIT SWITCH

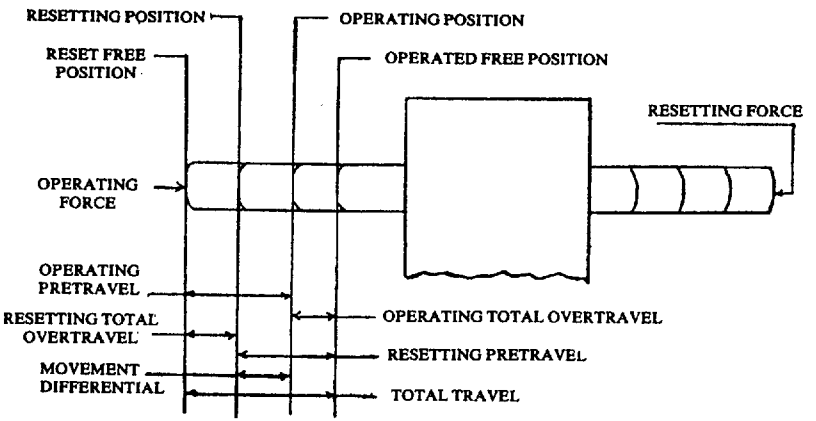


Fig. 2-225-4
MAINTAINED CONTACT PLUNGER-OPERATED LIMIT SWITCH

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OVERTRAVEL LIMIT POSITION

Overtravel limit position is that position of the actuator beyond which further overtravel would cause damage to the switch or actuator.

NEMA Standard 6-24-1957.

POWER-CIRCUIT LIMIT SWITCH

A power-circuit limit switch is a limit switch, the contacts of which are in the power circuit.

NEMA Standard 8-20-1966.

PRECISION SNAP-ACTING SWITCH

A precision snap-acting switch is a mechanically operated electric switch having predetermined and accurately controlled characteristics, and having contacts other than the blade and jaw, or mercury type, where the maximum separation between any butting contacts is 1/8 inch. A precision snap-acting switch consists of a basic switch used alone, a basic switch used with an actuator(s), or a basic switch used with an actuator(s) and an enclosure.

NEMA Standard 6-24-1957.

REPEAT ACCURACY DEVIATION

Repeat accuracy deviation is one half of the angular or linear variation in the travel of the actuator to reach an operating or resetting position divided by the average of the maximum and minimum observed travels for any 100 consecutive operations, expressed in terms of plus or minus percentage.

Repeat accuracy deviation is obtained from the following formula:

$$A_R = \pm 100 \frac{1/2(X_1 - X_2)}{1/2(X_1 + X_2)} = \pm 100 \frac{(X_1 - X_2)}{(X_1 + X_2)}$$

where –

A_R = Percent repeat accuracy deviation.

X_1 = Maximum observed travel.*

X_2 = Minimum observed travel.*

*To be obtained over 100 consecutive operations.

NEMA Standard 5-17-1971.

REPEATABILITY

Repeatability is the ability to consistently maintain the original operating characteristics.

NEMA Standard 6-24-1957.

SNAP-ACTING SWITCH

A snap-acting switch is one in which there is a rapid motion of the contacts from one position to another position, or their return. This action is relatively independent of the rate of travel of the actuator.

NEMA Standard 6-24-1957.

TOTAL TRAVEL

Total travel is the sum of the pretravel and total overtravel.

NEMA Standard 6-24-1957.

2-225.02 MOMENTARY CONTACT LIMIT SWITCH DEFINITIONS (ILLUSTRATED IN FIGS. 2-225-1 AND 2-225-2)

FORCE DIFFERENTIAL

Force differential is the difference between operating force and the releasing force.

NEMA Standard 6-24-1957.

FREE POSITION

Free position is the initial position of the actuator when there is no external force (other than gravity) applied on the actuator and the switch is in the specified position.

NEMA Standard 6-24-1957.

MOVEMENT DIFFERENTIAL

Movement differential is the distance or angle from the operating position to the releasing position.

NEMA Standard 6-24-1957.

NORMAL CONTACT POSITION

Normal contact position is that position of the contacts which exists when no operating force is applied.

NEMA Standard 6-24-1957.

PRETRAVEL

Pretravel is the distance or angle through which the actuator moves from the actuator free position to the actuator operating position.

NEMA Standard 6-24-1957.

RELEASING FORCE

Releasing force is the value to which the force on the actuator must be reduced to allow the contacts to snap from the operated contact position to the normal contact position.

NEMA Standard 6-24-1957.

RELEASING POSITION

Releasing position is that position of the actuator at which the contacts snap from the operated contact position to the normal contact position.

NEMA Standard 6-24-1957.

RELEASING TORQUE

Releasing torque is the value to which the torque on the actuator must be reduced to allow the contacts to snap from the operated contact position to the normal contact position.

NEMA Standard 6-24-1957.

TORQUE DIFFERENTIAL

Torque differential is the ditference between the operating torque and the releasing torque.

NEMA Standard 6-24-1957.

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TOTAL OVERTRAVEL

Total overtravel is the distance or angle through which the actuator moves when traveling from the actuator operating position to the overtravel limit position.

NEMA Standard 6-24-1957.

2-225.03 MAINTAINED CONTACT LIMIT SWITCH DEFINITIONS (ILLUSTRATED IN FIGS. 2-225-3 AND 2-225-4)

LEVER-OPERATED LIMIT SWITCH

A lever-operated limit switch is a limit switch in which the contact mechanism is controlled by an actuator lever attached to a rotatable shaft which is an integral part of the limit switch.

NEMA Standard 3-8-1978.

MOVEMENT DIFFERENTIAL

Movement differential is the distance or angle from the operating position to the resetting position.

NEMA Standard 3-14-1963.

OPERATED FREE POSITION

Operated free position is the position of the actuator when there is no external force (other than gravity) applied on the actuator and the switch is in the operated contact position.

NEMA Standard 3-14-1963.

OPERATING PRETRAVEL

Operating pretravel is the distance or angle through which the actuator moves from the reset free position to the operating position.

NEMA Standard 3-14-1963.

OPERATING TOTAL OVERTRAVEL

Operating total overtravel is the distance or angle through which the actuator moves when traveling from the operating position to the operated free position.

NEMA Standard 3-14-1963.

PLUNGER-OPERATED LIMIT SWITCH

A plunger-operated limit switch is a limit switch in which the contact mechanism is operated by a plunger-type device.

NEMA Standard 3-8-1978.

RESET CONTACT POSITION

Reset contact position of a switch is the position to which the contacts snap when the actuator is traveled to or beyond the resetting position.

NEMA Standard 3-14-1963.

RESET FREE POSITION

Reset free position is the position of the actuator when there is no external force (other than gravity) applied on the actuator and the switch is on the reset contact position.

NEMA Standard 3-14-1963.

RESETTING FORCE

Resetting force is the force which must be applied to the resetting mechanism to cause the moving contact to snap from one position to another.

NEMA Standard 6-24-1957.

RESETTING POSITION

Resetting position is the position of the actuator at which the moving contact snaps from the operated contact position to the reset contact position.

NEMA Standard 3-14-1963.

RESETTING PRETRAVEL

Resetting pretravel is the distance or angle through which the actuator moves from the operated free position to the resetting position.

NEMA Standard 3-14-1963.

RESETTING TORQUE

Resetting torque is that torque which must be applied to the resetting mechanism to cause the moving contact to snap from one position to another.

NEMA Standard 6-24-1957.

RESETTING TOTAL OVERTRAVEL

Resetting total overtravel is the distance or angle through which the actuator moves when traveling from the resetting position to the reset free position.

NEMA Standard 3-14-1963.

ROTATING CAM LIMIT SWITCH

A rotating cam limit switch is a limit switch in which the contact mechanism is operated by internal camming on a rotatable shaft which is an integral part of the limit switch and capable of being rotated through 360 degrees continuously.

NEMA Standard 3-8-1978.

RATINGS

2-225.20 CONTACT RATINGS

The contact ratings of limit switches used in control circuits shall be in accordance with Part ICS 2-125. For application, see ICS 2-225.80

NEMA Standard 5-17-1971.

2-225.21 SEMICONDUCTOR SWITCHING ELEMENT RATINGS

The ratings of limit switches having a semiconductor switching element for use in control circuits shall be in accordance with Part ICS 2-126 for the utilization category specified.

NEMA Standard 5-15-1989.

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DESIGN TESTS AND PERFORMANCE

2-225.40 CONTACT PERFORMANCE

The contacts of limit switches, when new, shall:

a. Not exceed the temperature rises given in Part 1-109 of NEMA Standards Publication No. ICS 1 when carrying continuous thermal test current.

b. Be capable of passing the overload, endurance and emergency condition tests described in Part ICS 2-125.

NEMA Standard 5-17-1971.

2-225.41 SEMICONDUCTOR SWITCHING ELEMENT PERFORMANCE

Semiconductor switching elements shall meet the performance requirements of Part ICS 2-126 corresponding to their rating designation for the utilization category specified.

NEMA Standard 5-15-1989.

2-225.42 TEMPERATURE RISE OF TERMINALS

The field wiring terminals of limit switches, when carrying rated current, shall not exceed the temperature rise given in Part 1-109 of NEMA Standards Publication No. ICS 1 when wired and tested in accordance with ICS 2-125.41 or 2-126.41.

NEMA Standard 5-17-1971.

MANUFACTURING

2-225.60 MAINTAINED CONTACT LIMIT SWITCHES

Maintained contact limit switches shall be manufactured or adjusted so that the contacts will not operate before the limit switch actuator has reached a point of travel at which it will continue to its operated free position without continuing external applied force.

NEMA Standard 5-17-1971.

APPLICATION

2-225.80 APPLICATION GUIDE FOR LIMIT SWITCHES FOR CONTACT OUTPUT

.01 Relating Load to Rating

The make and break ratings and test values shown in Tables 2-125-1 and 2-125-2 shall not be used as application ratings where the total number of operations is expected to substantially exceed the number specified in the test conditions described in Part ICS 2-125.

When the load is an alternating-current electromagnetically operated mechanical device whose coil current may be interrupted occasionally before completion of its stroke, the break current of the load shall be considered to be 50 percent of the make current of the load. The load limitations recommended in the following paragraph include provision for this situation.

NEMA Standard 5-17-1971.

When limit switches are used in a typical automatically operated sequencing system, it is recommended that the load be less than 25 percent of the make and break ratings given in Tables 2-125-1 and 2-125-2.

Because of the endless variety of application conditions in terms of the electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in this NEMA Standards Publication. Therefore, manufacturers' recommendations should be obtained regarding specific applications.

A maintenance program and schedule should be established to meet the needs of each particular installation to assure minimum down time. The program should include, for example, tightening connections, inspecting for evidence of overheating, removing dust and dirt, and replacing contacts or contact blocks in accordance with the manufacturers' recommendations.

Authorized Engineering Information 11-3-1983.

.02 Overlapping Contacts

Because of manufacturing tolerances and the various characteristics of electrical loads, the normally open and normally closed contacts of a limit switch may or may not be conducting current simultaneously during operation. If such overlap or non-overlap is essential, the manufacturer should be consulted.

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2-225.81 APPLICATION GUIDE FOR LIMIT SWITCHES HAVING SEMI-CONDUCTOR SWITCHING ELEMENTS

The utilization categories given in ICS 2-126 are considered standard. Any other type of application shall be based on agreement between the manufacturer and the user.

NEMA Standard 5-15-1989.

2-225.82 POLARITY

Opposite polarities should not be connected to the contacts of one limit switch unless the limit switch is specifically designed for such service. See Figure 2-225-5.

Authorized Engineering Information 1-13-1959.

2-225.83 VOLTAGE SOURCES

Voltage from different sources should not be connected to the contacts of one limit switch unless the switch is specifically designed for such service. See Figure 2-225-6.

Authorized Engineering Information 1-13-1959.

2-225.84 SLOW-MOTION OPERATION

Where relatively slow motions operate the limit switch, the switch should be snap-acting. See Figure 2-225-7.

Authorized Engineering Information 1-13-1959.

2-225.85 FAST-MOTION OPERATION

Where relatively fast motions are involved, the cam arrangement should be such that the actuator does not receive a severe impact. See Figure 2-225-8.

Authorized Engineering Information 1-13-1959.

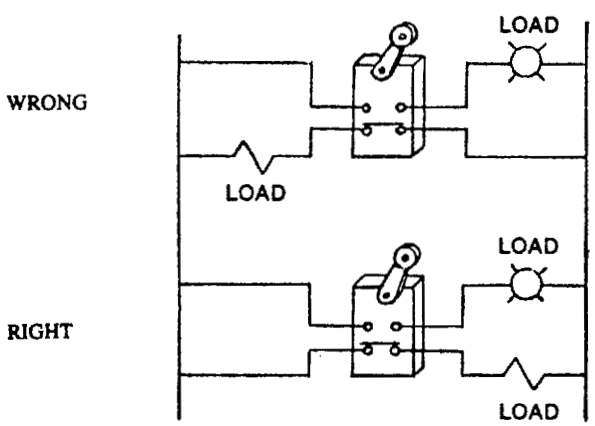


Figure 2-225-5
POLARITY

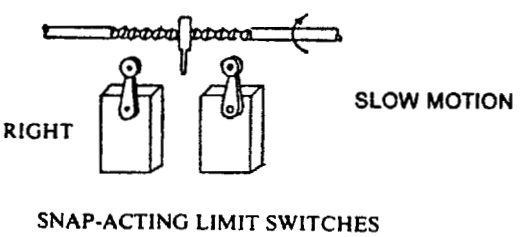


Figure 2-225-7
TYPICAL SLOW MOTION OPERATION

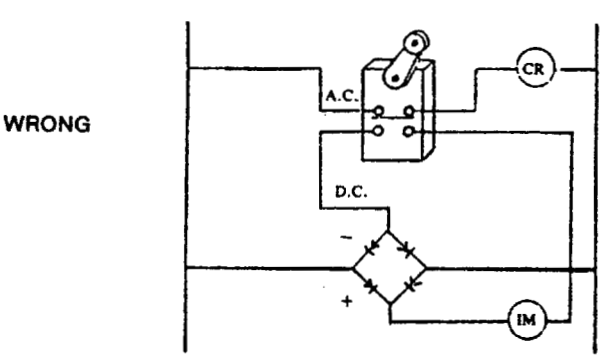


Figure 2-225-6
MIXED VOLTAGE SOURCES



Figure 2-225-8
CAM FOR FAST-MOTION OPERATION

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2-225.86 CAM DESIGN

Cam or dog arrangements should be such that the actuator is not suddenly released to snap back freely. See Figure 2-225-9.

Authorized Engineering Information 1-13-1959.

2-225.87 DWELL REQUIREMENTS

Where relatively fast motions are involved, the cams should be so designed that the limit switch will be held operated long enough to operate relays, valves, etc. See Figure 2-225-10.

Authorized Engineering Information 1-13-1959.

2-225.88 SUPPLEMENTARY ACTUATORS

Limit switches are designed for proper performance with the actuators with which they are supplied. Supplementary actuators should not be used unless the limit switches are specifically designed to accept them. See Figure 2-225-11.

Authorized Engineering Information 1-13-1959.

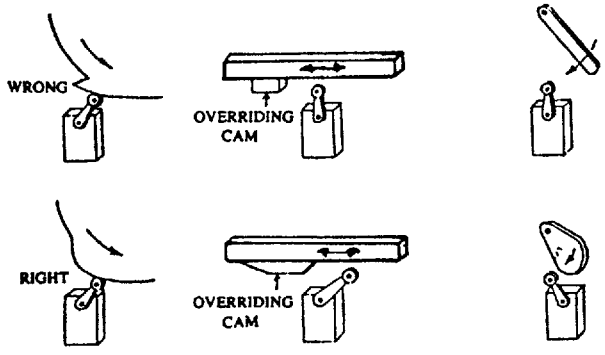


Figure 2-225-9
CAM DESIGNS



Figure 2-225-10
DWELL REQUIREMENTS

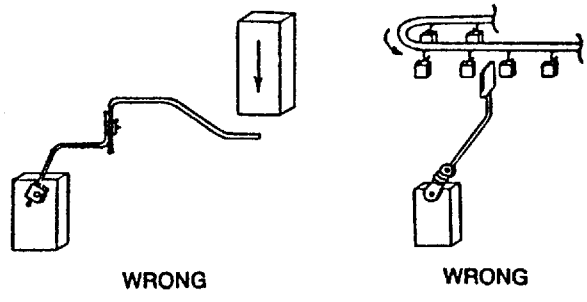


Figure 2-225-11
SUPPLEMENTARY ACTUATORS

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2-225.89 OVERTRAVEL LIMITATIONS

Operating mechanisms for limit switches should be so designed that, under any operating or emergency conditions, the limit switch is not operated beyond its overtravel limit position. A limit switch should not be used as a mechanical stop. See Figure 2-225-12.

Authorized Engineering Information 1-13-1959.

2-225.90 PLUNGER ACTUATORS

For limit switches with plunger actuators, the actuating force should be applied in line with the plunger axis. See Figure 2-225-13.

Authorized Engineering Information 3-8-1978.

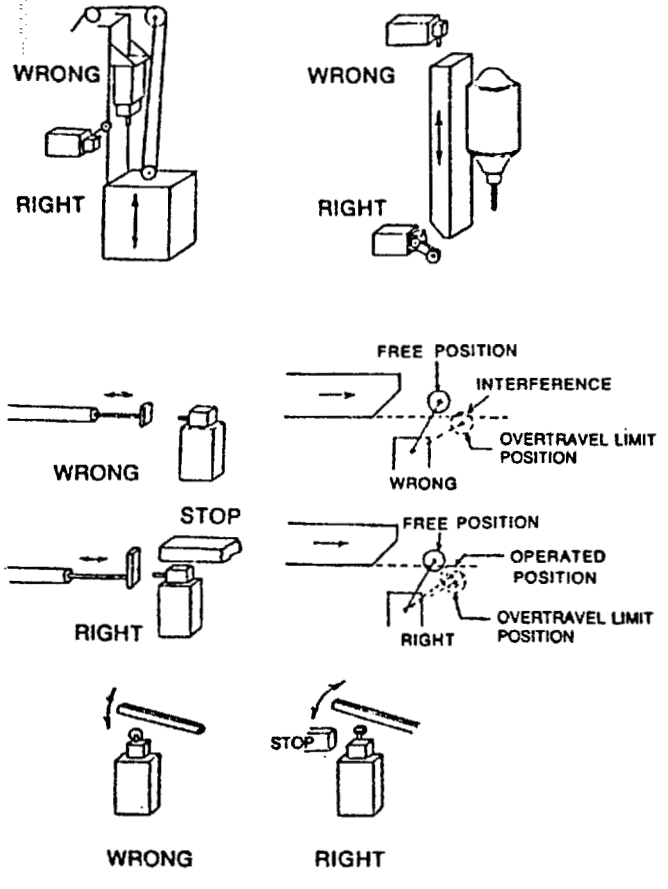


Figure 2-225-12
OVERTRAVEL LIMITATIONS

2-225.91 LEVER ACTUATORS

For limit switches with lever actuators, the actuating force should be applied perpendicular to the lever and perpendicular to the shaft axis about which the lever rotates. See Figure 2-225-14.

Authorized Engineering Information 1-13-1959.

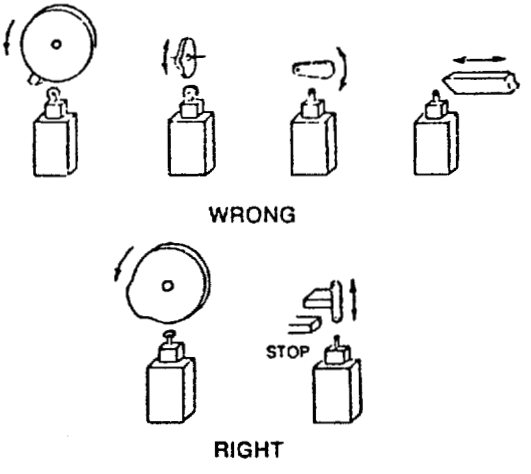


Figure 2-225-13
PUSHROD ACTUATORS

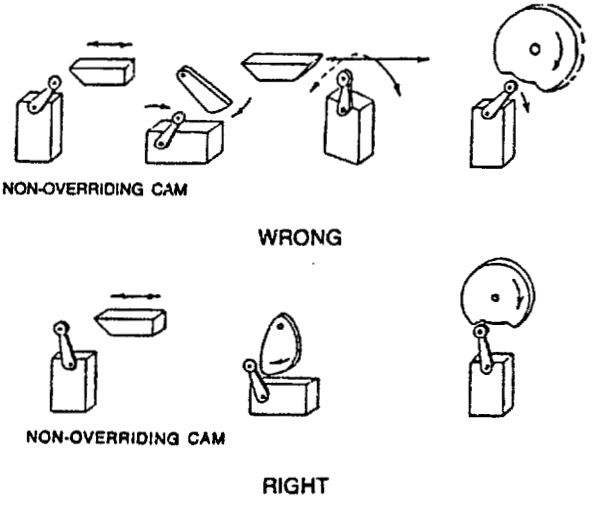


Figure 2-225-14
LEVER ACTUATORS

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2-225.92 ACTUATOR TRAVEL

A limit switch actuator must be allowed to move far enough for positive operation of the contacts. See Figure 2-225-15.

Authorized Engineering Information 1-13-1959.

2-225.93 LIMIT SWITCH LOCATION CONSTRAINTS

a. Limit switches should be mounted in locations which will prevent false operation by normal movements of operator or machine components. See Figure 2-225-16, Sketch A.

b. Limit switches should be mounted rigidly and in readily accessible locations, with suitable clearances to permit easy service and replacement when necessary. Cover plates should face the maintenance access point. See Figure 2-225-16, Sketch B.

c. Limit switches should not be submerged in or splashed with oils, coolants, or other liquids unless specifically designed for such service. See Figure 2-225-16, Sketch C.

d. Limit switches should be placed in locations where machining chips do not accumulate under normal operating conditions. See Figure 2-225-16, Sketch D.

e. Limit switches should not be used in locations where temperature or atmospheric conditions are beyond those for which they have been specifically designed. See Figure 2-225-16, Sketch E.

Authorized Engineering Information 1-13-1959.

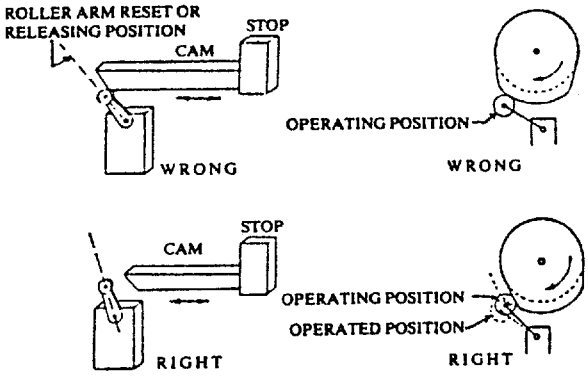
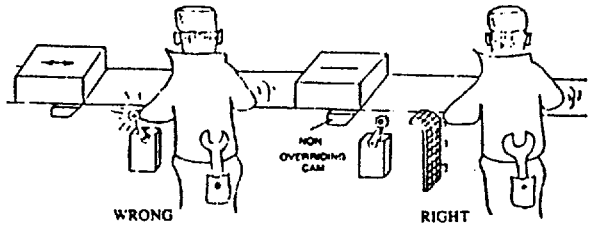
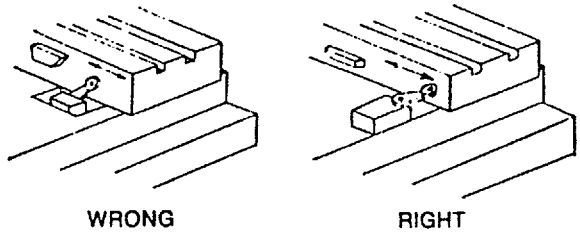


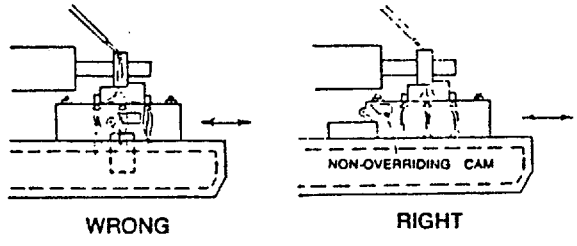
Figure 2-225-15
ACTUATOR TRAVEL



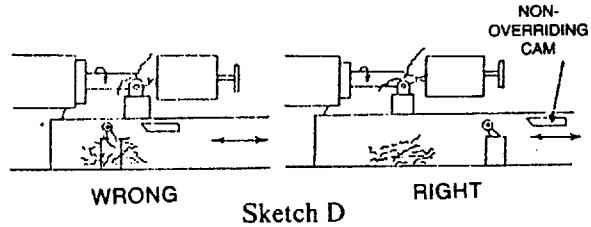
Sketch A



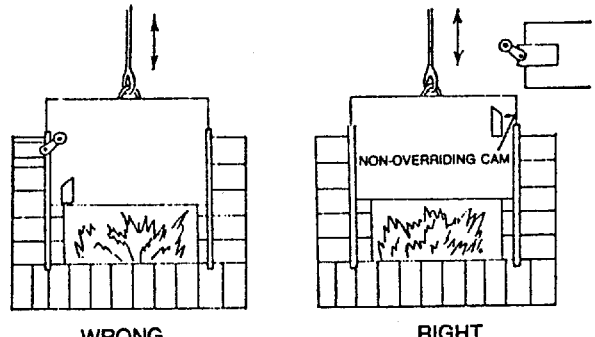
Sketch B



Sketch C



Sketch D



Sketch E

Figure 2-225-16
LIMIT SWITCH LOCATIONS

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2-225.94 LIMIT SWITCH SEALING

a. Sealing gaskets should be positioned properly, and all removable covers, operating heads, etc., should be securely fastened in place before placing the switch in operation. See Figure 2-225-17.

b. Liquids sometimes reach the interior of sealed switches by way of conduit connections either by seepage into conduit junctions and junction boxes or by condensation. All connection points exposed to fluid should be tightly sealed, and switches should not be located at the low point of long conduit runs. See Figure 2-225-18.

c. When liquids and atmospheres containing liquids in suspension cannot be prevented from entering the conduit system, sealing-type fittings or switches incorporating seals should be used. See Figure 2-225-19.

Authorized Engineering Information 5-17-1971.

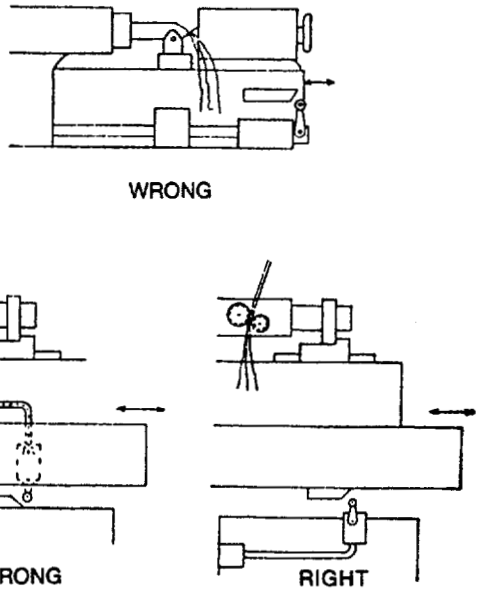


Figure 2-225-18
SEEPAGE AND CONDENSATION CONSIDERATIONS

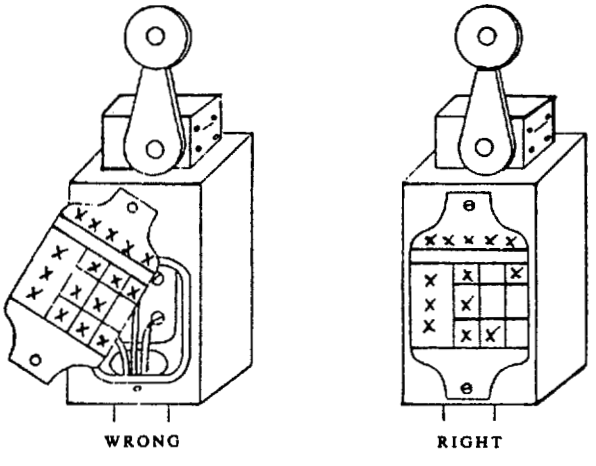


Figure 2-225-17
LIMIT SWITCH COVER POSITIONS

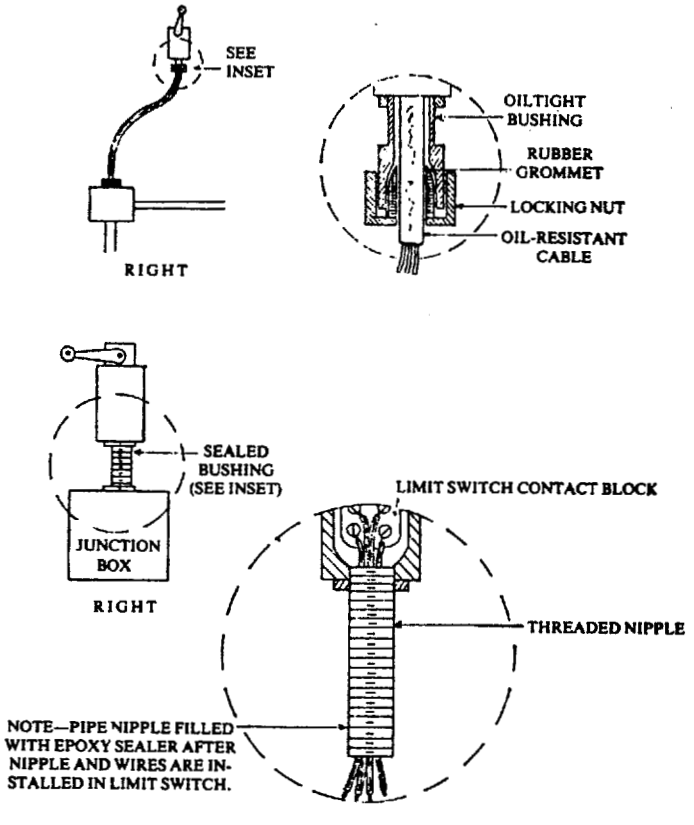


Figure 2-225-19
SEALING FITTINGS

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2-225.95 INTERLOCKING CONTROL CIRCUIT FOR PERSONNEL PROTECTION

Limit switches in some control designs, such as for metal fabrication and plastic molding, are applied in interlocking control circuits for personnel protection.

When so applied, it is recommended that:

a. the limit switch be used with at least one other device that will serve the same protective function,
b. the control circuit be so arranged that malfunction or improper sequencing of either device will prevent further operation of the controlled equipment, and
c. the failure mode of the switching element should be given consideration in applications of personnel protection.

Authorized Engineering Information 5-15-1989.

PREVENTIVE MAINTENANCE

2-225.96 PREVENTIVE MAINTENANCE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-1988.

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Part ICS 2-226

PRESSURE OPERATED SWITCHES

Part ICS 2-226 covers switches which are responsive to pressure and are rated for alternating-current motor applications or are rated for application in control circuits of industrial control apparatus. The National Fluid Power Association Standard for Pressure Switches is Publication NFPA T3.29.2.

Part ICS 2-125 or ICS 2-126 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication Nos. 250, ICS 1, and ICS 6 also apply to this part.

DEFINITIONS

2-226.01 DEFINITIONS

ALLOWABLE PRESSURE LIMITS

Allowable pressure limits are the maximum and minimum pressures stated by the manufacturer to which a pressure switch may be exposed for brief or extended periods without altering the performance characteristics of the switch.

NEMA Standard 7-14-1976.

Maximum allowable pressure is also referred to as overrange and includes surge pressures.

Authorized Engineering Information 7-14-1976.

CUT-IN PRESSURE

Cut-in pressure is that pressure at which the switch is actuated to energize the load.

NEMA Standard 7-14-1976.

The cut-in pressure may be the trip or reset point.

Authorized Engineering Information 7-14-1976.

CUT-OUT PRESSURE

Cut-out pressure is that pressure at which the switch is actuated to de-energize the load.

NEMA Standard 7-14-1976.

The cut-out pressure may be the trip or reset point.

Authorized Engineering Information 7-14-1976.

DRIFT

Drift, as applied to devices such as pressure switches, temperature switches, etc., is an inherent change in operating value for a given setting over a specified number of operations and specified environmental conditions.

Authorized Engineering Information 7-14-1976.

MAXIMUM STATIC PRESSURE

Maximum static pressure is that pressure which the pressure containing envelope of a pressure switch should sustain without rupture.

NEMA Standard 11-3-1983.

Maximum static pressure is sometimes called rated static pressure.

Authorized Engineering Information 7-14-1976.

OPERATING DIFFERENTIAL PRESSURE

Operating differential pressure is the difference between cut-in pressure and cut-out pressure.

NEMA Standard 7-14-1976.

Operating differential pressure is also called dead band or hysteresis.

Authorized Engineering Information 7-14-1976.

OPERATING PRESSURE RANGE

The operating pressure range is the range between the maximum and minimum pressure settings at which a pressure switch will operate and continue to operate within the manufacturer's specifications.

NEMA Standard 7-14-1976.

PRESSURE LIMIT CONTROL

Pressure limit control is a pressure switch set beyond the process operating pressure to limit the operation of the controlled equipment under abnormal conditions.

NEMA Standard 7-14-1976.

PRESSURE SWITCH

A pressure switch is a switch which is operated by a constituent part and is responsive to fluid (gas or liquid) pressure.

NEMA Standard 7-14-1976.

A pressure switch which operates primarily at pressure less than atmospheric is called a vacuum switch.

Authorized Engineering Information 7-14-1976.

PROOF PRESSURE

Proof pressure is the nondestructive static test pressure, in excess of the maximum allowable pressure, which causes no permanent deformation or malfunction.

NEMA Standard 7-14-1976.

PULSATION SNUBBER

A pulsation snubber is a device used with pressure switches to reduce the effect of pressure surges within the pressure system on the pressure responsive element of the switch.

NEMA Standard 7-14-1976.

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ELECTRICAL RATINGS

2-226.20 RATINGS OF PRESSURE SWITCHES FOR APPLICATION IN CONTROL CIRCUITS

The contact ratings of pressure switches whose contacts are used in control circuits of industrial control apparatus shall be in accordance with Part ICS 2-125.

NEMA Standard 11-3-1983.

2-226.21 CONTACT RATINGS OF PRESSURE SWITCHES USED AS AC MOTOR CONTROLLERS

The ratings of pressure switches for general use as motor controllers shall be in terms of horsepower and continuous thermal current for one or more utilization voltages.

The ratings of pressure switches used as an integral part of engineered motor and controller combinations shall be in terms of horsepower and continuous thermal current or motor full load and locked rotor current for one or more utilization voltages.

NEMA Standard 11-17-88.

The ratings may be on the basis for two poles controlling a three-phase motor or one pole controlling a single-phase motor.

Authorized Engineering Information 7-14-1976.

2-226.22 SEMICONDUCTOR SWITCHING ELEMENT RATINGS FOR CONTROL CIRCUITS

The ratings of pressure operated switches having semiconductor switching elements for use in control circuits shall be in accordance with Part ICS 2-126 for the utilization category specified.

NEMA Standard 5-15-1989.

MECHANICAL RATINGS

2-226.30 PRESSURE SWITCHES

A pressure switch shall have a specified operating pressure range and operating differential, allowable pressure limits, and a maximum static pressure. The maximum allowable pressure shall be less than the proof pressure and greater than the maximum of the operating range. All pressure values shall be expressed in terms of gauge pressure unless otherwise stated.

NEMA Standard 7-14-1976.

Unless a pressure switch is designed for operation at less than atmospheric pressure, a minimum pressure of zero is not recommended.

Authorized Engineering Information 7-14-1976.

2-226.31 PRESSURE LIMIT CONTROL

A pressure limit control shall have a specified cut-in or cut-out pressure, specified limits of drift, allowable pressure limits and a maximum static pressure.

NEMA Standard 7-14-1976.

DESIGN TESTS AND PERFORMANCE

2-226.40 TEMPERATURE RISE OF CONTACTS AND TERMINALS

The contacts and field wiring terminals of pressure switches, when carrying continuous thermal test current, shall not exceed the temperature rises given in Part 1-109 of NEMA Standards Publication No. ICS 1. The temperature rise test shall be made with new (unused) contacts carrying, but not making or breaking, current.

For the purpose of this test, the field wiring terminals of pressure switches shall be wired with wire sized appropriately for the switch rating. See Part ICS 2-125 for devices rated for control circuit applications.

NEMA Standard 7-14-1976.

2-226.41 CONTACT PERFORMANCE

The contacts of pressure switches which are rated for control circuit applications should be capable of passing the overload, endurance, and emergency condition tests described in Part ICS 2-125.

Authorized Engineering Information 7-14-1976.

2-226.42 MAKE AND BREAK DESIGN TEST

The make and break design test for pressure switches which are rated for alternating-current motor applications shall consist of making 6 times rated full load motor current at 40 to 50 percent power factor and breaking 1.5 times full load motor current at 75 to 80 percent power factor for 50 operations in a single continuous test without intervening maintenance or servicing at a rate

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of six operations per minute with a minimum "ON" time of 1 second per operation. The test shall be made at rated voltage.

If the switch is provided with an overload relay, an adjusting knob, or some similar means of causing the switch to open the locked rotor current of the motor, the break current shall be 6 times rated full load current.

NEMA Standard 11-17-1988.

2-226.43 SEMICONDUCTOR SWITCHING ELEMENT PERFORMANCE

Semiconductor switching elements shall meet the test and performance requirements of part ICS 2-126 corresponding to their rating designation for the utilization category specified.

NEMA Standard 5-15-1989.

2-226.44 DIELECTRIC TEST

Pressure switches shall be capable of withstanding the power frequency design dielectric test described in Part 1-109 of NEMA Standards Publication No. ICS 1 when mounted as they are intended to be used in service.

NEMA Standard 7-14-1976.

2-226.45 STRENGTH OF PARTS

The parts of a pressure switch shall meet the strength requirements of Underwriters Laboratories Publications UL 353, 508, 698, or 873, as applicable.

NEMA Standard 11-17-1988.

2-226.46 PRESSURE LIMIT CONTROL

A pressure limit control shall be evaluated in accordance with Underwriters Laboratories Publication UL 353 or 873, as applicable.

NEMA Standard 7-14-1976.

APPLICATION

2-226.80 SERVICE CONDITIONS

Pressure switches should not be applied with fluids which will corrode or react chemically with the material used for the pressure containing envelope. Permissible ambient temperatures below 0°C are based on the absence of freezing moisture in the presence of moving parts.

Authorized Engineering Information 7-14-1976.

2-226.81 SURGES

A pressure switch should not be applied where its pressure containing envelope is subjected to a surge which is greater than its maximum allowable pressure. A pressure switch which is used in a system pressurized by a reciprocating pump should be protected from surges by a pulsation snubber.

Authorized Engineering Information 7-14-1976.

2-226.82 APPLYING SWITCHES RATED FOR MOTOR APPLICATIONS

Pressure switches which are rated for motor applications should be used with motors having integral thermal protectors or an equivalent means for providing running overcurrent protection for the motor branch circuit. It should be noted that when two pole switches are used to control three-phase motors only two lines are disconnected when the switch is open and the motor terminal box contains live parts unless the branch circuit disconnect device is also open.

Authorized Engineering Information 7-14-1976.

2-226.83 RELATING TO CONTACT RATINGS

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in these NEMA Standards. Therefore, manufacturers' recommendations should be obtained regarding specific applications.

Authorized Engineering Information 11-3-1983.

2-226.84 APPLICATION GUIDE FOR PRESSURE OPERATED SWITCHES HAVING SEMI-CONDUCTOR SWITCHING ELEMENTS

The utilization categories given in ICS 2-126 are considered standard.

NEMA Standard 5-15-1989.

Applications not covered by the utilization categories in ICS 2-126 should be based on agreement between the manufacturer and user.

Authorized Engineering Information 5-15-1989.

PREVENTIVE MAINTENANCE

2-226.90 PREVENTIVE MAINTENANCE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-1988.

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Part ICS 2-227

TEMPERATURE OPERATED CONTROLLERS

Part ICS 2-227 covers switches and controllers which are responsive to temperature and are designed for process control and similar industrial applications. The switches and controllers are rated for alternating-current motor application, resistive loads and/or control circuit applications. Part ICS 2-227 does not apply to thermal overload relays nor to thermal protectors.

Part ICS 2-125 or ICS 2-126 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication Nos. 250, ICS 1 and ICS 6 also apply to this part.

DEFINITIONS

2-227.01 DEFINITIONS

ALLOWABLE TEMPERATURE LIMITS

Allowable temperature limits are the maximum and minimum temperatures to which a temperature switch may be exposed without altering its performance characteristics.

NEMA Standard 7-14-1976.

CUT-IN TEMPERATURE

Cut-in temperature is the temperature of the sensed medium at which a temperature switch is actuated to energize the load.

NEMA Standard 7-14-1976.

The cut-in temperature may be the trip or reset point.

Authorized Engineering Information 7-14-1976.

CUT-OUT TEMPERATURE

Cut-out temperature is the temperature of the sensed medium at which a temperature switch is actuated to de-energize the load.

NEMA Standard 7-14-1976.

The cut-out temperature may be the trip or reset point.

Authorized Engineering Information 7-14-1976.

OPERATING TEMPERATURE DIFFERENTIAL

Operating temperature differential is the difference between the cut-in and cut-out temperatures.

NEMA Standard 7-14-1976.

Operating differential temperature is also called dead band or hysteresis.

Authorized Engineering Information 7-14-1976.

OPERATING TEMPERATURE RANGE

Operating temperature range is the range between the maximum and minimum temperature settings at which a temperature switch will operate and continue to operate within the manufacturer's specifications.

NEMA Standard 7-14-1976.

PROPORTIONAL TEMPERATURE CONTROLLER

A proportional temperature controller is a controller which is responsive to temperature and which has a continuous relation between its output and its input within its operating temperature range.

NEMA Standard 7-14-1976.

REMOTE TEMPERATURE SENSING

Remote temperature sensing is that construction and installation of a temperature switch in which the sensing unit and the switch mechanism are thermally isolated so that the temperature of the sensed medium does not affect the performance of the switch mechanism.

NEMA Standard 7-14-1976.

TEMPERATURE LIMIT CONTROL

Temperature limit control is a temperature switch set beyond the process operating temperature to limit the operation of the controlled equipment under abnormal conditions.

NEMA Standard 7-14-1976.

TEMPERATURE SWITCH

A temperature switch is a two-state (on-off) controller which is responsive to the temperature of a sensed medium.

NEMA Standard 7-14-1976.

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ELECTRICAL RATINGS

2-227.20 CONTACT RATINGS FOR TEMPERATURE SWITCHES

Ratings of temperature switches whose contacts are used in control circuits of industrial control apparatus shall be in accordance with Part ICS 2-125.

NEMA Standard 11-3-1983.

2-227.21 TEMPERATURE SWITCHES AND PROPORTIONAL TEMPERATURE CONTROLLERS USED TO CONTROL NONINDUCTIVE LOADS

Ratings of temperature switches and proportional temperature controllers used to control noninductive loads shall be in terms of rated operational current and/or voltamperes or watts for one or more utilization voltages.

NEMA Standard 1-17-1988.

2-227.22 CONTACT RATINGS FOR TEMPERATURE SWITCHES USED AS CONTROLLERS

The ratings of temperature switches for general use as motor controllers shall be in terms of horsepower and rated operational current for one or more utilization voltages.

The ratings of temperature switches used as an integral part of engineered motor and controller combinations shall be in terms of horsepower and continuous thermal current or motor full load current and locked rotor current for one or more utilization voltages.

NEMA Standard 11-17-1988.

The ratings may be on the basis for two poles controlling a three-phase motor or one pole controlling a single-phase motor.

Authorized Engineering Information 7-14-1976.

2-227.23 SEMICONDUCTOR SWITCHING ELEMENT RATINGS

The ratings of temperature operated controllers having semiconductor switching elements for use in control circuits shall be in accordance with Part ICS 2-126 for the utilization category specified.

NEMA Standard 5-15-1989.

TEMPERATURE RATINGS

2-227.30 TEMPERATURE SWITCHES

A temperature switch shall have a specified operating range, operating differential, and allowable temperature limits.

NEMA Standard 11-3-1983.

2-227.31 PROPORTIONAL TEMPERATURE CONTROLLERS

A proportional temperature controller shall have a specified operating range, a specified relation between input and output, and allowable temperature limits.

NEMA Standard 11-3-1983.

2-227.32 TEMPERATURE LIMIT CONTROLS

A temperature limit control shall have a specified cut-in or cut-out temperature, specified limits of drift, and allowable temperature limits.

NEMA Standard 11-3-1983.

2-227.33 ALLOWABLE TEMPERATURE LIMITS

The allowable temperature limits of a temperature controller shall exceed the operating temperature range.

NEMA Standard 11-3-1983.

DESIGN TESTS AND PERFORMANCE

2-227.40 TEMPERATURE RISE

The contacts and field wiring terminals of temperature switches and proportional temperature controllers, when carrying continuous thermal test current and with the sensing element exposed to maximum allowable temperature, shall not exceed the temperature rises given in Part 1-109 of NEMA Standards Publication No. ICS 1. The temperature rise test shall be made with new (unused) contacts carrying, but not making or breaking, current.

For the purposes of this test, the field wiring terminals of temperature switches shall be wired with wire sized appropriately for the switch rating. See Part ICS 2-125 for devices rated for control circuit applications.

NEMA Standard 7-14-1976.

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2-227.41 CONTACT PERFORMANCE

The contacts of temperature switches which are rated for control circuit application shall be capable of passing the overload endurance and emergency condition tests described in Part ICS 2-125.

NEMA Standard 7-14-1976.

2-227.42 CONTACT MAKE AND BREAK DESIGN TEST

The make and break design test for temperature switches which are rated for alternating-current motor applications, and which will not be called upon to interrupt locked rotor current, shall consist of making 6 times rated full load motor current at 40 to 50 percent power factor and breaking 1.5 times motor full load current at 75 to 80 percent power factor for 50 operations in a single continuous test without intervening maintenance or servicing at a practical rate. The test shall be made at rated voltage.

If the switch is provided with an overload relay, an adjusting knob, or some similar means of causing the switch to open the locked rotor current of the motor, the break current shall be 6 times rated full load current.

NEMA Standard 11-17-1988.

2-227.43 SEMICONDUCTOR SWITCHING ELEMENT PERFORMANCE

Semiconductor switching elements for use in industrial control circuit apparatus shall meet the test and performance requirements of Part ICS 2-126 corresponding to their rating designation for the utilization categories specified.

NEMA Standard 5-15-1989.

2-227.44 DIELECTRIC TEST

Temperature switches shall be capable of withstanding the power frequency design dielectric test described in Part 1-109 of NEMA Standards Publication No. ICS 1 when mounted as they are intended to be used in service.

NEMA Standard 7-14-1976.

2-227.45 TEMPERATURE LIMIT CONTROL

A temperature limit control shall be evaluated in accordance with Underwriters Laboratories Publication UL 353 or 873, as applicable.

NEMA Standard 7-14-1976.

MANUFACTURING

2-227.60 MATERIALS

Temperature switches and proportional temperature controllers by their nature may be subjected to ambient temperature operating conditions above or below those given in Part 1-108 of NEMA Standards Publication No. ICS 1 and, therefore, should incorporate materials suitable to the application.

Authorized Engineering Information 7-14-1976.

2-227.61 TEMPERATURE SWITCH MARKINGS

When temperature switches or proportional temperature controllers are rated for tungsten lamp loads, they should be so marked.

Authorized Engineering Information 7-14-1976.

APPLICATION

2-227.80 SERVICE CONDITIONS

Temperature switches and proportional temperature controllers should not be exposed to or applied at temperatures beyond the manufacturer's allowable temperature limits. Allowable temperatures below 0°C are based on the absence of freezing moisture in the presence of moving parts. Temperature controllers should not be applied with fluids which will corrode or act chemically with their sensing elements. Wells are usually available to provide protection.

Authorized Engineering Information 7-14-1976.

2-227.81 TEMPERATURE RATING OF CONDUCTORS

Conductors which are exposed to the sensed medium, when connected to temperature switches or proportional temperature controllers, should have a maximum operating temperature rating not less than the total temperature attained by the conductor.

Authorized Engineering Information 7-14-1976.

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2-227.82 APPLYING SWITCHES RATED FOR MOTOR APPLICATIONS

Temperature switches which are rated for motor applications should be used with motors having integral thermal protectors or an equivalent means for providing running overcurrent protection for the motor branch circuit. It should be noted that when two pole switches are used to control three-phase motors, only two lines are disconnected when the switch is open and the motor terminal box contains live parts unless the branch circuit disconnect device is also open.

Authorized Engineering Information 7-14-1976.

2-227.83 RELATING TO CONTACT RATINGS

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in this NEMA Standards Publication. Therefore, manufacturers' recommendations should be obtained regarding specific applications.

Authorized Engineering Information 11-3-1983.

2-227.84 APPLICATION GUIDE FOR TEMPERATURE OPERATED CONTROLLERS HAVING SEMICONDUCTOR SWITCHING ELEMENTS

The utilization categories given in ICS 2-126 are considered standard.

NEMA Standard 5-15-1989.

Applications not covered by the utilization categories in ICS 2-126 should be based on agreement between the manufacturer and the user.

Authorized Engineering Information 5-15-1989.

PREVENTIVE MAINTENANCE

2-227.90 PREVENTIVE MAINTENANCE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-1988.

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Part ICS 2-228

LIQUID LEVEL SWITCHES

Part ICS 2-228 covers switches which are responsive to liquid levels and are rated for alternating-current motor applications or for applications in control of industrial control apparatus. The design of a liquid level switch may be based on such principles as buoyancy, liquid weight, optics, capacitance, sound, etc.

Part ICS 2-125 or ICS 2-126 applies to this part unless otherwise specified. The definitions and standards of NEMA Standards Publication Nos. 250, ICS 1 and ICS 6 also apply to this part.

DEFINITIONS

2-228.01 DEFINITIONS

FLOAT SWITCH

A float switch is a liquid level switch which is operated by a buoyant constituent part.

NEMA Standard 8-20-1966.

LIQUID LEVEL SWITCH

A liquid level switch is a switch which is responsive to the level of a liquid.

NEMA Standard 7-14-1976.

RATINGS

2-228.20 CONTACT RATINGS FOR LIQUID LEVEL SWITCHES FOR APPLICATION IN CONTROL CIRCUITS

The contact ratings of liquid level switches whose contacts are used in control circuits shall be in accordance with Part ICS 2-125.

NEMA Standard 11-3-1983.

2-228.21 CONTACT RATINGS FOR LIQUID LEVEL SWITCHES USED AS AC MOTOR CONTROLLERS

The ratings of liquid level switches for general use as motor controllers shall be in terms of horsepower and continuous current for one or more utilization voltages.

The ratings of liquid level switches used as an integral part of engineered motor and controller combinations shall be in terms of horsepower and continuous current or motor full load and locked rotor currents for one or more utilization voltages.

NEMA Standard 1-11-1984.

The ratings may be on the basis for two poles controlling a three-phase motor or one pole controlling a single-phase motor.

Authorized Engineering Information 7-14-1976.

2-228.22 SEMICONDUCTOR SWITCHING ELEMENT RATINGS

The ratings of liquid lelvel switches having semiconductor switching elements for use in control circuits shall be in accordance with Part ICS 2-126 for the utilization category specified.

NEMA Standard 5-15-1989.

DESIGN TESTS AND PERFORMANCE

2-228.40 TEMPERATURE RISE OF CONTACTS AND TERMINALS

The contacts and field wiring terminals of liquid level switches when carrying continuous thermal test current shall not exceed the temperature rise given in Part 1-109 of NEMA Standards Publication No. ICS 1. The temperature rise test shall be made with new (unused) contacts carrying, but not making or breaking, current.

For the purpose of this test, the field wiring terminals of liquid level switches shall be wired with the wire sized appropriately for the switch rating. See Part ICS 2-125 for devices rated for control circuit applications.

NEMA Standard 7-14-1976.

2-228.41 CONTACT PERFORMANCE

The contacts of liquid level switches which are rated for control circuit applications shall be capable of pass-

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ing the overload, endurance and emergency condition tests described in Part ICS 2-125.

NEMA Standard 7-14-1976.

2-228.42 MAKE AND BREAK DESIGN TEST

The make and break design test for liquid level switches which are rated for alternating-current motor applications shall consist of making 6 times rated full load motor current at 40 to 50 percent power factor and breaking 1.5 times motor full load current at 75 to 80 percent power factor for 50 operations in a single continuous test, without intervening maintenance or servicing, at a practical rate. The test shall be made at rated voltage.

If the switch is provided with an overload relay, an override button, or some similar means of causing the switch to open the locked rotor current of the motor, the break current shall be 6 times rated full load current. An actuating lever to which the level sensing element is attached is not considered to be a similar means.

NEMA Standard 1-11-1984.

2-228.43 SEMICONDUCTOR SWITCHING ELEMENT PERFORMANCE

Semiconductor switching elements shall meet the test and performance requirements of Part ICS 2-126 corresponding to their rating designation for the utilization category specified.

NEMA Standard 5-15-1989.

2-228.44 DIELECTRIC TEST

Liquid level switches shall be capable of withstanding the power frequency design dielectric test described in Part 1-109 of NEMA Standards Publication No. ICS 1 when mounted as they are intended to be used in service.

NEMA Standard 7-14-1976.

APPLICATION

2-228.80 SERVICE CONDITIONS

Parts of liquid level switches should not be placed in contact with liquids which will corrode or react chemically with such parts. Permissible ambient temperatures below 0°C are based on the absence of freezing moisture in the presence of moving parts.

Authorized Engineering Information 7-14-1976.

2-228.81 APPLYING SWITCHES RATED FOR MOTOR APPLICATION

Liquid level switches which are rated for motor applications should be used with motors having integral thermal protectors or an equivalent means for providing running overcurrent protection for the motor branch circuit. It should be noted that when two pole switches are used to control three-phase motors, only two lines are disconnected when the switch is open and the motor terminal box contains live parts unless the branch circuit disconnect device is also open.

Authorized Engineering Information 7-14-1976.

2-228.82 RELATING TO CONTACT RATINGS

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in this NEMA Standards Publication. Therefore, manufacturers' recommendations should be obtained regarding specific applications.

Authorized Engineering Information 11-3-1983.

2-228.83 APPLICATION GUIDE FOR LIQUID LEVEL SWITCHES HAVING SEMICONDUCTOR SWITCHING ELEMENTS

The utilization categories given in Part ICS 2-126 are considered standard.

NEMA Standard 5-15-1989.

Applications not covered by the utilization categories in ICS 2-126 should be based on agreement between the manufacturer and the user.

Authorized Engineering Information 5-15-1989.

PREVENTIVE MAINTENANCE

2-228.90 PREVENTIVE MAINTENANCE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-1988.

2-228.91 SPECIFIC MAINTENANCE INSTRUCTIONS

Inspect for evidence of loss of buoyancy.

Authorized Engineering Information 1-27-1988.

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Part 2-229

PROXIMITY SWITCHES

Part ICS 2-229 covers control circuit devices that sense the presence of designated objects by means other than physical contact. These devices respond to a change in either self-generated or externally generated signals, which, in turn, produces a bi-state output circuit.

Type 1 (non-break beam) proximity switches operate on the principle that the designated object reflects, absorbs, or alters energy radiated from the sensor.

Type 2 (break beam) proximity switches operate on the principle that the designated object interrupts a beam directed between a sender and a receiver.

The definitions and standards of NEMA Standards Publication Nos. 250, ICS 1, ICS 2, and ICS 6 also apply to this part unless otherwise stated.

DEFINITIONS

2-229.01 GENERAL DEFINITIONS

BREAK-BEAM PRINCIPLE.

A system of sensing where the energy beam between transmitter and receiver is interrupted by the designated object.

CAPACITIVE PROXIMITY SWITCH.

A device that detects a change in dielectric in its sensing zone. The output signal is produced by the entry or exit from the sensing zone of a metallic or non-metallic object producing sufficient capacitance change to operate the device.

DARK-OPERATED OPTICAL PROXIMITY SWITCH.

A proximity device that conducts load current in the normally open output when it detects an absence of light.

DESIGNATED OBJECT.

The item, material, or configuration that a proximity switch is intended to detect. A standard target is one form of a designated object.

EXCESS GAIN, PHOTOELECTRIC SWITCHES.

Excess gain is defined as the ratio of the signal received, given "clean air and clean lens," to the minimum signal which is required for operation (the threshold signal).

Excess gain is a measure of the energy available to overcome contamination; it relates directly to attenuation. Optical alignment is required to obtain maximum excess gain.

NEMA Standard 8-20-1986.

FREE ZONE OF A PROXIMITY SWITCH.

The space around the proximity switch which must be kept free of any material capable of significantly affecting the sensing characteristics of the proximity switch.

INDUCTIVE PROXIMITY SWITCH.

A device producing a high frequency electromagnetic field in a sensing zone. The output signal is determined by the entry into or exit from the electromagnetic field of a metallic object large enough to trigger the device.

LIGHT-OPERATED OPTICAL PROXIMITY SWITCH.

A proximity device that conducts load current in the normally open output when it detects the presence of light.

MAGNETIC PROXIMITY SWITCH.

A device that detects a specified change in a static magnetic field within the sensing zone of the switch, and causes the output to change its state.

NOMINAL RATE OF OPERATION.

The number of circuit openings and closings that a proximity switch can make in a specified time period, under specified test conditions.

NORMALLY CLOSED PROXIMITY SWITCH.

A proximity switch that conducts load current when no object is detected, and blocks load current when an object is detected.

NORMALLY OPEN PROXIMITY SWITCH.

A proximity switch that blocks load current when no object is detected, and conducts load current when an object is detected.

OPTICAL PROXIMITY SWITCH.

A device that detects a specified change in light intensity within the sensing zone of the switch, and causes the output to change its state.

REPEAT ACCURACY—INDUCTIVE, CAPACITIVE, OR MAGNETIC PROXIMITY SWITCHES.

A measure of the maximum deviation in the operating distance that will be experienced in successive operations of the switch for any specified operating conditions. (See ICS 2-229.50.)

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RESPONSE TIME.

The time required for the device output to respond when the target enters or exits the sensing zone.

Turn-On Time: The time required for the output to respond after the target reaches the operate point.

Turn-Off Time: The time required for the output to respond after the target reaches the release point.

SHIELDED INDUCTIVE, CAPACITIVE, OR MAGNETIC PROXIMITY SWITCH.

A proximity switch that can be embedded in metal up to the plane of its working face and whose sensing characteristics are not significantly affected by the metal.

SNAP-ACTION.

The characteristic assigned to a proximity switch if the rate of change of its output state is independent of the speed of the designated object.

SONIC PROXIMITY SWITCH.

A device that detects a specified change in acoustical energy within the sensing zone of the switch, and causes the output to change its state.

STANDARD TARGET.

A standardized, designated object used for making comparative measurements of the operating distance. Its characteristics and its relationship to a sensing face must be specified. (See ICS 2-229.43.01 and 2-229.45.01.)

STARTUP TIME (TIME DELAY BEFORE AVAILABILITY).

The time interval between the switching on of the supply current and the moment when a proximity switch is ready to operate. (See ICS 2-229.24.)

UNSHIELDED INDUCTIVE, CAPACITIVEOR MAGNETIC PROXIMITY SWITCH.

A proximity switch requiring a free zone around its sensing face to maintain its characteristics.

NEMA Standard 11-15-1984.

2-229.02 DEFINITIONS PERTAINING TO TYPE 1

AXIAL APPROACH.

The approach of a designated object with its center moving along the reference axis and towards the sensing face.

DIFFERENTIAL TRAVEL (HYSTERESIS), H.

The distance between the operate point when a standard target approaches the proximity switch axially and the release point when the target moves away. (See Figure 2-229-1.)

EFFECTIVE OPERATING RANGE, S_r, INDUCTIVE, CAPACITIVE, OR MAGNETIC PROXIMITY SWITCH.

The operating range of an individual proximity switch, measured at a specified voltage in a 20°C ambient, in accordance with ICS 2-229.43. (See Figure 2-229-1.)

LATERAL APPROACH.

The approach of a designated object in a plane perpendicular to and towards the reference axis of the sensing face of the proximity switch.

OPERATING DISTANCE WITH STANDARD TARGET, S.

The distance, S, at which the Standard Target approaching the sensing face axially causes the output to change its state.

RATED OPERATING DISTANCE, S_n.

A standard used to designate the nominal operating distance. It does not take into account either manufacturing tolerances or variations due to external conditions such as voltage, temperature, and so forth. (See Figure 2-229-1.)

REFERENCE AXIS.

The axis which is perpendicular to the sensing face and passes through its center.

SENSING FACE OF AN INDUCTIVE PROXIMITY SWITCH.

A surface of the switch through which the electromagnetic field is projected.

USABLE OPERATING RANGE, S_u.

The operating range recommended by the manufacturer, over which a proximity switch will properly operate under prescribed conditions of temperature and voltage.

NEMA Standard 11-15-1984.

2-229.03 DEFINITIONS PERTAINING TO TYPE 2

RATED RANGE, R_n.

A value assigned by the manufacturer to designate the maximum recommended distance between the sender and receiver elements (Mode T), or sensor and reflector (Mode R) under specified conditions. (See Figure 2-229-2.)

REFERENCE AXIS.

An axis perpendicular to, and through the center of, the sender and receiver elements' (Mode T) sensing faces, when they are aligned (sensor and reflector, Mode R). (See Figures 2-229-2 and 2-229-3.)

NEMA Standard 11-15-1984.

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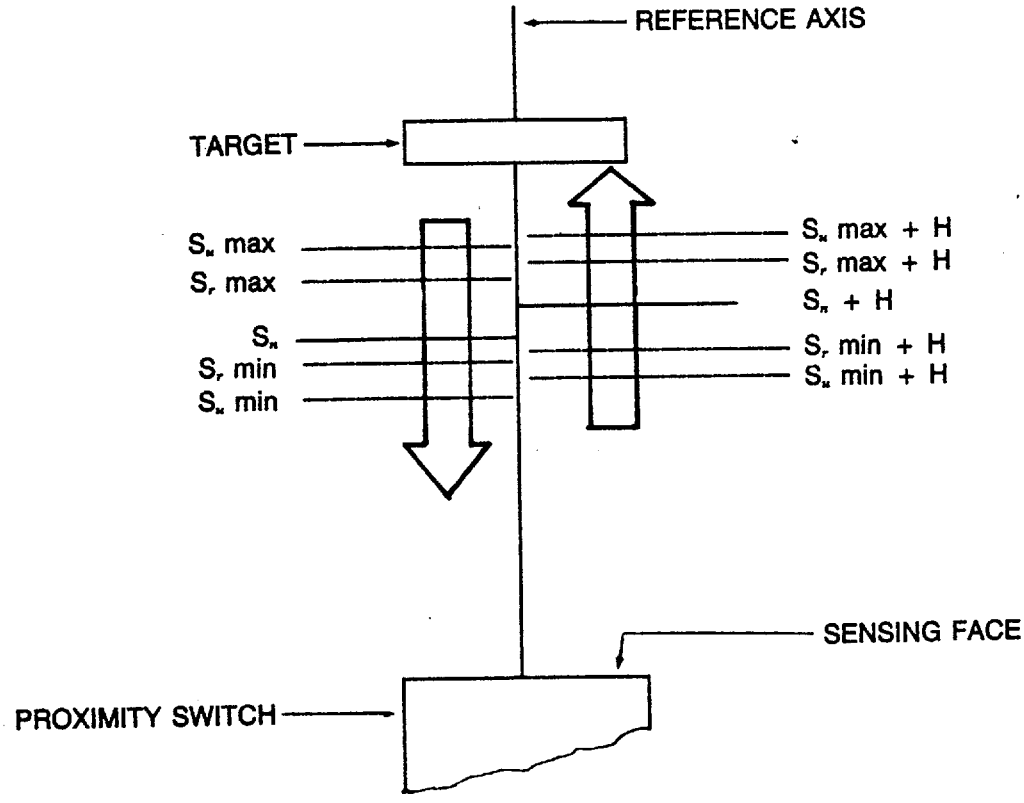


Figure 2-229-1
DISTANCE MEASUREMENTS FOR TYPE 1 PROXIMITY SWITCHES

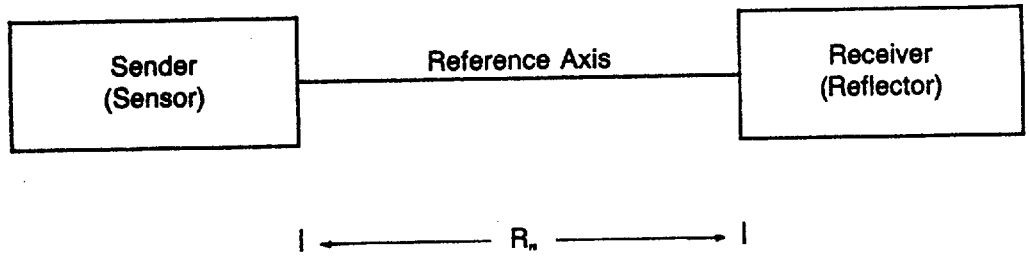


Figure 2-229-2
DISTANCE MEASUREMENTS FOR TYPE 2 PROXIMITY SWITCHES

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2-229.05 CLASSIFICATION OF PROXIMITY SWITCHES BY SENSING MEANS

.01 Inductive

Inductive proximity switches are Type 1 devices used to sense metallic objects. In the NEMA classification system, inductive proximity switches for use with magnetic metals are designated by the letter "F" in the fourth position. The letter "N" is used for non-magnetic metals and the letter "M" is used for universal detection. An induced current in the designated object causes a change in the electromagnetic field of the proximity switch. This change is detected and causes a change in state of the output of the switch. In the NEMA classification system, inductive proximity switches are designated by the letter "I" in the second position.

.02 Capacitive

Capacitive proximity switches are Type 1 devices used to sense metallic or non-metallic objects. In the NEMA classification system, capacitive proximity switches for use with metallic objects are designated by the letter "M" in the fourth position. The letter "T" designates a device for use with both metallic and nonmetallic objects. The designated object serves to change the dielectric of the capacitor, causing a change in state of the output of the switch. In the NEMA classification system, capacitive proximity switches are designated by the letter "C" in the second position.

.03 Magnetic

Magnetic proximity switches are Type 1 devices used to sense magnetic objects, and are of two designs. In one design, designated "F" in the fourth position of the NEMA code, the proximity switch and designated object combine to produce a magnetic circuit with less reluctance than the switch without the object. In the other design, designated "P" in the fourth position, the designated object is a permanent magnet that combines with the proximity switch to complete a magnetic circuit.

In both cases the change in magnetic field strength causes a change in state of the output of the proximity switch.

In the NEMA classification system, magnetic proximity switches are designated by letter "G" in the second position.

.04 Optical

Optical proximity switches are light sensitive switches used to sense objects that either reflect (Type 1) or interrupt (Type 2) light. The switch responds to a beam of light, either visible or invisible, that is either reflected or broken by the designated object, causing a change in state of the output of the switch. Such devices are generally called "photoelectric" switches. The three operating modes of photoelectric switches are shown in Figure 2-229-3. In the NEMA classification system, optical proximity switches are designated by the letter "O" in the first position.

.05 Ultrasonic

Ultrasonic (sometimes called sonic) proximity switches are used to sense objects that reflect (Type 1) or interrupt (Type 2) sound waves emitted by the switch. The switch responds to ultrasonic waves that are reflected by or broken by the designated object, causing a change in state of the output of the switch.

In the NEMA classification system, ultrasonic proximity switches are designated by the letter "U" in the second position.

NEMA Standard 11-15-1984.

2-229.06 CLASSIFICATION OF PROXIMITY SWITCHES BY OUTPUT

The output of a proximity switch may be through contacts rated in accordance with Part ICS 2-125 or a semiconductor rated in accordance with Proposed Part ICS 2-126 (under consideration). Output ratings may be ac or dc, or both. Output forms may be Normally Open (NO) or Normally Closed (NC), or both.

Authorized Engineering Information 11-15-1984.

2-229.07 CLASSIFICATION OF PROXIMITY SWITCHES BY CONFIGURATION

All proximity switches consist of a sensing means and output circuitry. Most proximity switches generate a signal to be sensed. Those that do not, depend upon a source of generated signal provided by a designated object.

These devices respond to a change in either self-generated or externally-generated signals, which, in turn, actuate an output circuit.

Authorized Engineering Information 11-15-1984.

Proximity switches shall have one of two configurations:

a. *Two-Part:* The sensing means and output circuitry are in separated enclosures.
b. *Self-Contained:* The sensing means and output circuitry are mounted as a single unit.

NEMA Standard 11-15-1984.

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2-229.08 DIMENSIONAL CLASSIFICATIONS OF SELF-CONTAINED PROXIMITY SWITCHES

Two types of self-contained proximity switches are classified by dimension.

.01 Standard Dimensions of Cylindrical Switches

Self-contained proximity switches that are cylindrical in shape and have the dimensions and thread sizes shown in Table 2-229-1, may be designated NEMA Style C8, C12, C18, or C30 proximity switches. (See Figure 2-229-4.)

Authorized Engineering Information 11-15-1984.

.02 Standard Dimensions of Rectangular Switches

Self-contained proximity switches that are rectangular in shape and have a square cross section of approximately 35 mm x 35 mm are designated as NEMA Style R35, with a square cross section of approximately 40 mm x 40 mm are designated as NEMA Style R40, and with a square cross section of approximately 80 mm x 80 mm are designated as NEMA Style R80.

Authorized Engineering Information 11-15-1984.

229.09 TOLERANCE TO ENVIRONMENTAL CONDITIONS

Proximity switches are designed for standard conditions of service per ICS 1-108, except for ambient temperature limits, which are -20°C to +70°C. For applications pertaining to the following environmental conditions, consult the manufacturer.

.01 Electrical Noise

Electrical noise is any unwanted signal which can be introduced into the solid-state circuitry of a proximity switch. Such devices operate at low energy levels and are designed to be immune to some degree of electrical noise. Manufacturer's instructions for locating, mounting, and wiring proximity switches are intended to minimize the effect of electrical noise. Note that there are no electrical noise withstandability requirements for dc proximity switches established by these standards.

.02 Temperature Limits

The performance of proximity switches may be affected by temperature outside the normal ambient service conditions for proximity switches, which are -20°C to +70°C.

.03 Ambient Light

Optical proximity switches may vary in their sensitivity to various light sources such as solar, incandescent, fluorescent, and others. Consult the manufacturer's instructions to determine the degree to which the switch must be shielded.

Table 2-229-1
DIMENSIONS OF CYLINDRICAL

PROXIMITY SWITCHES

			Nut Dimensions			Length			
Style	Nominal Diameter d_1 (mm)	Thread Size (metric)	Thickness m (mm)	Across Corners d_3 (mm)	Across Flats Sw (mm)	Minimum L_1 (mm)	Maximum L_2 (mm)	Maximum† L_3 (mm)	Maximum d_2
C8	8	M8 ×1	4	15	13	40	60	4	
C12	12	M12×1	4	20	17	40	80	8	
C18	18	M18×1	4	28	24	50	100	16	
C30	30	M30×1.5	5	42	36	50	100	30	‡

† For Class I Shielded Proximity Switches, Dimension L_3 shall not exceed 1 mm.
‡ d_2 shall not exceed minor diameter of the thread.

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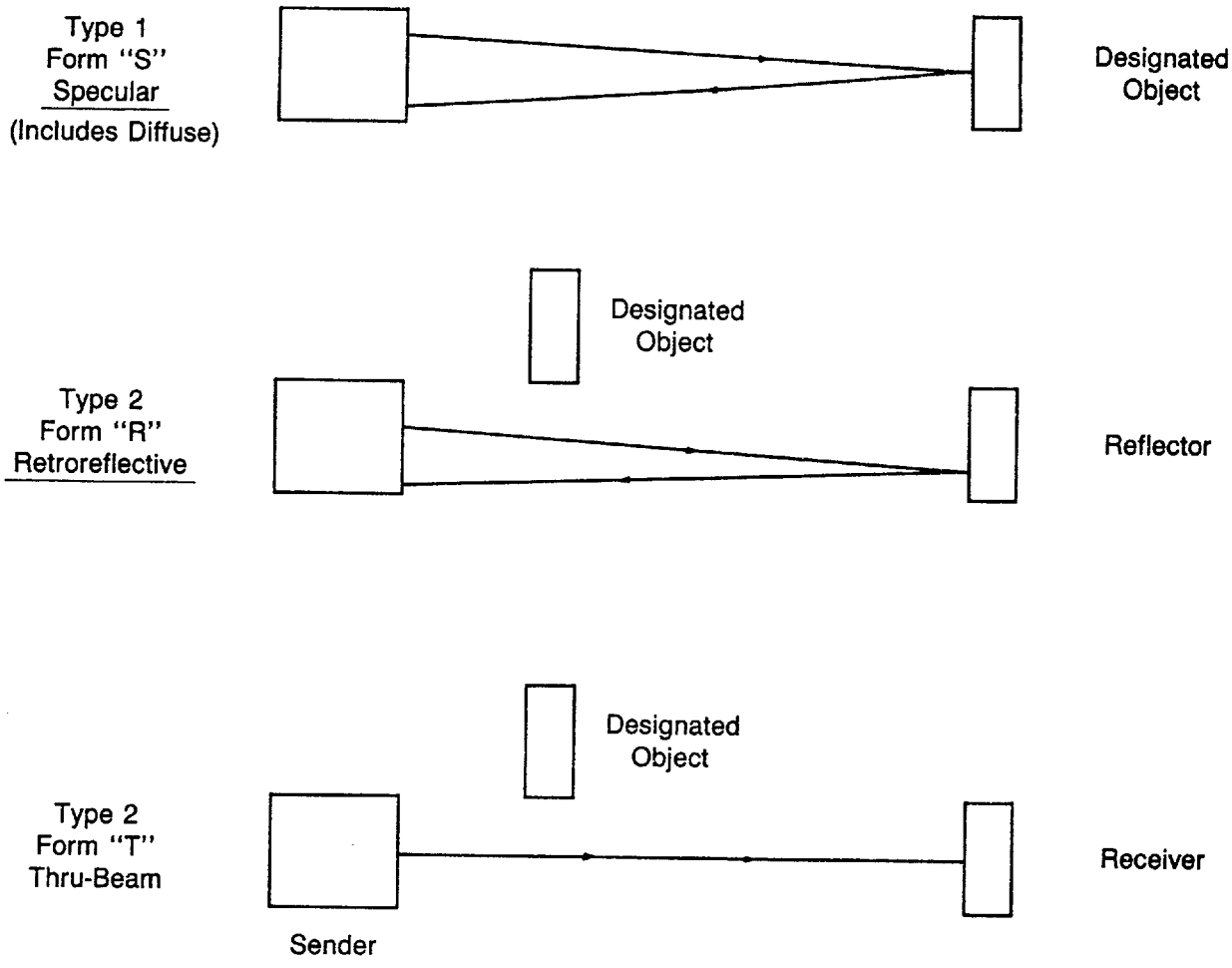


Figure 2-229-3
FORMS OF PHOTOELECTRIC SWITCHES

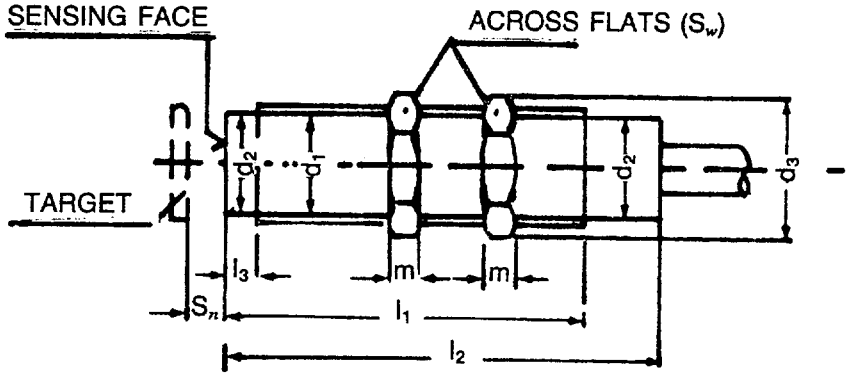


Figure 2-229-4
PROXIMITY SWITCH, CYLINDRICAL

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.04 Surrounding Metal

Proximity switches are identified by the manufacturer as suitable or not suitable for embedding in metal. See ICS 2-229.01.

.05 Magnetic Fields

The performance of proximity switches may be affected by magnetic fields.

.06 Moisture

The presence of moisture in air or in hygroscopic material being sensed may affect the performance of a capacitive, optical, or sonic proximity switch.

.07 Grounding

A change in potential of the designated object with respect to ground (earth) may affect the operation of a capacitive proximity switch.

.08 Airborne Particulates

A change in density, or accumulation, of airborne particulates in the sensing zone of sonic, capacitive, or optical proximity switches may affect their performance.

Accumulation of airborne conductive or magnetic particulates in the sensing zone of inductive or magnetic proximity switches may also affect their performance.

.09 Shock and Vibration

Shock and vibration may affect the accuracy and repeatability of proximity switches and eventually may reduce their life.

.10 Circuit Considerations

The performance of proximity switches with semiconductor outputs may be affected by the manner in which they are connected in the electrical circuit (i.e., series or parallel). See ICS 1.1, *Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control.*

.11 Nuclear Radiation

The performance of proximity switches may be affected by nuclear radiation.

Authorized Engineering Information 11-15-1984.

2-229.10 ENCLOSURES

Proximity switches in their enclosures shall be designated by type numbers in accordance with NEMA Standards Publication 250, *Enclosures for Electrical Equipment (1000 Volts Maximum).*

NEMA Standard 11-15-1984.

2-229.11 INDICATORS

Proximity devices may incorporate status indicators to designate POWER ON, or other operating conditions.

Authorized Engineering Information 11-15-1984.

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RATINGS

2-229.20 NOMINAL INPUT VOLTAGE RATINGS

The nominal input voltage ratings of a proximity switch may be one, or a combination of those shown in Table 2-229-2.

Authorized Engineering Information 11-15-1984.

2-229.21 OUTPUT RATINGS

The output ratings of proximity switches with contacts shall be in accordance with Part ICS 2-125 or Part ICS 2-219.

The output ratings of proximity switches with semiconductor outputs shall be in accordance with Part ICS 2-126 .

Suggested Standard for Future Design 11-15-1984.

2-229.22 RATED OPERATING DISTANCE, S_n

The rated operating distance characteristics shall be as shown in Table 2-229-3.

Suggested Standard for Future Design 11-15-1984.

Table 2-229-2
NOMINAL INPUT VOLTAGE RATINGS

Alternating Current Volts		
50 hertz	60 hertz	Direct Current Volts
24	24	5
48	48	12
110	115 or 120	24
115	200 or 208	36
127	230 or 240	48
220	265 or 277	115 or 120
240	460 or 480	230 or 240
380		
415		

Table 2-229-3
RATED OPERATING CHARACTERISTICS AND VARIATIONS FOR SELF-CONTAINED TYPE 1 INDUCTIVE PROXIMITY SWITCHES

NEMA Class	Size		Rated Operating Distance (mm) S_n		Allowed Variations in Operating Distance Due to:	
			Shielded	Unshielded	Manufacturing	Temperature and Voltage Changes
IC8	M8×1	metric thread	1	2	$.9S_n \le S_r \le 1.1S_n$	$.9S_r \le S_u \le 1.1S_r$
IC12	M12×1	metric thread	2	4		
IC18	M18×1	metric thread	5	8		
IC30	M30×1.5	metric thread	10	15		
IR35	35 × 35 mm		*	*		
IR40	40 × 40 mm		*	*		
IR80	80 × 80 mm		*	*		

* Consult manufacturer for details.

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2-229.23 RATE OF OPERATION

Every proximity device shall have a specified nominal rate of operation that is used for calibration and evaluation purposes. (See Part ICS 2-229.45.)

Suggested Standard for Future Design 11-15-1984.

2-229.24 MAXIMUM START-UP TIME

The start-up time for a proximity switch shall not exceed 300 milliseconds.

Suggested Standard for Future Design 11-15-1984.

DESIGN TESTS AND PERFORMANCE

2-229.40 ELECTRICAL NOISE WITHSTANDABILITY

Alternating current proximity switches shall be capable of withstanding the noise test described in Part ICS 1-109 without malfunctioning when the generated noise is injected onto the power supply circuit and onto the output circuit. The tests shall be performed with the device in both the energized and de-energized states. For Type 1 switches, the energized condition is defined with the standard target at S_u minimum and the de-energized condition with the target at S_u maximum plus H.

Suggested Standard for Future Design 11-15-1984.

2-229.41 SHOCK AND VIBRATION WITHSTANDABILITY AND ENDURANCE

(Under consideration.)

2-229.42 THERMAL CYCLING AND HUMIDITY TEST PROCEDURE

.01 Test Temperature Limits

.01 The low shall be the minimum rated ambient temperature.

.02 The high limit shall be the maximum rated ambient temperature.

.02 Apparatus

.The accuracy of the test temperature shall be within ±2°C.

.03 Test Sequence

.01 Check operating characteristics and examine for physical faults such as cracks and separation of permanently sealed areas.

.02 Place in chamber, with chamber at low limit temperature for 3 hours minimum.

.03 Remove from chamber and expose to room temperature for 3 hours minimum.

.04 Place in chamber, with chamber at high limit temperature for 3 hours minimum.

.05 Repeat .03.

.06 Repeat .02-.05 for a total of 5 cycles.

.07 Place in humidity chamber at 95% relative humidity at 40°C for 24 hours minimum.

.08 Remove from chamber and repeat .01 within 30 minutes.

.04 Performance

Operating characteristics and physical parameters measured preceding and following thermal cycling and humidity tests shall meet the manufacturer's specification.

.05 Criteria for Failure

Deterioration or any change in performance or physical characteristics that could prevent the proximity switch from meeting functional maintenance and service requirements during its service life, shall be considered a failure. Any change which results in a switch being out of specification shall be a failure.

Suggested Standard for Future Design 11-15-1984.

2-229.43 OPERATING DISTANCE VERIFICATION FOR TYPE 1 PROXIMITY SWITCHES

.01 Construction of the Target

Targets for Type 1 proximity switches shall be as shown in Table 2-229-4.

.02 Measurement

As shown in Figure 2-229-5, the target is moved slowly (not faster than 1 mm per second) towards the proximity switch in an axial approach and the operating distance is measured.

.03 Operating Conditions

Effective operating range (S_r) shall be verified by the manufacturer using the method shown in Figure 2-229-1 at 20°C and nominal voltage.

The usable operating range (S_u) is verified with the proximity switch and its immediate environment at both the maximum and the minimum temperature specified by the manufacturer. Verification at each temperature is made.

a. For single input voltage rated devices, tests shall be conducted at 85% and 110% of the rated voltage.

b. For devices with a specified voltage range, tests shall be conducted at the minimum and maximum voltages.

Where no temperature range has been specified, the maximum and minimum temperatures shall be +70°C and -20°C, respectively.

Suggested Standard for Future Design 11-15-1984.

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Table 2-229-4
STANDARD SQUARE TARGETS FOR TYPE 1 PROXIMITY SWITCHES

Sensing Means	Target Material	Target Thickness	Target Size
Inductive			
M&F (Magnetic)	Mild Steel	1 mm	Per note
N (Nonmagnetic)	Aluminum	1 mm	Per note
Capacitive			
M (Metallic)	Mild Steel, Grounded	1 mm	Per note
T (Any Material)	Glass	3 mm	Per note
Magnetic			
F (Magnetic)	Mild Steel	3 mm	75 × 75 mm
P (Perm. Magnet)	Perm. Magnet	. . .	As specified by the manufacturer
Optical			
	90% Reflective White Paper	. . .	130 × 130 mm
Ultrasonic			
	Glass	3 mm	Per note

NOTE: This only refers to inductive and capacitive. Other size targets shall be permitted to be used for production calibration if the results can be correlated to standard test data. The length of the side of the square (m) is equal to: either the diameter of the circle inscribed on the active surface of the sensitive face, or three times the rated operating distance, whichever is the greater.

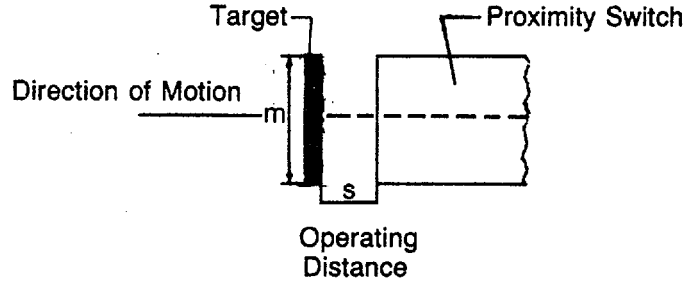


Figure 2-229-5
METHOD FOR MEASURING THE OPERATING DISTANCE

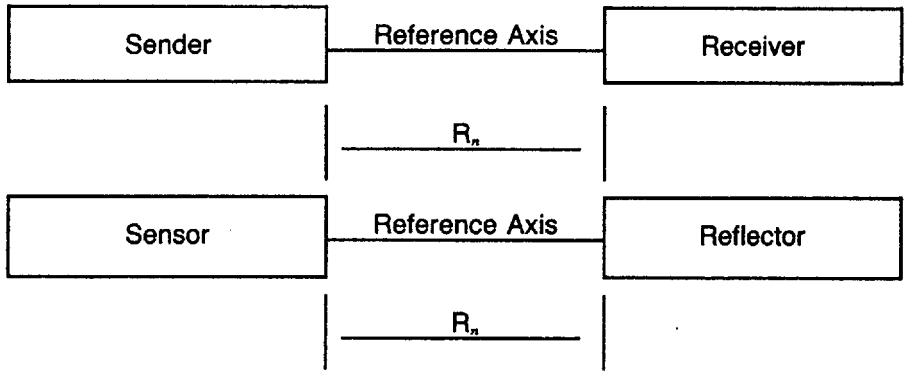


Figure 2-229-6
MEASUREMENT OF RATED RANGE R_n

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2-229.44 OPERATING DISTANCE VERIFICATION OF TYPE 2 PROXIMITY SWITCHES

.01 Construction of the Reflector

The standard reflector (for Type 2 Mode "R" optical proximity switches only) used for measurement of rated range R_n shall be a 76 mm diameter clear acrylic prismatic reflective disc.

.02 Measurement of Rated Range, R_n

As shown in Figure 2-229-6, the sender and receiver (Type 2 Mode "T") or the sensor and reflector (Type 2 Mode "R") are aligned along the reference axis. The maximum distance at which the device operates correctly is the rated range (R_n).

.03 Method for Measuring the Rated Range Operating Conditions

Rated range (R_n) shall be verified by the manufacturer using the method shown in Figure 2-229-6 at 20°C and nominal voltage, in clear air.

The operating distance is verified with the proximity switch and its immediate environment at both the maximum and the minimum temperature specified by the manufacturer. Verification at each temperature is made.

a. For single input voltage rated devices, tests shall be conducted at 85% and 110% of the rated voltage.
b. For devices with a specified voltage range, tests shall be conducted at the minimum and maximum voltages.

Where no temperature range has been specified the maximum and minimum temperatures shall be +70°C and -20°C, respectively.

Suggested Standard for Future Design 11-15-1984.

2-229.45 RATE OF OPERATION VERIFICATION FOR PROXIMITY SWITCHES

The following test procedure using Figure 2-229-7 is applicable for frequencies up to 300 Hz. For higher frequencies, other equivalent methods shall be used.

.01 Construction of the Target

a. The target for Type 1 switches shall be as specified in Table 2-229-4.
b. The target for Type 2 switches shall be as specified by the manufacturer.
c. For both Type 1 and Type 2 switches, a 75 x 75 mm target shall be permitted to be used to simplify the test fixture.

.02 Measurement, Type 1 Switches

A resistive load at the maximum rated current value of the device shall be used for the test.

As the speed of the rotation of the disc is increased from zero, the output of the proximity switch is observed on a cathode ray oscilloscope. (See Figure 2-229-8.)

An illustration of the output signal is shown in Figure 2-229-8. As the speed increases, the durations, t_1 and t_2, decrease.

The maximum rate of operation (operating frequency) f is determined from the following relationship.

$$f = \frac{1}{t_1 + t_2}$$

For dc switches, the maximum rate of operation is determined when the output signal fails to track the targets on the rotating disc.

For ac switches, the maximum rate of operation is determined when either t_1 or t_2 has decreased to ½ period of the line frequency.

For ac switches, the minimum rate of operation shall be at least 10% of line frequency. For example, a 60 cycle device shall operate at a minimum of 6 Hz.

.03 Measurement, Type 2 Switches

Measurements are identical to ICS 2-229.45.02 for Type 1 switches with the physical arrangement of Figure 2-229-7, Method B employed.

Measurement shall be made at R_n for devices whose operating frequency is dependent on distance. Otherwise, any convenient distance shall be used.

Suggested Standard for Future Design 11-15-1984.

2-229.46 TEMPERATURE RISE OF CURRENT CARRYING PARTS

The output means and field wiring terminals of proximity switches, when carrying rated continuous (load) current, shall not exceed the temperature rises given in Part ICS 1-109. When the proximity switch has output contacts, the temperature rise test shall be made with new (unused) contacts carrying, but not making or breaking, current.

NEMA Standard 11-15-1984.

For the purpose of this test, the proximity switches shall be wired with wire sized appropriately for the switch current rating. See Parts ICS 2-125 and ICS 2-126 for devices rated for control circuit application.

Suggested Standard for Future Design 11-15-1984.

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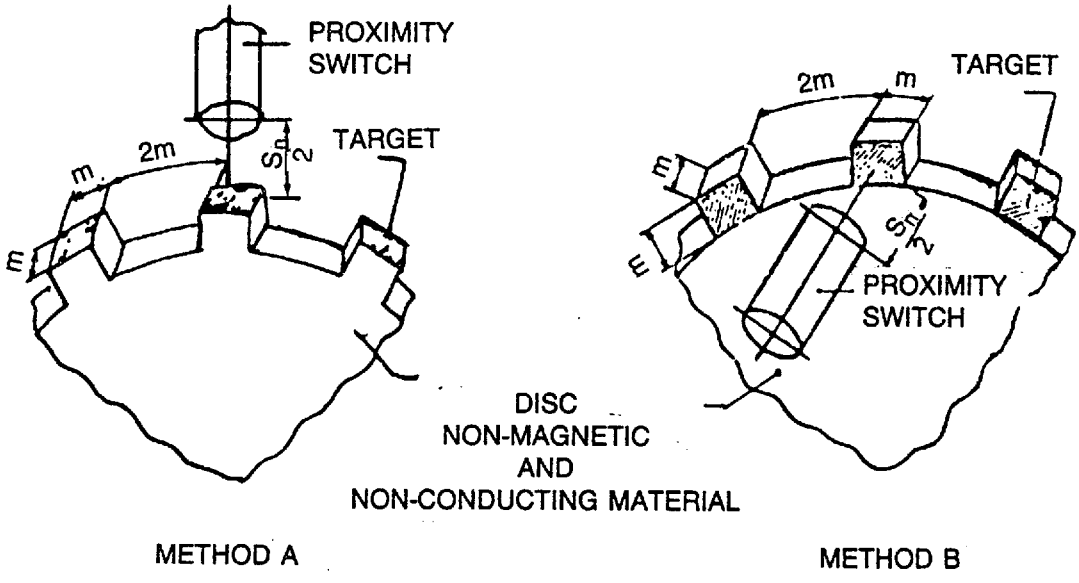


Figure 2-229-7
METHOD FOR MEASURING THE NOMINAL RATE OF OPERATION

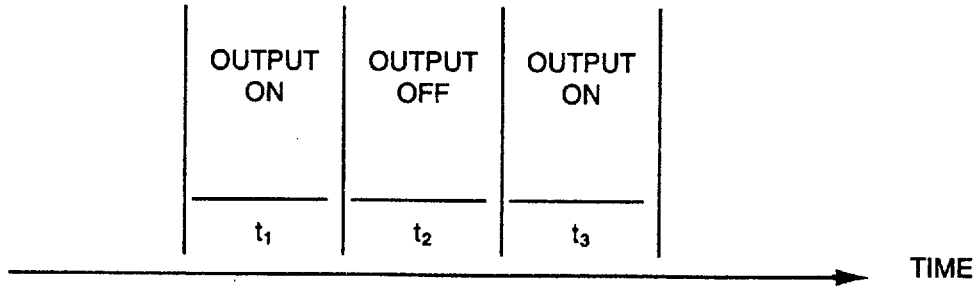


Figure 2-229-8
OUTPUT SIGNAL OF TYPE 1 PROXIMITY SWITCHES
DURING THE VERIFICATION OF RATE OF OPERATION

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2-229.47 OUTPUT PERFORMANCE

The output means of proximity switches that are rated for control circuit applications shall be capable of passing the tests described in Parts ICS 2-125 and ICS 2-126.

Suggested Standard for Future Design 11-15-1984.

2-229.48 TEST FOR ERRONEOUS OUTPUT FOR TYPE 1 PROXIMITY SWITCHES

To test for this property, a standard target shall be used to operate the Type 1 proximity switch. The standard target shall be moved away axially to a point 1.5 times S_r maximum, as shown in Figure 2-229-1. The test load shall be resistive and require a current equal to maximum rated current but not less than 1 milliampere. The power to the proximity switch shall be turned OFF and then restored. The normally open output shall not operate when power is reapplied. A change of state of the normally open output when power is restored shall be considered a failure. The test current shall consist of at least 10 applications of power with at least 5 seconds off time between each reapplication.

Suggested Standard for Future Design 11-15-1984.

Two-wire proximity switches, in which the device operating power flows through the load, may exhibit a "power-on-momentary current" phenomenon while the proximity switch power supply is being charged. This momentary current may exceed the off-state current of the proximity switch. Loads sensitive to low signal levels, such as programmable controller inputs and small relays, may be temporarily energized by this momentary current.

Manufacturers should provide instructions to assist users to take this into consideration when they design circuits.

Authorized Engineering Information 8-20-1986.

2-229.49 TEST FOR ERRONEOUS OUTPUT FOR TYPE 2 PROXIMITY SWITCHES

To test for this property the output is monitored without a target. The test load shall be resistive and require a current equal to the minimum rated current but not less than 1 milliampere. The normally open output shall not operate when power is applied. A change of state of the normally open output when power is applied shall be considered a failure.

Suggested Standard for Future Design 11-15-1984.

2-229.50 REPEAT ACCURACY, R

The repeat accuracy of any operating distance shall be measured at least hourly over an 8-hour period with an ambient temperature of 20°C and with specified rated input voltage and current continuously applied. The difference in readings when measured in accordance with ICS 2-229.43 shall not exceed 5% of the average of the largest and the smallest value.

Suggested Standard For Future Design 11-15-1984.

2-229.60 MARKING

Each proximity switch shall be marked with its input ratings expressed in volts, amperes, or volt amperes and its output designation in accordance with 2-229.21.

Suggested Standard for Future Design 11-15-1984.

Proximity switches may be marked by a NEMA code number incorporating the type, class, style, material, and form number from Table 2-229-5.

Authorized Engineering Information 11-15-1984.

2-229.61 USER INSTRUCTIONS

Each proximity switch shall include appropriate instructions for the proper application of the switch such as, but not limited to, the shielding required for optical proximity switches, temperature limitations, embedding in metal, mounting, free zone requirements, operation in the presence of air contaminants, response times, and start-up times.

NEMA Standard 11-15-1984.

APPLICATION

2-229.80 SERVICE CONDITIONS

Proximity switches shall be applied under the usual service and installation conditions described in Part ICS 1-108 unless the device is specifically marked with the exceptions.

NEMA Standard 11-15-1984.

2-229.81 INSTALLATION

Particular care should be taken in the mounting of a proximity switch so that it will not be subject to physical damage and so that the sensing portion of the device is not influenced by extraneous objects. The manufacturer's instructions regarding the shielding of conductors should be observed in order to prevent erratic operation.

If a hazardous condition can result from the unintended operation of a proximity switch, access to the sensing face of the switch should be guarded.

Where the safety of personnel or the elimination of hazard is dependent upon the operation of a proximity switch, the recommendations of ICS 1.1 should be followed.

Authorized Engineering Information 11-15-1984.

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Table 2-229-5
CLASSIFICATION CODE DESIGNATIONS FOR PROXIMITY SWITCHES

Sensing Principle		Sensing Means		Case Style		Target Material		Output Form	
Description	Type	Description	Class	Description	Style	Description	Material	Description	Form
Non-Break Beam	1	Inductive	I	35mm Rectangular	R35	Ferrous (Magnetic) Metal	F	Normally Open	A
				40mm Rectangular	R40				
				80mm Rectangular	R80	Any Metal	M	Normally Closed	B
				8mm Cylindrical	C8				
				12mm Cylindrical	C12				
				18mm Cylindrical	C18	Non-Ferrous (Non-Magnetic) Metal	N		
				30mm Cylindrical	C30				
		Capacitive	C	35mm Rectangular	R35	Any Metal	M	Normally Open	A
				40mm Rectangular	R40				
				80mm Rectangular	R80	Any Material	T	Normally Closed	B
				8mm Cylindrical	C8				
				12mm Cylindrical	C12				
				18mm Cylindrical	C18				
				30mm Cylindrical	C30				
		Magnetic	G	35mm Rectangular	R35	Ferrous (Magnetic) Metal	F	Normally Open	A
				40mm Rectangular	R40				
				8mm Cylindrical	C8	Permanent Magnet	P	Normally Closed	B
				12mm Cylindrical	C12				
				18mm Cylindrical	C18				
				30mm Cylindrical	C30				
		Optical	O	35mm Rectangular	R35	Any Material[1]	T	Normally Open	A
				40mm Rectangular	R40				
				8mm Cylindrical	C8			Normally Closed	B
				12mm Cylindrical	C12				
				18mm Cylindrical	C18				
				30mm Cylindrical	C30				
		Ultrasonic	U	35mm Rectangular	R35	Any Material[2]	T	Normally Open	A
				40mm Rectangular	R40				
				80mm Rectangular	R80			Normally Closed	B
				8mm Cylindrical	C8				
				12mm Cylindrical	C12				
				18mm Cylindrical	C18				
				30mm Cylindrical	C30				
Break Beam	2	Optical	O	35mm Rectangular	R35	Any Material[3]	T	Normally Open	A
				40mm Rectangular	R40				
				8mm Cylindrical	C8			Normally Open	B
				12mm Cylindrical	C12				
				18mm Cylindrical	C18				
				30mm Cylindrical	C30				
		Ultrasonic	U	35mm Rectangular	R35	Any Material	T	Normally Open	A
				40mm Rectangular	R40				
				80mm Rectangular	R80			Normally Closed	B
				8mm Cylindrical	C8				
				12mm Cylindrical	C12				
				18mm Cylindrical	C18				
				30mm Cylindrical	C30				

[1] Sensed surface must be optically reflective.
[2] Sensed surface must be sonically reflective.
[3] Sensed surface must be opaque.

(Cont.)

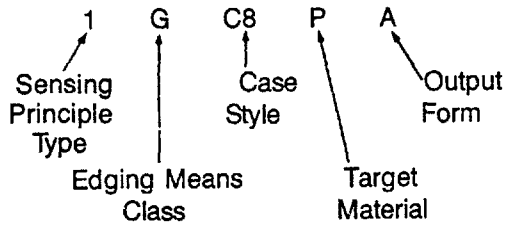
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Table 2-229-5
CLASSIFICATION CODE DESIGNATIONS FOR PROXIMITY SWITCHES
(Cont.)

NEMA Classification Explanation

Example:



2-229.82 SPECIAL APPLICATIONS

When using proximity switches with programmable controllers, the following items require special consideration to assure compatibility.

1. Maximum steady state leakage current
2. Transient leakage current during power up
3. Maximum on state voltage
4. Minimum operating voltage
5. Maximum load impedance
6. Minimum load current.

Authorized Engineering Information 11-15-1984.

PREVENTIVE MAINTENANCE

2-229.90 PREVENTIVE MAINTNENACE GUIDE

See ICS 1-115 for general maintenance instructions.

Authorized Engineering Information 1-27-1988.

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Part ICS 2-302†

MAINTENANCE OF MOTOR CONTROLLERS AFTER A FAULT CONDITION

Part ICS 2-302 covers the procedures to be followed in order to return to service a motor controller which has been subjected to a short circuit or a ground fault. These procedures are not intended to cover other elements of the branch circuit, such as wiring and motors, which may also require attention.

The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

GENERAL

2-302.01 INTRODUCTION

In a motor branch circuit which has been properly installed, coordinated and in service prior to the fault, opening of the branch-circuit short-circuit protective device (fuse, circuit breaker, motor short circuit protector, etc.) indicates a fault condition in excess of operating overload. This fault condition must be corrected and the necessary repairs or replacements made before re-energizing the branch circuit.

It is recommended that the following general procedures be observed by qualified personnel in the inspection and repair of the motor controller involved in the fault. Manufacturers' service instructions should also be consulted for additional details.

Authorized Engineering Information 1-5-1977.

PROCEDURES

CAUTION —IT MUST BE UNDERSTOOD THAT ALL INSPECTIONS AND TESTS ARE TO BE MADE ON CONTROLLERS AND EQUIPMENT WHICH ARE DE-ENERGIZED, DISCONNECTED AND ISOLATED SO THAT ACCIDENTAL CONTACT CANNOT BE MADE WITH LIVE PARTS AND SO THAT ALL PLANT SAFETY PROCEDURES WILL BE OBSERVED.

2-302.02 ENCLOSURE

Substantial damage to the enclosure such as deformation, displacement of parts or burning, requires replacement of the entire controller.

Authorized Engineering Information 1-5-1977.

2-302.03 DISCONNECT DEVICES

.01 Circuit Breakers

Examine the enclosure interior and the circuit breaker for evidence of possible damage. If evidence of damage is not apparent, the breaker may be reset and turned "ON." If it is suspected that the circuit breaker has opened several short-circuit faults or if signs of possible deterioration appear within the enclosure, the test described in par. AB 1-2.38 of the NEMA Standards Publication for *Molded Case Circuit Breakers,* Publication No. AB 1, should be performed before restoring the breaker to service.

.02 Disconnect Switch

The external operating handle must be capable of opening the switch. If the handle fails to open the switch or if visual inspection after opening indicates deterioration beyond normal wear and tear, such as overheating, contact blade or jaw pitting, insulation breakage or charring, the switch must be replaced.

.03 Fuse Holders

Deterioration of fuse holders or their insulating mounts requires their replacement.

Authorized Engineering Information 1-5-1977.

2-302.04 TERMINALS AND INTERNAL CONDUCTORS

Indications of arcing damage or overheating, or both, such as discoloration and melting of insulation, require the replacement of damaged parts.

Authorized Engineering Information 1-5-1977.

2-302.05 MOTOR STARTER

.01 Contactor

Contacts showing heat damage, displacement of metal, or loss of adequate wear allowance require replacement of the contacts and, where applicable, the contact springs. If deterioration extends beyond the contacts, such as binding in the guides or evidence of

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insulation damage, the damaged parts of the entire contactor must be replaced.

.02 Overload Relays

a. If burnout of the current element of an overload relay has occurred, the complete overload relay must be replaced. Any indication that an arc has struck and/or any indication of burning of the insulation of the overload relay also requires replacement of the overload relay.

b. If there is no visual indication of damage that would require replacement of the overload relay, the relay must be electrically or mechanically tripped to verify the proper functioning of the overload relay contact(s).

c. If there is no visual indication of damage that would require replacement of the overload relay with solid-state output, the overload relay output shall be checked within the minimum and maximum current rating for proper functioning.

NEMA Standard 1-15-1986.

2-302.06 RETURN TO SERVICE

Before returning the controller to service, checks should be made for the tightness of electrical connections and for the absence of short circuits, grounds and leakage.

All equipment enclosures should be closed and secured before the branch circuit is energized.

Authorized Engineering Information 1-5-1977.

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Part ICS 2-321

AC GENERAL-PURPOSE CLASS A MAGNETIC CONTROLLERS FOR INDUCTION MOTORS RATED IN HORSEPOWER 600 VOLTS AND LESS, 50 AND 60 HERTZ

Part ICS 2-321 applies to Class A combination and noncombination magnetic controllers for squirrel cage and wound-rotor induction motors rated in horsepower for application at 600 volts and less, 50 and 60 hertz. The standards of Parts ICS 2-110 and ICS 2-222 also apply to Part ICS 2-321. See Part ICS 2-327 for magnetic controllers for induction motors rated in full-load and locked-rotor currents.

The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part unless otherwise specified.

GENERAL INFORMATION AND FEATURES

2-321.05 TYPICAL METHODS OF CONTROLLING MOTORS

Typical methods of controlling motors are shown in Figures 2-321-1 through 2-321-5. An "X" in the contactor sequence chart indicates closed contacts.

Authorized Engineering Information 5-18-1964.

2-321.06 DETERMINATION OF MOTOR -STARTING LINE CURRENT

The starting current values for the various methods of motor starting may be determined as follows.

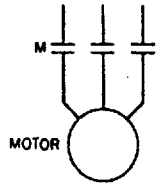
.01 Full-voltage Starting

See Figure 2-321-1. The starting current is equal to the locked-rotor current at full voltage.

.02 Reactor or Resistor Reduced-voltage Starting

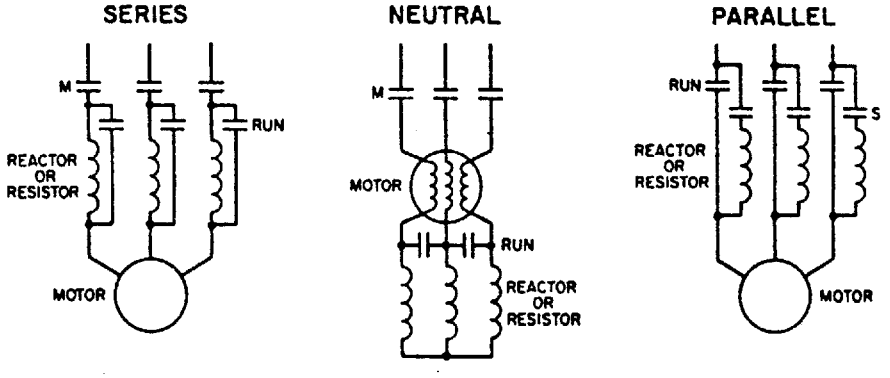
With reactor or resistor starting (Figure 2-321-2), the starting current is determined from the phasor sum of the impedances of the starting reactor or resistor and of the motor under locked-rotor conditions.

Authorized Engineering Information 9-20-1972.



CONTACTOR SEQUENCE	
CONTACTOR	START AND RUN
M	X

Fig. 2-321-1
FULL-VOLTAGE CONTROLLER



CONTACTOR SEQUENCE		
CON-TACTOR	START	RUN
M	X	X
RUN		X

CONTACTOR SEQUENCE		
CON-TACTOR	START	RUN
M	X	X
RUN		X

CONTACTOR SEQUENCE			
CON-TACTOR	START	TRAN-SITION	RUN
S	X	X	X*
RUN		X	X

* OPEN OR CLOSED

Fig. 2-321-2
REDUCED VOLTAGE CONTROLLER—REACTOR OR RESISTOR

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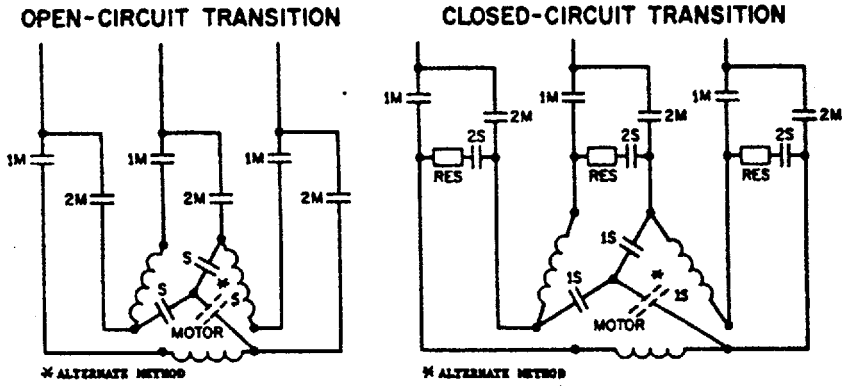
.03 Wye-delta Starting

Wye-delta controllers connect the phase windings first in wye relationship for the effect of reduced-voltage starting and, subsequently, reconnect these phase windings in delta relationship for running.

NEMA Standard 5-18-1964.

With wye-delta starting (Figure 2-321-3), the starting current on the wye connection is equal to 0.33 times the locked-rotor current on the delta connection.

Authorized Engineering Information 9-20-1972.



CONTACTOR SEQUENCE				
CONTACTOR	START		TRANSITION	RUN
1M		X	X	X
2M				X
S	X			

CONTACTOR SEQUENCE						
CONTACTOR	START		TRANSITION			RUN
			1	2	3	
1M		X	X	X	X	X
2M					X	X
1S	X		X			
2S			X	X	X	

Fig. 2-321-3
WYE-DELTA CONTROLLERS

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.04 Part-winding Starting

Part-winding controllers first connect a part of the motor winding to the supply lines as the first starting step and then connect the remaining portion of the winding to the supply lines as the second step. Part-winding controllers are also of the reduced-voltage type, the reduced voltage being obtained by the use of a resistor or reactor connected in series with the first-mentioned portion of the winding.

NEMA Standard 7-15-1970.

With part-winding starting (Fig. 2-321-4), the starting current is the locked-rotor current of the motor connected for starting.

Authorized Engineering Information 9-20-1972.

.05 Autotransformer Reduced Voltage Starting

1. The starting current drawn from line = $I \times p^2 + 0.25\ I_m$.
2. The starting current taken by the motor = $I \times p$.
3. The autotransformer neutral current = $I \times p - (I \times p^2 + 0.25\ I_m)$.

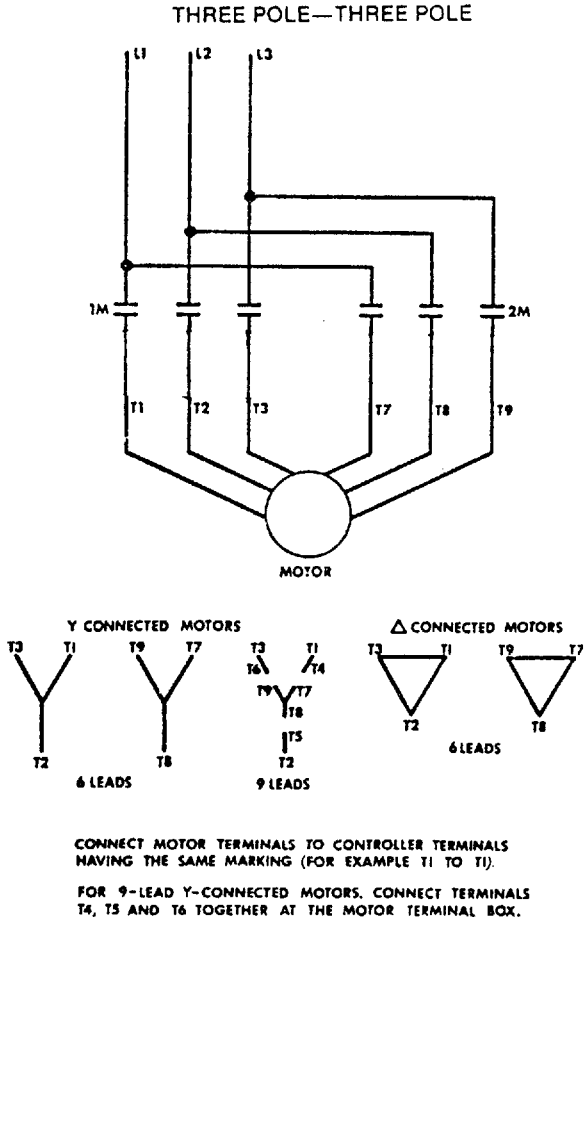
where –

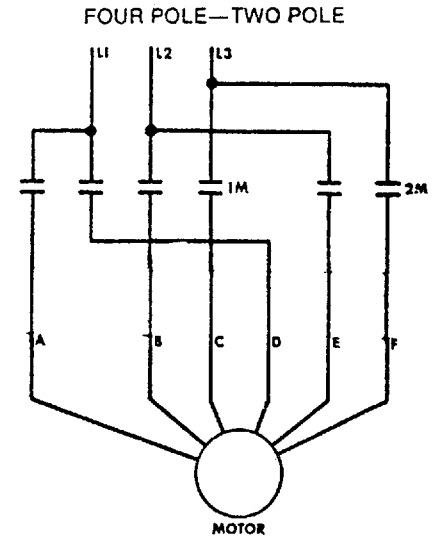
I = Locked-rotor amperes at full voltage.

p = Transformer tap used (fraction of full voltage).

I_m = Rated full-load current of motor. The term "$0.25\ I_m$" is introduced to allow for transformer magnetizing current.

Authorized Engineering Information 9-20-1972.





—TABLE OF MOTOR LEAD CONNECTIONS—

PART WINDING SCHEMES	LETTERED TERMINALS IN PANEL					
	A	B	C	D	E	F
1/2 Y OR Δ 6 LEADS	T1	T2	T3	T7	T8	T9
1/2 Y 9 LEADS ◊	T1	T2	T3	T7	T8	T9
1/2 Δ 9 LEADS □	T1	T8	T3	T6	T2	T9
2/3 Y OR Δ 6 LEADS	T1	T2	T9	T7	T8	T3
2/3 Y 9 LEADS ◊	T1	T2	19	T7	T8	T3
2/3 Δ 9 LEADS □	T1	T4	T9	T6	T2	T3

◊ CONNECT TERMINALS 4, 5 AND 6 TOGETHER AT TERMINAL BOX.

□ CONNECT TERMINALS 4 AND 8, 5 AND 9, 6 AND 7 TOGETHER IN THREE SEPARATE PAIRS AT TERMINAL BOX.

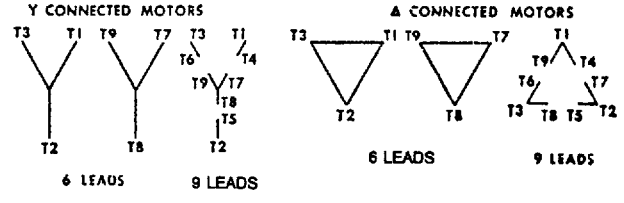


Fig. 2-321-4
FULL VOLTAGE PART WINDING CONTROLLERS

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2-321.07 TYPES OF WYE-DELTA CONTROLLERS

The types of wye-delta magnet controllers for induction motors shall be the following.

.01 Open-circuit Transition

These are enclosed, nonplugging, nonjogging controllers for the effect of reduced-voltage starting of motors by the open-circuit-transition method, consisting of:

a. Two three-pole magnetic contactors, 1M and 2M, for the line connections to the motor.
b. One two-pole magnetic contactor, S, where the S contactor is the same size as the 1M and 2M contactors, or a three-pole contactor where the S contactor is one size smaller than the 1M and 2M contactors for effecting the wye neutral connection.
c. One means (timing) for maintaining the wye (starting) connection for a predetermined accelerating time.
d. One set of mechanical and electrical interlocks to prevent closing 2M before S opens.
e. Three overload units,* one in each phase winding, unless equivalent protection is otherwise provided for the motor, the motor control apparatus and the branch-circuit conductors against excessive heating due to motor overloads.
f. Provision for separately mounted control pushbuttons.

.02 Closed-circuit Transition

These are enclosed, nonplugging, nonjogging controllers for the effect of reduced-voltage starting of motors by the closed-circuit-transition method, consisting of:

a. Two three-pole magnetic contactors, 1M and 2M, for the line connections to the motor.
b. One two-pole magnetic contactor, 1S, where the 1S contactor is the same size as the 1M and 2M contactors, or a three-pole contactor where the 1S contactor is one size smaller than the 1M and 2M contactors for effecting the wye neutral connection.
c. One three-pole magnetic contactor, 2S, for the transition resistor connections.
d. One transition resistor for each phase.
e. One means (timing) for maintaining the wye (starting) connection for a predetermined accelerating time.
f. One set of mechanical and electrical interlocks to prevent closing 2M before 1S opens.
g. Three overload units,* one in each phase winding, unless equivalent protection is otherwise provided for the motor, the motor control apparatus and the branch-circuit conductors against excessive heating due to motor overloads.
h. Provision for separately mounted control pushbuttons.

NEMA Standard 9-20-1972.

2-321.08 TYPES OF PART-WINDING CONTROLLERS

The types of part-winding magnetic controllers for induction motors shall be as shown in par. .01 and .02.

.01 Full-voltage Part-winding Controllers

These are enclosed, nonplugging, nonjogging, full-voltage controllers for motors suitable for part-winding starting, consisting of:

a. A magnetic contactor used to connect one part of the motor winding to the supply lines.
b. A magnetic contactor used to connect a second part of the motor winding to the supply lines.
c. Means to delay the closing of the second contactor.
d. Running overcurrent protection for each motor winding unless equivalent protection is otherwise provided for the motor, the motor control apparatus and the branch-circuit conductors against excessive heating due to motor overloads.
e. Provision for separately mounted control pushbuttons.

*Phase current is 0.577 x line current.

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.02 Reduced-voltage Part-winding Controllers

These are enclosed, nonplugging, nonjogging, reduced-voltage controllers for motors suitable for part-winding starting, consisting of:

a. A magnetic contactor used to connect one part of the motor winding to the supply lines.
b. A resistor or reactor connected into the circuit of this motor winding.
c. A magnetic contactor used to short-circuit the resistor or reactor.
d. A magnetic contactor used to connect a second part of the motor winding to the supply lines.
e. Means to delay the closing of the contactors covered in items c. and d. above.
f. Running overcurrent (overload) protection for each motor winding unless equivalent protection is otherwise provided for the motor, the motor control apparatus and the branch-circuit conductors against excessive heating due to motor overloads.
g. Provision for separately mounted control push-buttons.

.03 Pole Arrangements for Part-winding Controllers

For one-half winding starting of motors having equal windings that are wye connected with either six or nine leads brought out and for motors that are delta connected with six leads brought out, the controller shall have either a three-pole contactor for the first part of the winding and another three-pole contactor for the second part, or a four-pole contactor for the first part of the winding and a two-pole contactor for the second part.

For two-thirds winding starting of motors having equal windings that are wye connected with either six or nine leads brought out and for motors that are delta connected with either six or nine leads brought out, the controller shall have a four-pole contactor for the first part of the winding and a two-pole contactor for the second part.

NEMA Standard 7-15-1970.

2-321.10 CONNECTIONS FOR TWO-SPEED MOTOR CONTROLLERS

A single-winding two-speed motor carries current in various configurations of wye and delta to provide either constant torque, variable torque, or constant horsepower at each speed. A two-winding two-speed motor carries current in only one of its windings at each speed. Each winding may be either a wye or delta configuration. To preclude short-circuit current being induced in an unused delta winding, motor controllers used with two-winding motors having one or more delta connections are constructed to open one corner of each delta winding not in the circuit.

NOTE: When controllers are to be supplied for more than two speeds, NEMA Standards Publication MG 1-1987, para. 1-2.65, should be consulted.

Authorized Engineering Information 1-27-1988.

Motor connections for two-speed motor controllers shall be in accordance with Figures 2-321-5.1 and 2-321-5.2 for two-winding and single-winding motors, respectively.

NEMA Standard 1-27-1987.

2-321.11 COMBINATION MOTOR CONTROLLERS

.01 General

A combination motor controller shall consist of an externally operable circuit-disconnecting means and a magnetic motor controller mounted in a single enclosure. The motor controller shall include motor and branch-circuit overcurrent (overload) protection unless equivalent protection is otherwise provided. When required by the particular application, a circuit breaker (serving also as an externally operable disconnecting means) or provision for fuses shall be included for protection against overcurrent due to short circuits or ground faults.

.02 Manually Operated Disconnect Switches in Combination Motor Controllers

For a combination motor controller rated 50 horsepower or less, the switch shall be a motor-circuit switch having a horsepower rating as great as the horsepower rating of the combination motor controller at the rated voltage.

For a combination motor controller rated more than 50 horsepower, the switch need not be a motor-circuit switch, but it shall be capable of interrupting the maximum operating overload current of a motor of the same horsepower rating as that of the combination motor controller at the rated voltage.

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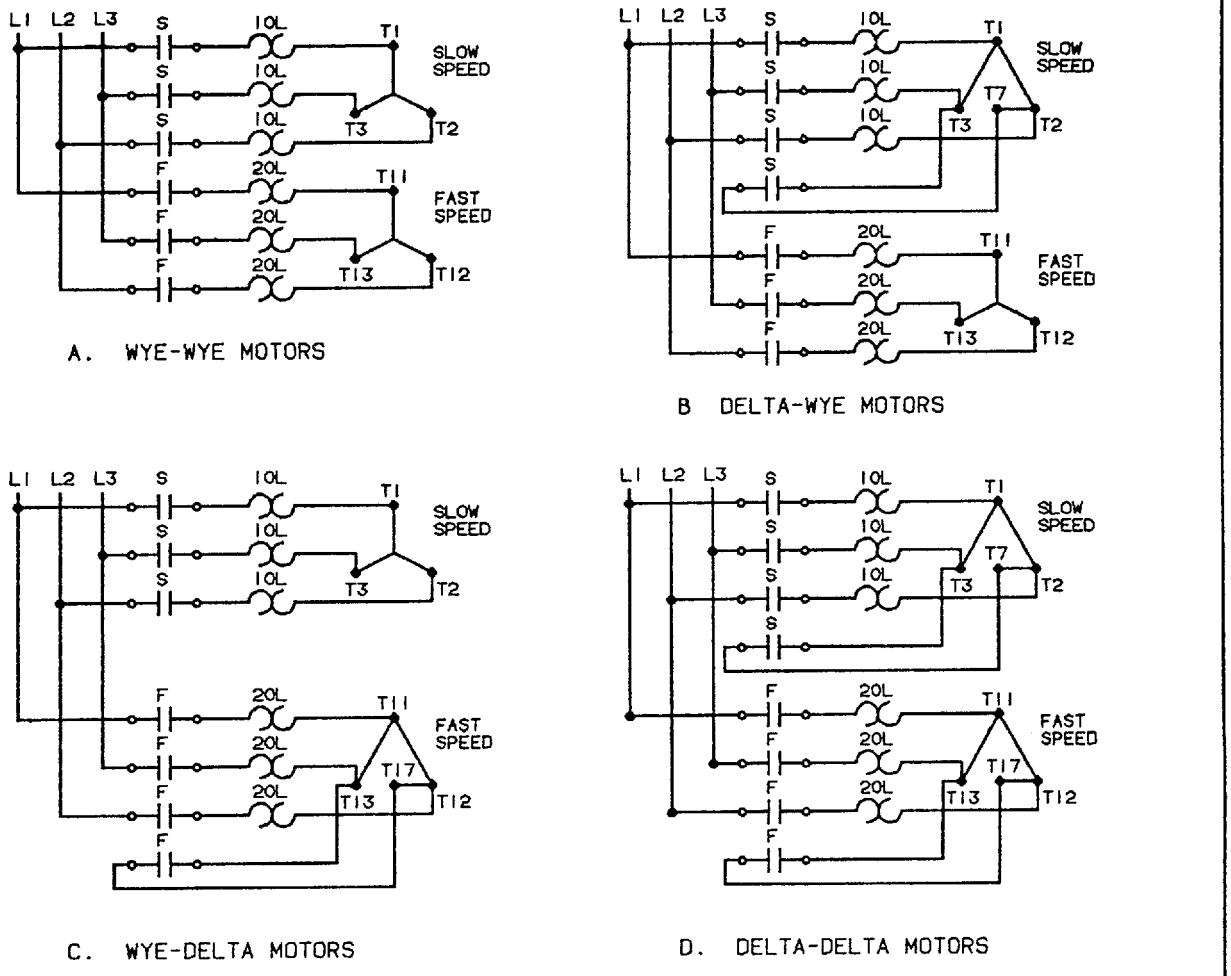


Figure 2-321-5.1
CONTROLLERS FOR TWO-WINDING TWO-SPEED MOTORS

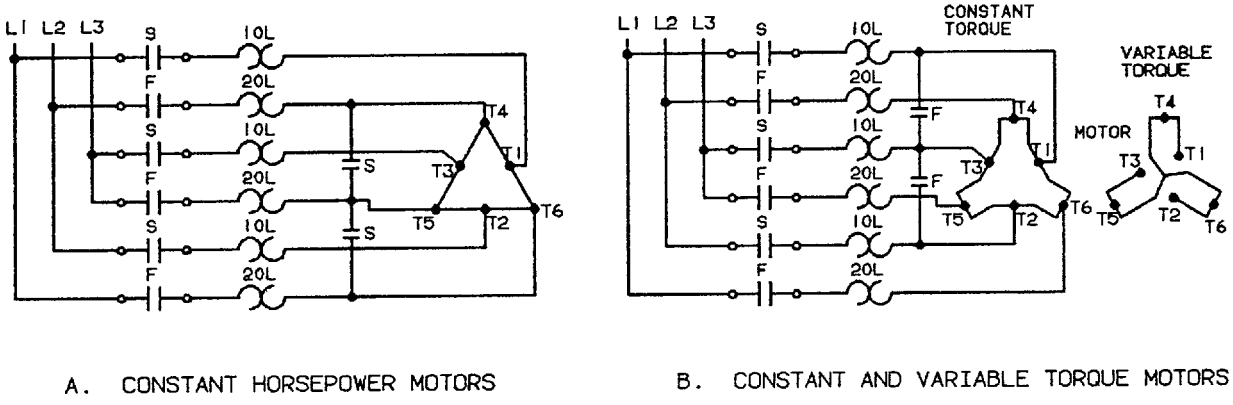


Figure 2-321-5.2
CONTROLLERS FOR SINGLE-WINDING TWO-SPEED MOTORS

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.03 Circuit Breakers in Combination Motor Controllers

Circuit breakers in combination motor controllers shall be either of the inverse-time or the instantaneous-trip magnetic type.

NEMA Standard 9-20-1978.

The combination motor controller which includes an instantaneous trip circuit breaker, is considered an integral unit and is assigned an interrupting rating by the controller manufacturer.

Authorized Engineering Information 9-20-1978.

2-321.12 TYPES OF COMBINATION MOTOR CONTROLLERS

Part ICS 2-321 applies to combination motor controllers of the following types:

a. Full-voltage, nonreversing.
b. Full-voltage, reversing.
c. Full-voltage, two-speed, two winding.
d. Full-voltage, two-speed, one winding.
e. Part winding, nonreversing.
f. Wye delta, single step, nonreversing.
g. Reduced-voltage, single step, nonreversing.

The types of combination motor controllers listed above shall be permitted to exist in single enclosures or as combination units in control centers, switchboards, bus-way plug-in devices and panelboards.

NEMA Standard 3-12-1975.

2-321.13 INTERLOCKING OF COMBINATION MOTOR CONTROLLER DOORS

Enclosures of combination motor controllers shall be equipped with a hinged door which is firmly held in place and interlocked with its associated disconnecting means so that the door cannot be opened without first opening the disconnecting means.

Means shall be provided for locking the disconnecting means in the open position when the door is closed.

When required by the particular application, a deactivating means (defeater) shall be provided to permit entry into the enclosure when the disconnecting means is closed.

NEMA Standard 1-6-1966.

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RATINGS

2-321.20 CURRENT RATINGS

.01 Continuous-current Ratings

The continuous-current ratings shown in Part ICS 2-321 represent the maximum rms current, in amperes, which the controller shall be permitted to carry continuously without exceeding the temperature rises permitted by Part 1-109 of NEMA Standards Publication No. ICS 1.

.02 Service-limit Current Ratings

The service-limit current ratings shown in Part ICS 2-321 represent the maximum rms current, in amperes, which the controller shall be permitted to carry for protracted periods in normal service. At service-limit current ratings, temperature rises shall be permitted to exceed those obtained by testing the controller at it continuous current rating. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

NEMA Standard 5-18-1964.

2-321.21 BASIS OF HORSEPOWER RATINGS

The horsepower ratings of alternating-current general-purpose controllers are based on the use of three-pole primary contactors for two- and three-phase motors and of two-pole primary contactors for single-phase motors.

NEMA Standard 6-30-1958.

2-321.22 RATINGS OF FULL-VOLTAGE SINGLE-SPEED MAGNETIC CONTROLLERS FOR NON-PLUGGING AND NONJOGGING DUTY

The ratings of full-voltage magnetic controllers for nonplugging and nonjogging, reversing and nonreversing duty shall be:

a. In accordance with Table 2-321-1 for three-phase controllers.

b. In accordance with Table 2-321-2 for single-phase controllers.

Table 2-321-1
RATINGS FOR THREE-PHASE SINGLE-SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR NONPLUGGING AND NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	Horsepower† at 60 Hertz 200 Volts	Horsepower† at 60 Hertz 230 Volts	Horsepower† at 50 Hertz 380 Volts	Horsepower† at 60 Hertz 460 or 575 Volts	Service-limit Current Rating* Amperes
00	9	1-1/2	1-1/2	1-1/2	2	11
0	18	3	3	5	5	21
1	27	7-1/2	7-1/2	10	10	32
2	45	10	15	25	25	52
3	90	25	30	50	50	104
4	135	40	50	75	100	156
5	270	75	100	150	200	311
6	540	150	200	300	400	621
7	810	...	300	...	600	932
8	1215	...	450	...	900	1400
9	2250	...	800	...	1600	2590

* See ICS 2-321.20.

† These horsepower ratings are based on the locked-rotor current ratings given in Table 2-327-1. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded. (This note is approved as Authorized Engineering Information.)

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These ratings shall be permitted to be used for occasional jogging or plugging for limited time periods, such as machine set-ups. During such limited time periods, the rate of operation shall not exceed five openings or closings per minute and shall be not more than ten in a 10-minute period.

For duties exceeding the foregoing, see ICS 2-321.23.

These controllers shall not be used with motors whose full-load current or horsepower rating exceeds the continuous current or horsepower ratings given in Tables 2-321-1 and 2-321-2. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

The horsepower ratings of two-phase four-wire and two-phase three-wire controllers shall be the same as those shown in Table 2-321-1 for three-phase controllers. Controllers used in two-phase three-wire circuits shall be applied on the basis of the average of the currents in the three legs of the two-phase circuit.

NEMA Standard 5-20-1974.

2-321.23 RATINGS OF FULL-VOLTAGE SINGLE-SPEED MAGNETIC CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE OR JOGGING DUTY

The rating of full-voltage magnetic controllers for plug-stop, plug-reverse, and jogging duty requiring repeated interruption of stalled motor current or repeated closing of high transient currents encountered in rapid motor reversal beyond that described in ICS 2-321.22, shall be:

a. In accordance with Table 2-321-3 for three-phase controllers.
b. In accordance with Table 2-321-4 for single-phase controllers.

Table 2-321-2
RATINGS FOR SINGLE-PHASE FULL-VOLTAGE MAGNETIC CONTROLLERS FOR NONPLUGGING AND NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	Single-phase Horsepower at		Service-limit Current Rating,* Amperes
		115 Volts	230 Volts	
00	9	1/3	1	11
0	18	1	2	21
1	27	2	3	32
1P	36	3	5	42
2	45	3	7-1/2	52

* See ICS 2-321.20.

Table 2-321-3
RATINGS FOR THREE-PHASE SINGLE-SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE OR JOGGING DUTY

Size of Controller	Continuous Current Rating* Amperes	Horsepower† at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 or 575 Volts	Service-limit Current Rating,* Amperes
0	18	1-1/2	1-1/2	1-1/2	2	21
1	27	3	3	5	5	32
2	45	7-1/2	10	15	15	52
3	90	15	20	30	30	104
4	135	25	30	50	60	156
5	270	60	75	125	150	311
6	540	125	150	250	300	621

* See ICS 2-321.20.

† These horsepower ratings are based on the locked-rotor current ratings given in Table 2-327-3. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded. (This note is approved as Authorized Engineering Information.)

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These controllers shall not be used with motors whose full-load current or horsepower rating exceeds the continuous current or horsepower ratings given in Tables 2-321-3 and 2-321-4. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

The horsepower ratings of two-phase four-wire and two-phase three-wire controllers shall be the same as those shown in Table 2-321-3 for three-phase controllers. Controllers used on two-phase three-wire circuits shall be applied on the basis of the average of the currents in the three legs of the two-phase circuit.

NEMA Standard 5-20-1974.

2-321.24 RATINGS OF REDUCED-VOLTAGE GENERAL-PURPOSE CONTROLLERS

Reduced-voltage general-purpose controllers include primary resistor controllers, autotransformer controllers, and reactor controllers.

NEMA Standard 5-18-1964.

The ratings of reduced-voltage general-purpose reversing or nonreversing controllers, when mounted in any type of enclosure and whether or not provided with running overcurrent (overload) protection or other auxiliary devices, shall be:

a. In accordance with Table 2-321-5 for three-phase controllers.
b. In accordance with Table 2-321-6 for single-phase controllers.

Table 2-321-4
RATINGS FOR SINGLE-PHASE SINGLE-SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR JOGGING DUTY

Size of Controller	Continuous Current Rating* Amperes	Single-phase Horsepower at 115 Volts	Single-phase Horsepower at 230 Volts	Service-limit Current Rating,* Amperes
0	18	1/2	1	21
1	27	1	2	32
1P	36	1-1/2	3	42
2	45	2	5	52

* See ICS 2-321.20.

Table 2-321-5
RATINGS FOR THREE-PHASE REDUCED-VOLTAGE MAGNETIC CONTROLLERS FOR NONPLUGGING AND NONJOGGING DUTY

Size of Controller	Continuous Current Rating* Amperes	Horsepower† at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 or 575 Volts	Service-limit Current Rating,* Amperes
1	27	7-1/2	7-1/2	10	10	32
2	45	10	15	25	25	52
3	90	25	30	50	50	104
4	135	40	50	75	100	156
5	270	75	100	150	200	311
6	540	150	200	300	400	621
7	810	...	300	...	600	932
8	1215	...	450	...	900	1400
9	2250	...	800	...	1600	2590

* See ICS 2-321.20.
† These horsepower ratings are based on the locked-rotor current ratings given in Table 2-327-4. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded. (This note is approved as Authorized Engineering Information.)

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These controllers shall not be used with motors whose full-load current or horsepower rating exceeds the continuous current or horsepower ratings given in Tables 2-321-5 and 2-321-6. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

The horsepower ratings of two-phase four-wire and two-phase three-wire controllers shall be the same as those shown in Table 2-321-5 for three-phase controllers. Controllers used on two-phase three-wire circuits shall be applied on the basis of the average of the currents in the three legs of the two-phase circuit.

The accelerating contactor of single-step two-point controllers shall be of the same size as the line contactor when the line contactor is Size 4 or smaller. When the line contactor is Size 5 or larger, an accelerating contactor of the next smaller size may be used.

Accelerating contactors for multistep controllers and for increment (network) controllers shall be selected so that the rating for each resistor step will be not less than one-sixth times the maximum rms current for that step.

For the temperature test for primary resistor controllers, see Part ICS 2-213.

For the temperature test for primary reactor and autotransformer controllers, see Part ICS 2-214.

Resistors for controllers with automatic acceleration shall be Class Number 116 except where the application requires the use of other duty resistors. See Part ICS 2-213.

NEMA Standard 5-17-1971.

2-321.25 RATINGS OF WYE-DELTA MAGNETIC CONTROLLERS

Ratings of wye-delta magnetic controllers shall be in accordance with Table 2-321-7.

NEMA Standard 9-20-1972.

Table 2-321-6
RATINGS FOR SINGLE-PHASE REDUCED-VOLTAGE GENERAL-PURPOSE REVERSING OR NONREVERSING MAGNETIC CONTROLLERS

Size of Controller	Continuous Current Rating,* Amperes	Single-phase Horsepower at 115 Volts	Single-phase Horsepower at 230 Volts	Service-limit Current Rating,* Amperes
1	27	2	3	32
2	45	3	7-1/2	52

* See ICS 2-321.20.

Table 2-321-7
RATINGS FOR WYE-DELTA MAGNETIC CONTROLLERS FOR NONPLUGGING NONJOGGING DUTY FOR EITHER OPEN- OR CLOSED-CIRCUIT TRANSITION

Size of Controller	Continuous Current Rating,* Amperes	Contactor Size 1M and 2M†	Contactor Size S or 1S	Contactor Size 2S	Three-phase Horsepower at 60 Hertz 200 Volts	Three-phase Horsepower at 60 Hertz 230 Volts	Three-phase Horsepower at 50 Hertz 380 Volts	Three-phase Horsepower at 60 Hertz 460 or 575 Volts	Service-limit Current Rating,* Amperes
1YD	47	1	1	‡	10	10	15	15	55
2YD	78	2	2	‡	20	25	40	40	90
3YD	156	3	3	‡	40	50	75	75	179
4YD	233	4	4	‡	60	75	150	150	270
5YD	467	5	4	‡	150	150	250	300	538
6YD	935	6	5	‡	300	350	500	700	1075
7YD	1400	7	6	‡	500	500	800	1000	1610
8YD	2100	8	7	‡	750	800	1000	1500	2420
9YD	3900	9	8	‡	1500	1500	2000	3000	4480

* See ICS 2-321.20.
† Each contactor 1M and 2M carries only 0.577 times the motor line current when the motor is switched to the delta (running) connections. See ICS 2-321.06.03 and Fig. 2-321-3.
‡ Contactor 2S shall be capable of interrupting the current in the transition resistor circuit.

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2-321.26 RATINGS OF PART-WINDING CONTROLLERS

Ratings for full-voltage part-winding controllers shall be in accordance with Table 2-321-8.

Ratings for reduced-voltage part-winding controllers shall be in accordance with Table 2-321-9.

NEMA Standard 7-17-1973.

Table 2-321-8
RATINGS FOR FULL VOLTAGE PART WINDING CONTROLLERS FOR NONPLUGGING, NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	Contactor Size Line† (1 M and 2M)	Three-Phase Horsepower at** 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 or 575 Volts	Service-Limit Current Rating,* Amperes
1PW	54	1	10	10	15	15	64
2PW	90	2	20	25	40	40	104
3PW	180	3	40	50	75	75	208
4PW	270	4	75	75	150	150	312
5PW	540	5	150	150	250	350	622
6PW	1080	6	...	300	500	600	1242
7PW	1620	7	...	450	800	900	1864
8PW	2430	8	...	700	...	1400	2800
9PW	4500	9	...	1300	...	2600	5180

* See ICS 2-321.20.
† Contactors 1M and 2M are each intended to carry one half of the motor running line current. See ICS 2-321.06.04 and Figure 2-321-4.
** The horsepower ratings are based on locked-rotor currents corresponding to 65 percent of the full-winding values.

Table 2-321-9
RATINGS FOR REDUCED VOLTAGE PART WINDING CONTROLLERS FOR NONPLUGGING, NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	Contactor Size Line† (1 M and 2 M)	Contactor Size Accelerating	Three-Phase Horsepower at** 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 or 575 Volts	Service-Limit Current Rating,* Amperes
1PW	54	1	1	10	10	15	15	64
2PW	90	2	2	20	25	40	40	104
3PW	180	3	3	40	50	75	75	208
4PW	270	4	4	75	75	150	150	312
5PW	540	5	4‡	150	150	250	350	622
6PW	1080	6	5‡	...	300	500	600	1242
7PW	1620	7	6‡	...	450	800	900	1864
8PW	2430	8	7‡	...	700	...	1400	2800
9PW	4500	9	8‡	...	1300	...	2600	5180

* See ICS 2-321.20.
† Contactors 1M and 2M are each intended to carry one half of the motor running line current. See ICS 2-321.06.04 and Figure 2-321-4.
‡ The use of one size smaller accelerating contactor on sizes 5PW and larger is suitable when the contactor is shunted by its associated line contactor. (This sentence is approved as Authorized Engineering Information.)
** The horsepower ratings are based on locked-rotor currents corresponding to 65 percent of the full-winding values.

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2-321.27 RATINGS OF THREE-PHASE MULTISPEED CONTROLLERS FOR NONPLUGGING AND NON-JOGGING DUTY

.01 For Constant-torque and Variable-torque Motors (Two, Three and Four Speeds)

The ratings of controllers for nonplugging and nonjogging duty shall be in accordance with Table 2-321-10. These controllers shall not be used with motors whose full-load current or horsepower ratings exceed the continuous current or horsepower ratings given in Table 2-321-10. The current rating of overcurrent overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

.02 For Constant-horsepower Motors (Two, Three and Four Speeds)

The ratings of controllers for nonplugging and nonjogging, reversing and nonreversing duty, requiring five or less openings per minute, when mounted in any type of enclosure and whether or not provided with running overcurrent (overload) protection or other auxiliary devices, shall be in accordance with Table 2-321-11.

NEMA Standard 5-17-1971.

2-321.28 RATINGS OF THREE-PHASE CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE OR JOGGING DUTY

The ratings of controllers for constant-torque, variable-torque and constant-horsepower motors for plug-stop, plug-reverse or jogging duty shall be in accordance with ICS 2-321.23 and Table 2-321-3.

NEMA Standard 5-18-1964.

Table 2-321-10
RATINGS FOR THREE-PHASE MULTISPEED MAGNETIC CONTROLLERS FOR NONPLUGGING AND NONJOGGING DUTY FOR CONSTANT-TORQUE AND VARIABLE-TORQUE MOTORS (TWO, THREE AND FOUR SPEED)

Size of Controller	Continuous Current Rating,* Amperes	Horsepower† at 60 Hertz 200 Volts	Horsepower† at 60 Hertz 230 Volts	Horsepower† at 50 Hertz 380 Volts	Horsepower† at 60 Hertz 460 or 575 Volts	Service-limit Current Rating,* Amperes
0	18	3	3	5	5	21
1	27	7-1/2	7-1/2	10	10	32
2	45	10	15	25	25	52
3	90	25	30	50	50	104
4	135	40	50	75	100	156
5	270	75	100	150	200	311
6	540	150	200	300	400	621
7	810	...	300	...	600	932
8	1215	...	450	...	900	1400
9	2250	...	800	...	1600	2590

* See ICS 2-321.20.

† These horsepower ratings are based on the locked-rotor current ratings given in Table 2-327-1. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded. (This note is approved as Authorized Engineering Information.)

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2-321.29 RATINGS OF PRIMARY CONTACTORS OF MAGNETIC WOUND-ROTOR CONTROLLERS FOR REVERSING AND NON-REVERSING DUTY

The ratings of primary contactors of wound-rotor motor controllers for reversing and nonreversing duty, when mounted in any type of enclosure and whether or not provided with running overcurrent (overload) protection or other auxiliary devices, shall be as shown in Table 2-321-12.

These controllers shall not be used with motors whose full-load current or horsepower rating exceeds the continuous current or horsepower rating given in Table 2-321-12. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

The horsepower ratings of two-phase four-wire and two-phase three-wire controllers shall be the same as those shown in Table 2-321-12. Controllers used on two-phase three-wire circuits shall be applied on the basis of the average of the currents in the three legs of the two-phase circuit.

NEMA Standard 5-18-1964.

Table 2-321-11
RATINGS FOR THREE-PHASE MULTISPEED MAGNETIC CONTROLLERS FOR NONPLUGGING AND NONJOGGING DUTY FOR CONSTANT-HORSEPOWER MOTORS (TWO, THREE AND FOUR SPEED)

Size of Controller	Continuous Current Rating,* Amperes	Horsepower† at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 or 575 Volts	Service-limit Current Rating,* Amperes
0	18	2	2	3	3	21
1	27	5	5	7-1/2	7-1/2	32
2	45	7-1/2	10	20	20	52
3	90	20	25	40	40	104
4	135	30	40	60	75	156
5	270	60	75	100	150	311
6	540	100	150	200	300	621
7	810	...	225	...	450	932
8	1215	...	350	...	700	1400
9	2250	...	600	...	1200	2590

* See ICS 2-321.20.

† These horsepower ratings are based on the locked-rotor current ratings given in Table 2-327-1. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded. (This note is approved as Authorized Engineering Information.)

Table 2-321-12
RATINGS FOR PRIMARY CONTACTORS OF MAGNETIC WOUND-ROTOR MOTOR CONTROLLERS FOR REVERSING AND NONREVERSING DUTY

Controller Size	Continuous Current Rating,* Amperes	Three-phase Horsepower at 115 Volts	230 Volts	460 or 575 Volts	Service-limit Current Rating,* Amperes
1	27	3	7-1/2	10	32
2	45	...	15	25	52
3	90	...	30	50	104
4	135	...	50	100	156
5	270	...	100	200	311
6	540	...	200	400	621
7	810	...	300	600	932
8	1215	...	450	900	1400
9	2250	...	800	1600	2590

* See ICS 2-321.20.

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2-321.30 SERVICE CLASSIFICATION OF RESISTORS FOR SECONDARY CIRCUITS

Resistors for controllers with automatic acceleration shall be Class No. 135 or 136 except where the application requires the use of other duty resistors. See Part ICS 2-213.

NEMA Standard 5-18-1964.

2-321.31 ACCELERATING (SECONDARY) CONTACTORS OF MAGNETIC WOUND-ROTOR MOTOR CONTROLLERS FOR REVERSING AND NONREVERSING DUTY

For nonplugging reversing and nonreversing service, wound-rotor induction motor controllers shall be provided with the minimum number of accelerating contactors shown in Table 2-321-13.

When a controller is used for reversing plugging service, one plugging contactor shall be added to the number of contactors required for acceleration.

The intermediate accelerating contactors and plugging contactors, when required for automatically accelerating contactors, shall be so selected that the rating will be not less than one-sixth times the maximum rms accelerating current for that step.

The final accelerating contactor shall be so selected that the continuous rating will be not less than the motor rated secondary current.

When a three-pole accelerating contactor is connected in closed delta, its current rating shall be 150 percent of the current rating of the corresponding two-pole contactor connected in open delta.

NEMA Standard 5-18-1964.

2-321.32 RATINGS OF COMBINATION MOTOR CONTROLLERS

.01 Voltage Rating

The voltage ratings of combination motor controllers shall be in accordance with Part 1-112 of NEMA Standards Publication No. ICS 1.

.02 Range of Operating Voltage

The range of operating voltage of combination motor controllers shall be in accordance with Part ICS 2-110.

.03 Magnetic Motor Controllers

The ratings of magnetic motor controllers used in combination motor controllers shall be in accordance with Part ICS 2-321.

NEMA Standard 9-20-1972.

2-321.33 SHORT CIRCUIT CURRENT RATING OF COMBINATION AND NON-COMBINATION MOTOR CONTROLLERS

Class A combination controllers and non-combination controllers (with a specified short circuit protection device) shall have one or more short circuit current ratings expressed in maximum available fault current (RMS Symmetrical Amperes) at the specified power factor (X/R ratio) as given in UL 508 and the rated system voltage. Short circuit current values are shown in Table 2-321-14.

NEMA Standard 11-20-1986.

Table 2-321-13
ACCELERATING CONTACTORS FOR WOUND-ROTOR MOTOR CONTROLLERS

Horsepower Rating	Minimum Number of Accelerating Contactors
15	1
75	2
150	3
300	4
600	5
1200	6

Table 2-321-14
SHORT CIRCUIT CURRENT RATING
(RMS Symmetrical Amperes)

1,000	18,000	42,000	100,000
5,000	22,000	50,000	125,000
7,500	25,000	65,000	150,000
10,000	30,000	85,000	200,000
14,000	35,000		

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DESIGN TESTS AND PERFORMANCE

2-321.40 GENERAL

Class A controllers shall meet the applicable test and performance requirements of Part ICS 2-110.

NEMA Standard 1-17-1974.

2-321.41 SHORT-TIME OPERATING CAPABILITY

.01 A new Class A controller with overload relay(s) shall be capable of meeting the requirements of ICS 2-110.42 at 6.4 times the current rating of its highest rated overload relay for the time necessary for its overload relay to trip.

NEMA Standard 5-25-1988.

6.4 x current rating corresponds to 8 x MFLC for a service factor 1.15 motor protected at 125 percent.

Authorized Engineering Information 5-25-1988.

.02 A new Class A Controller without overload relays shall be capable of meeting the requirements of ICS 2-110.42 at 8 x the current corresponding to the horsepower rating of the contactor for 20 seconds.

NEMA Standard 5-25-1988.

2-321.42 PERFORMANCE TESTS

Motor controllers shall be evaluated in accordance with Underwriters Laboratories Inc. Publication No. UL 508.

NEMA Standard 11-17-1988.

2-321.43 DESIGN TEST FOR SHORT-CIRCUIT CURRENT RATINGS FOR NON-COMBINATION CONTROLLERS

Selected noncombination motor controllers and combination motor controllers which do not include short-circuit protection shall be tested to verify their ability to withstand short circuits. The short-circuit protective devices shall be selected in accordance with the *National Electrical Code* or the limitations marked on the controller by the manufacturer.

Non-combination motor controllers shall be evaluated and marked in accordance with UL 508.

NEMA Standard 11-20-1986.

A manufacturer may determine that his designs meet the standard performance criteria by test or by a combination of test and calculation or interpolation.

Authorized Engineering Information 5-12-1975.

2-321.44 DESIGN TEST FOR SHORT-CIRCUIT CURRENT RATINGS FOR COMBINATION CONTROLLERS

Selected combination motor controllers which include short-circuit protection shall be tested to verify the ability of the overcurrent devices and other components which may be involved, such as disconnect devices (including operating mechanisms), starters, wiring and enclosures, to withstand short circuits.

Combination motor controllers shall be evaluated in accordance with Underwriters Laboratories Inc. Publication No. UL 508.

NEMA Standard 11-20-1986.

A manufacturer may determine that his designs meet the standard performance criteria by test or by a combination of test and calculation or interpolation.

Authorized Engineering Information 3-12-1975.

2-321.45 SHORT-TIME SURGE CAPABILITY

.01 A new Class A controller with overload relay(s) shall be capable of meeting the requirements of ICS 2-110.42 at 12 x the current rating of its highest rated overload relay for 1 second or for the time necessary for its overload relay to trip, whichever is shorter.

NEMA Standard 5-25-1988.

12 x current rating corresponds to 15 x MFLC for a service factor 1.15 motor, protected at 125 percent.

Authorized Engineering Information 5-25-1988.

For convenience of testing, the duration of the surge capability test shall be permitted to be shortened (to not less than 0.9 seconds) in order to suit the available test current provided that the value of the I^2t (Joule Integral) is maintained.

.02 A new Class A controller without overload relays shall be capable of meeting the requirements of ICS 2-110.42 at 15 x rated continuous current for 1 second.

For convenience of testing, the duration of the surge capability shall be permitted to be shortened (to not less than 0.9 seconds) in order to suit the available value of the test current provided that the value of the I^2t (Joule Integral) is maintained.

NEMA Standard 5-25-1988.

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MANUFACTURING

2-321.60 WIRING AND CONNECTIONS FOR FULL-VOLTAGE SINGLE-SPEED MAGNETIC CONTROLLERS

All controllers rated 600 volts or less shall be marked and wired in accordance with Table 2-321-15, where applicable.

The sequence of line and load terminal markings shall be L1, L2, L3, L4 and T1, T2, T3, T4, reading from left to right when looking at the front of the controller. If the leads come in to the left or right of the controller, then the sequence of lead numbering shall be the same as if the controller were rotated to these positions.

When a stop button is assembled with the controller, it may actuate the contacts of the overload relays.

When the control circuit on an alternating-current controller which is provided with a stepdown transformer for the control circuit power requires an overcurrent protective device, it shall be protected in accordance with Figure 2-321-6.

NEMA Standard 1-11-1984.

Table 2-321-15
CONTROL AND POWER CONNECTIONS

		One Phase	Two Phase Four Wire	Three Phase
Line terminal markings on controller		L1, L2	L1, L3 Phase 1: L2, L4 Phase 2	L1, L2, L3
Ground when used		L1 is always	...	L2
For reversing, interchange lines		...	L1, L3	L1, L3
Motor running overcurrent units in	1 element devices	L1	...	...
	2 element devices	...	...*	...
	3 element devices	...	...	L1, L2, L3
Control circuit		L1, L2	L1, L3	L1, L2

* For three pole contactors used, refer to Figure 2-321-7.

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When a three-phase three-pole nonreversing full-voltage controller is used on a two-phase three-wire or two-phase four-wire application, Figure 2-321-7 or a suitable note, or a combination of both, should be used as a guide in making connections.

Control circuit contacts, such as those of pushbuttons, master switches, relays and interlocks, shall be connected between L1 and associated coils. Exceptions include circuits controlled by double-pole contacts opening both sides of a circuit, motor running overcurrent device contacts, and electrical interlocks whose circuit wiring between coils and L2 does not extend beyond the controller enclosure.

Authorized Engineering Information 5-18-1964.

When terminals are provided for external START-STOP pushbutton switches for nonreversing controllers, the controller terminals shall be marked 1, 2 and 3 as indicated in Figure 2-321-8.

Control circuit markings for reversing controllers shall be 1, 2, 3, 4, 5, 6 and 7 and in accordance with Figure 2-321-9.

NEMA Standard 5-17-1971.

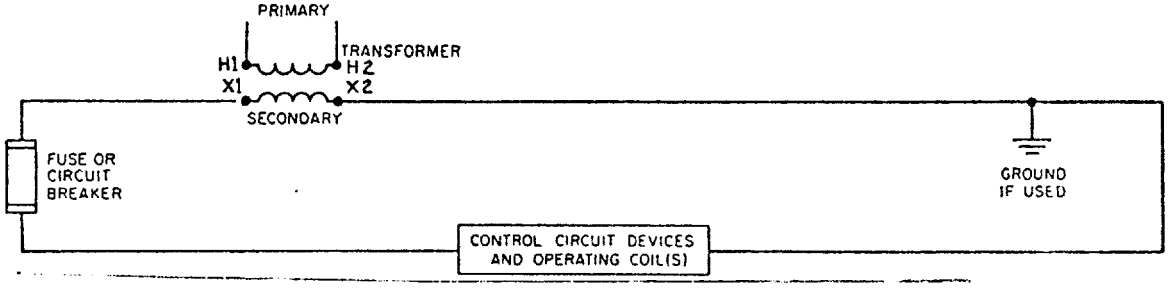
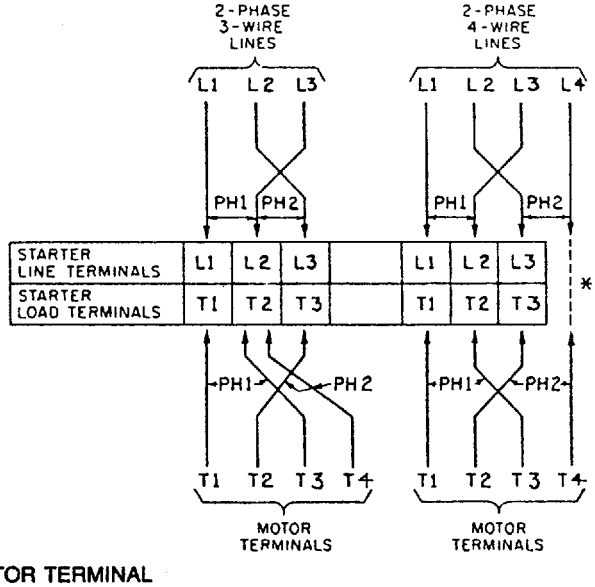


Fig. 2-321-6
CONTROL CIRCUIT OVERCURRENT PROTECTION



* LINE LEAD GOES
DIRECTLY TO MOTOR TERMINAL

Fig. 2-321-7
THREE-PHASE CONTROLLERS FOR TWO-PHASE APPLICATIONS

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2-321.61 TERMINAL MARKINGS FOR PART-WINDING MAGNETIC CONTROLLERS

.01 Controllers With Three-pole Contactors

For controllers having three-pole contactors, the controller terminal markings shall be as follows:

a. For the section of the motor winding first connected to the supply lines—T, T2, T3.

b. For the other section of the motor winding—T7, T8, T9.

.02 Controllers With a Four-pole and Two-pole Contactor

For controllers having a four-pole contactor and a two-pole contactor, the controller terminal markings shall be as follows:

a. For the section of the motor winding first connected to the supply lines—A, B, C, D.

b. For the other section of the motor winding—E, F.

NEMA Standard 7-15-1970.

2-321.62 LOCATION OF OVERLOAD RELAY CONTACTS IN CIRCUIT

The contacts of overload relays are located as shown in Figures 2-321-8 and 2-321-9 so as to minimize the exposure of these contacts to fault currents which might weld them closed. Since these contacts are normally closed, a welded condition may remain undetected and result in the loss of running overcurrent protection. In the case of reversing and other multiple contactor controllers, a single overload relay should be used to sense the state of the motor, regardless of the direction or rotation or the duty cycle.

Analysis of Figure 2-321-9 reveals that the overload relay contacts can perform their function for both directions of rotation only if they are located as shown or connected on either side of the STOP button. However, if the overload relay contacts are located on either side of the STOP button, they may be exposed to a ground fault current in the remote control station wiring.

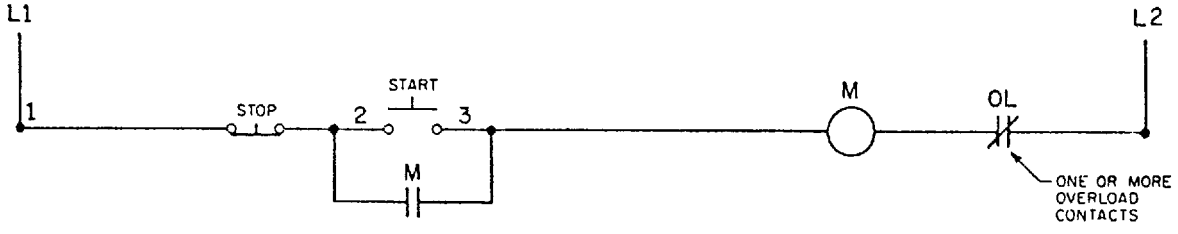
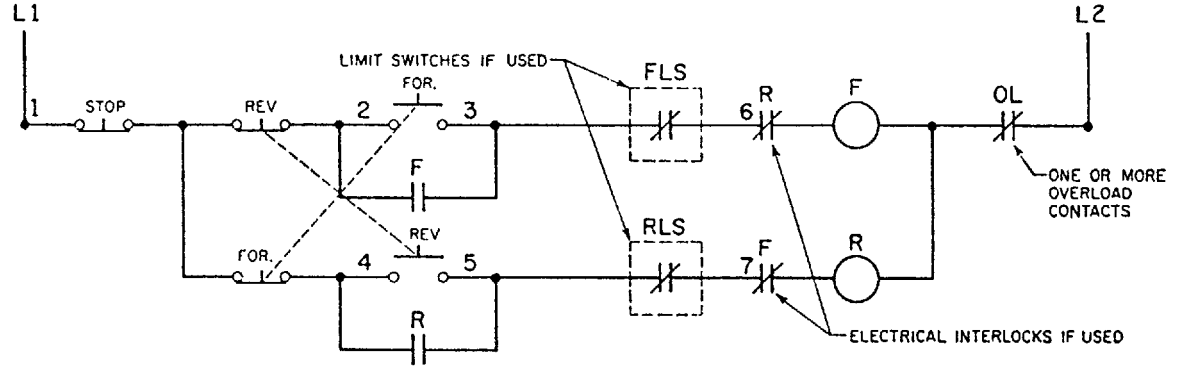


Fig. 2-321-8
CONTROL CIRCUIT TERMINAL MARKINGS FOR NONREVERSING CONTROLLERS



If normally closed pushbutton contacts are omitted and wires 2 and 4 are common, the common connection shall be marked 2. If the controller is not intended for limit-switch connection, numbers 6 and 7 may be omitted.

Fig. 2-321-9
CONTROL CIRCUIT TERMINAL MARKINGS FOR REVERSING CONTROLLERS

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9009279 0000621 T29

The foregoing applies to the control circuit shown in Figure 2-321-8 except that another location, to the left of the coil, is available. In this location, the risk of welding contacts is present when L2 is grounded, as it often is, and a short circuit occurs between the coil winding and grounded parts of the controller, which may be the case when a coil burns out.

Authorized Engineering Information 1-5-1977.

2-321.63 CONTROL CIRCUIT TERMINAL MARKINGS FOR TWO-SPEED MAGNETIC CONTROLLERS

Magnetic controllers for two-speed motors shall have control circuit terminals marked in accordance with Figure 2-321-10.

NEMA Standard 1-27-1988.

APPLICATION

2-321.80 SELECTION OF SHORT-CIRCUIIT AND GROUND-FAULT OVER-CURRENT PROTECTION FOR MOTOR BRANCH CIRCUITS

.01 For Other than Part Winding Start Motors

(Under consideration.)

.02 For Part Winding Start Motors

When selecting branch-circuit overcurrent protection, it is recommended that one of the following alternatives be followed:

a. Use a branch-circuit overcurrent device having a setting or rating not more than 200 percent of the total rated full-load current of the motor, or

b. Use a separate branch-circuit overcurrent device of the appropriate rating for each motor winding.

Authorized Engineering Information 5-18-1964.

2-321.81 EFFECTS OF CAPACITORS ON CONTROLLER APPLICATIONS

When capacitors are connected directly across the terminals of an alternating-current motor on the load side of the motor overcurrent device, the controllers shall be applied in accordance with this standard. See Part ICS 2-210.

Because of the resulting reductions in the current passing through the controller, the rating of the motor overcurrent device shall be reduced to assure adequate motor overload protection.

The motor manufacturer should be consulted as to the maximum permissible size of the capacitor and the proper rating of the motor overcurrent protective device. (This sentence has been approved as Authorized Engineering Information.)

The rating of such capacitors shall not exceed the value required to raise the no-load power factor of the motor to unity. Capacitors of these maximum ratings usually result in a full-load power factor of 95 to 98 percent.

NEMA Standard 5-18-1964.

2-321.82 SELECTION OF PUSHBUTTONS FOR USE WITH MAGNETIC CONTROLLERS

See Part ICS 2-216.

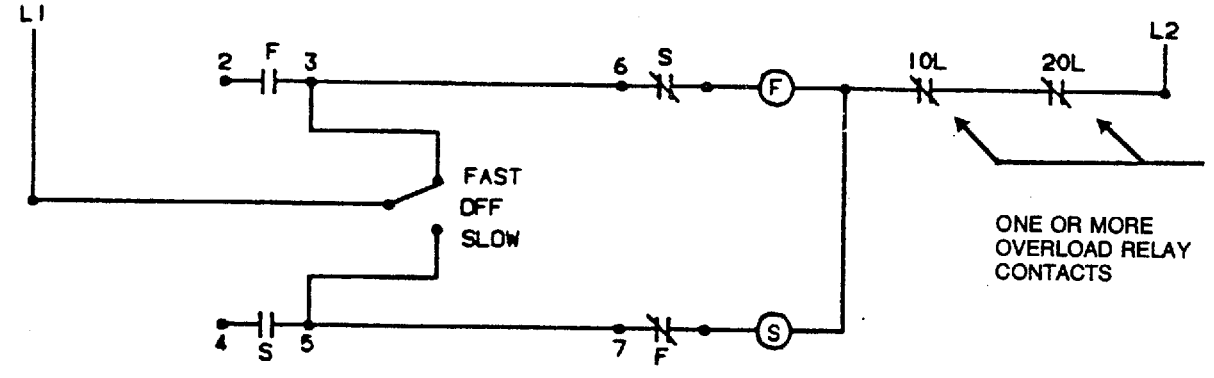
2-321.100 PREVENTIVE MAINTENANCE GUIDE

See Part ICS 1-115, of NEMA Standards Publication ICS 1, for general maintenance instructions.

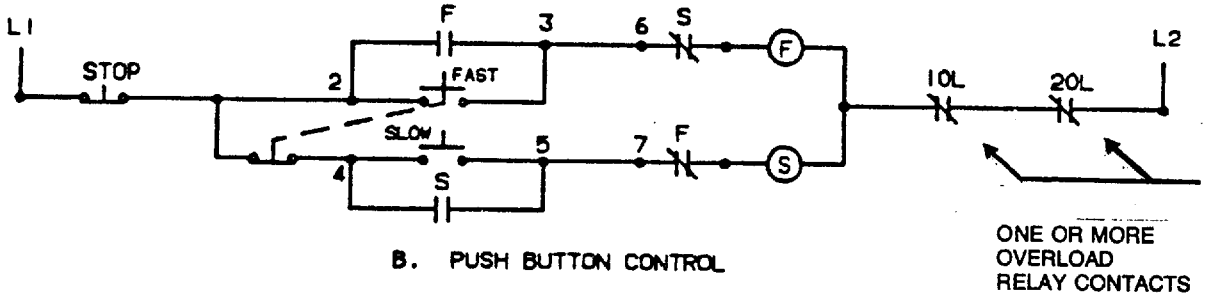
Authorized Engineering Information 5-25-1988.

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A. SELECTOR SWITCH CONTROL



B. PUSH BUTTON CONTROL

CONTACTORS "F" & "S" ARE MECHANICALLY INTERLOCKED

Figure 2-321-10
CONTROL CIRCUIT TERMINAL MARKINGS
FOR TWO-SPEED CONTROLLERS

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Part ICS 2-322

AC MOTOR CONTROL CENTERS

Part ICS 2-322 covers three-phase alternating current 50 and 60 hertz motor control centers rated 600 volts and less. Part ICS 2-110 applies to this part unless otherwise specified.

DEFINITIONS

2-322.01 DEFINITIONS

MOTOR CONTROL CENTER

A floor-mounted assembly of one or more enclosed vertical sections having a horizontal common power bus and principally containing combination motor control units. These units are mounted one above the other in the vertical sections. The sections normally incorporate vertical buses connected to the common power bus, thus extending the common power supply to the individual units. Power may be supplied to the individual units by bus bar connections, by stab connection, or by suitable wiring.

NEMA Standard 3-6-1985.

COMBINATION MOTOR CONTROL UNIT

A control unit that includes an externally operable circuit disconnecting means, motor branch-circuit overcurrent protection and a magnetic motor controller with associated auxiliary devices when used. The disconnecting means and motor branch-circuit overcurrent protection consists of a fusible disconnecting device or circuit breaker. If the latter is used, it is either an inverse time (thermal-magnetic or dual magnetic) or an instantaneous magnetic type circuit breaker. The motor controller shall include motor overload protection unless equivalent protection is otherwise provided.

Two sets of externally operable circuit disconnecting means, each with branch circuit overcurrent protection and magnetic motor controller, may be mounted in a single compartment to form a dual unit.

NEMA Standard 3-6-1985.

FEEDER TAP UNIT

A unit that includes an externally operable circuit disconnecting means and branch-circuit overcurrent protection, principally used for non-motor loads.

Two sets of externally operable circuit means, each with branch-circuit overcurrent protection, may be mounted in a single compartment to form a dual unit.

NEMA Standard 3-6-1985.

FUTURE UNIT SPACE

Unit space specified and equipped to accept a future unit.

NEMA Standard 3-6-1985.

BLANK UNIT SPACE

Unit space not equipped to accept a future unit.

NEMA Standard 3-6-1985.

UNUSABLE UNIT SPACE

Unit space not suitable to accept a future unit.

NEMA Standard 3-6-1985.

STANDARD DRAWINGS

Arrangement drawings and wiring diagrams prepared using manufacturer's standard drawing sizes, device symbols, and identification and numbering designation.

NEMA Standard 3-6-1985.

CUSTOM DRAWINGS

Manufacturer's drawings made to meet user custom requirements.

NEMA Standard 3-6-1985.

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GENERAL INFORMATION AND FEATURES

Motor control centers are provided as either Class I or Class II assemblies. Motor control centers are factory wired as either type A, B, or C.

Authorized Engineering Information 3-6-1985.

2-322.08 CLASSES OF MOTOR CONTROL CENTERS

Motor control centers shall be provided as either Class I or Class II assemblies. With either class the user may specify the physical arrangement of units within the motor control center subject to the design parameters of the manufacturer.

Equipment described in paragraphs 2-322.08.01 and 2-322.08.02 shall be supplied with the manufacturer's standard drawings and shall be designated as Class I or Class II, as selected by the user.

Equipment described in paragraph 2-322.08.03 shall be supplied with the manufacturer's custom drawings and shall be designated as Class I-S or Class II-S, as selected by the user.

.01 Class I – Independent Units

Class I motor control centers shall consist of mechanical groupings of combination motor control units, feeder tap units, other units and electrical devices arranged in a convenient assembly. The manufacturer shall furnish drawings that include:

a. Overall dimensions of the motor control center, identification of units and their location in the motor control center, locations of incoming line terminals, mounting dimensions, available conduit entrance areas, and the location of the master terminal board if required (Type C wiring only), and
b. Manufacturer's standard diagrams for individual units, and master terminal boards (Type C wiring only), consisting of a drawing(s) that:
    1. Identifies electrical devices,
    2. Indicates electrical connections, and
    3. Indicates terminal numbering designations.

NOTE – When a combination schematic and/or writing diagram for a unit(s) is supplied showing optional devices, the manufacturer shall provide information to indicate which devices are actually furnished.

.02 Class II – Interconnected Units

Class II motor control centers shall be the same as Class I motor centers with the addition of manufacturer furnished electrical interlocking and wiring between units as specifically described in overall control system diagrams supplied by the purchaser.

In addition to the drawings furnished for Class I motor control centers, the manufacturer shall furnish drawings that indicate factory interconnections within the motor control center.

NEMA Standard 3-6-1985.

.03 Class I-S & II-S – Motor Control Centers With Custom Drawing Requirements

Class I-S and II-S motor control centers shall be the same as Class I and II motor control centers except custom drawings shall be provided in lieu of standard drawings as specified by the user.

Examples of custom drawings are:

Special identifications for electrical devices,
Special terminal numbering designations, and
Special sizes of drawings.

The drawings supplied by the manufacturer shall convey the same information as drawings provided with Class I and II motor control centers, additionally modified as specified by the user.

NEMA Standard 3-6-1985.

2-322.09 CIRCUIT WIRING

All circuit components within each unit shall be factory wired.

NEMA Standard 3-6-1985.

2-322.10 TYPES OF WIRING

.01 Type A

User field wiring shall connect directly to device terminals internal to the unit and shall be provided only on Class I motor control centers.

NEMA Standard 3-6-1985.

.02 Type B

a. Type B user field load wiring for combination motor control units size 3 or smaller shall be designated as B-D or B-T, according to the following:

    B-D connects directly to the device terminals, which are located immediately adjacent, and readily accessible, to the vertical wireway;

    B-T connects directly to a load terminal block in, or adjacent to, the unit.

    NEMA Standard 3-6-1985.

b. Type B user field load wiring for combination motor control units larger than size 3, and for feeder tap units, shall connect directly to unit device terminals.

    NEMA Standard 3-6-1985.

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c. Type B user field control wiring shall connect directly to unit terminal block(s) located in or adjacent to each combination motor control unit.

NEMA Standard 3-6-1985.

.03 TYPE C

User field control wiring shall connect directly to master terminal blocks mounted at the top or bottom of those vertical sections that contain combination motor control units or control assemblies. Combination motor control units and control assemblies shall be factory wired to their master terminal blocks.

User field load wiring for combination motor control units size 3 or smaller shall connect directly to master terminal blocks mounted at the top or bottom of vertical sections. Motor control unit load wiring shall be factory wired to the master terminal blocks.

User field load wiring for combination motor control units larger than size 3, and for feeder tap units, shall connect directly to unit device terminals.

NEMA Standard 3-6-1985.

RATINGS

2-322.20 VOLTAGE RATING

The control-center voltage rating shall be in accordance with Part 1-112 of NEMA Standard Publication No. ICS 1. The rated voltage is the voltage to which the performance characteristics of control centers are related.

NEMA Standard 7-16-1969.

2-322.21 COMBINATION MOTOR CONTROL UNIT RATINGS

The ratings of magnetic motor controllers of the combination motor control units shall be in accordance with Parts ICS 2-321 and 2-327.

NEMA Standard 7-16-1969.

2-322.22 CONTINUOUS-CURRENT RATINGS OF BUSES

The horizontal common power bus shall have a continuous-current rating of 600, 800, 1000, 1200 amperes or higher as required by a particular application. Vertical bus extensions installed in a section shall have a minimum continuous-current rating of 300 amperes.

NEMA Standard 7-16-1969.

2-322.23 BASIS FOR SHORT-CIRCUIT CURRENT RATING OF MOTOR CONTROL CENTERS

.01 Available Short-Circuit Current

The available short-circuit current is the short-circuit current available at the motor control center line terminals plus motor contribuion. The available short-circuit current shall be in RMS symmetrical amperes.

NEMA Standard 7-22-1987.

.02 Short-Circuit Current Rating

Unless a current limiting means is used in a series combination (as defined in ICS 2-322.23.03) with a motor control center, the short-circuit current rating shall be the lowest of the following:

1. The short-circuit current rating of the bus structure, or
2. The lowest short-circuit current rating of any installed combination motor control unit, or
3. The short-circuit current rating of any installed feeder tap unit.

NEMA Standard 7-22-1987.

.03 Series Combination Rating

A series combination short-circuit current rating is the higher rating obtained by adding an internal or external current limiting means in series with a lower rated motor control center.

Examples of current limiting means include:

Current Limiting Circuit Breakers,
Current Limiting Fuses, and
Current Limiting Reactors.

The series combination rating shall not exceed the rating of the current limiting device and shall be selected from Table 2-322-1.

NEMA Standard 7-22-1987.

For motor control centers with ratings over 100,000 amperes, a current limiting means limiting the current to 100,000 amperes or below is recommended.

Authorized Engineering Information 1-5-1977.

2-322.24 STANDARD SHORT-CIRCUIT RATINGS OF MOTOR CONTROL CENTERS

.01 Combination Motor Control Unit and Feeder Tap Unit

The combination motor control unit and feeder tap unit of a motor control center shall have a short-circuit current rating. The rating shall be selected from Table 2-322-1.

A combination motor control center shall be permitted to have a short-circuit rating greater than the short-circuit current rating of any individual component as determined by design tests.

NEMA Standard 7-22-1987.

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.02 Bus Structure

The bus structure (horizontal and vertical bus) of a motor control cent shall have a short-circuit current rating. The rating shall be selected from Table 2-322-2.

All short-circuit current ratings shall be based upon the test procedures, performance, and criteria described in ICS 2-322.40, 2-322.41, and 2-322.42.

NEMA Standard 7-22-1987.

DESIGN AND PERFORMANCE

2-322.40 DESIGN TEST CONCEPT

Design tests are those tests made to determine the adequacy of the design of a particular type, style, or model of motor control center to meet its assigned ratings and to operate satisfactorily under normal service application conditions or under special conditions, if specified. Design tests are made only on representative motor control centers to substantiate the ratings assigned and are not contemplated in normal production.

All design tests shall be made by the manufacturer using a three-phase power supply for the tests specified in ICS 2-322.41 and 2-322.42.

NEMA Standard 7-16-1986.

2.322.41 HORIZONTAL COMMON POWER BUS AND VERTICAL BUS EXTENSION – SHORT-CIRCUIT WITHSTAND TESTS

.01 Tests

Short circuit current tests shall be conducted according to the requirements of Underwriters Laboratories Inc., Publication No. UL 845, *Standard for Motor Control Centers,* on both the horizontal bus structure and vertical bus structure.

Each motor control center section shall have a short circuit current rating expressed in RMS symmetrical amperes maximum.

NEMA Standard 7-22-1987.

Table 2-322-1
SHORT-CIRCUIT CURRENT RATING

RMS Symmetrical Amperes		
5000	25,000	65,000
7500	30,000	85,000
10,000	35,000	100,000
14,000	42,000	
18,000	50,000	
22,000		

Table 2-322-2
BUS STRUCTURE SHORT-CIRCUIT CURRENT RATINGS

RMS Symmetrical Amperes	
22,000	65,000
25,000	85,000
42,000	100,000
50,000	

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.02 Performance Criteria

The performance shall be acceptable if the motor control center complies with the requirements in UL 845.

NEMA Standard 7-22-1987.

Criteria for performance may be summarized as follows.

a. There is no permanent dislocation of the bus bars or cable that would affect the normal functioning of the assembly.
b. There is no distortion of the vertical buses that would impair normal insertion of the unit.
c. There is no cracking or breaking of an insulating base that would impair the support of live parts.
d. The ground fuse is not opened.
e. There is no damage due to arcing.
f. Stab-in assemblies (if used) and vertical buses at the point of contact are in essentially the same mechanical and electrical condition as before the test.
g. The enclosure or a part of the enclosure has not been damaged or displaced to the extent that a live part is accessible.
h. There is no dielectric breakdown between live parts of opposite polarity and between live parts and the enclosure.

Authorized Engineering Information 7-22-1987.

2-322.42 COMBINATION MOTOR CONTROL UNIT AND FEEDER TAP UNIT—SHORT-CIRCUIT INTERRUPTING TESTS

.01 Test

Short circuit current tests shall be conducted to verify the compatibility of the overcurrent devices and other involved components such as stab-in unit, lein-side wiring, enclosure, door or cover and load side terminals. The short circuit tests shall be conducted according to the requirements of Underwriters Laboratories Inc., Publication No. UL 845, *Standard for Motor Control Centers.*

Each combination motor control center unit and each feeder tap unit shall have a maximum short circuit current rating expressed in RMS symmetrical amperes.

.02 Performance Criteria

The performance shall be acceptable if the combination motor control unit or feeder tap unit complies with the requirements of UL 845.

NEMA Standard 7-22-1987.

Criteria for performance may be summarized as follows.

a. There is no dielectric breakdown at the unit disconnect and the fault current is interrupted by the branch circuit protective device.
b. There is no discharge of parts outside the unit.
c. There is no damage to a conductor or terminal connector and the conductor has not pulled out of the terminal connector.
d. The unit door or cover has not blown open and the operating mechanism for the disconnect and the door interlocks shall permit the opening of the door.
e. The disconnecting means is capable of being opened manually with normal operation of the operating handle.
f. Stab-in assemblies (if used) and vertical buses at the point of contact are in essentially the same mechanical and electrical condition as before the test.

Authorized Engineering Information 7-22-1987.

.03 Location of Units

Units shall be tested while installed in a motor control center section in a location as close as practicable to the motor control center incoming line terminals.

.04 Unit Fault Connection

The fault connection shall be made at the load terminals of the unit. It shall consist of three insulated conductors, each not more than 4 feet long and with a current-carrying capacity appropriate for the maximum horsepower or maximum current rating of the unit.

.05 Enclosure Ground Test Circuit

The motor control center unit enclosure shall be solidly connected to the test circuit conductor which supplies the center conductor (L2) of the unit.

.06 Test Voltage and Frequency

Units shall be tested at the three-phase 60-hertz rated voltage of the motor control center in which they are to be applied. The test voltage shall be determined at the line terminals of the motor control center by measuring the open-circuit line-to-line voltage immediately before the test.

.07 Test Current

The available short-circuit current at the line terminals of the motor control center in which the unit is tested shall be not less than the short-circuit current rating of the motor control center in which the unit is to be applied.

.08 Test Circuit Calibration

The rms available symmetrical short-circuit current shall be determined by measuring the current with the motor control center line terminals short-circuited. The current shall be determined at an instant one-half cycle (at 60 hertz frequency) after the short circuit occurs and shall be calculated in accordance with IEEE Standard

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C37.09, *Test Procedure for AC High Voltage Circuit Breaker Rated on a Symmetrical Current Basis.* The test circuit power factor shall be in accordance with Table 2-322-3.

Table 2-332-3
TEST CIRCUIT POWER FACTOR

Short-circuit Current Rating, Rms Symmetrical Amperes	Maximum Power Factor, Percent
10,000	50
14,000	30
22,000 and above	20

Resistance and reactance components of the test circuits shall not be connected in parallel, except that an air-core reactor in any phase may be shunted by resistance in which the voltampere loss is approximately 0.6 percent of the reactive voltamperes of the air-core reactor in that phase.

.09 Test Duty Cycle

Each combination motor control unit tested shall have one open (O) test. The unit disconnecting means and controller contactor shall be closed prior to the test. The operating coil of the contactor may be energized from a separate source.

Short-circuit current shall be initiated by random closing of the test circuit.

Each feeder tap unit shall have one open (O) test. The disconnecting means shall be closed prior to the test.

Short-circuit current shall be initiated by random closing of the test circuit.

.10 Performance Criteria

After completion of the short-circuit test, the condition of the unit shall be as follows.

a. The fault current shall have been interrupted by the unit branch-circuit protective device.
b. Immediately following the short-circuit test, the unit shall withstand a dielectric test of twice rated voltage at 60 hertz for 1 minute on the line side of the disconnecting means from line to line and from each line to ground. In this test, circuit breakers shall be left in the tripped position and fusible disconnect devices shall be left closed with the fuses left in their holders.
c. In a fusible disconnect device, contact welding is acceptable if normal operation of the operating mechanism will break the weld.
d. A combination motor control unit or feeder tap unit may require repair or replacement.
e. The operating mechanism for the disconnect device and the door interlocks shall permit opening of the door.
f. Stab-in assemblies (when employed) and vertical buses at the point of contact shall be in essentially the same mechanical and electrical condition as before the test.
g. The unit door must remain closed in its normal position and shall operate normally.

Suggested Standard for Future Design 7-7-1965.

2-322.43 RANGE OF OPERATING VOLTAGE

The range of operating voltage of the control center shall be in accordance with Part ICS 2-110.

NEMA Standard 7-16-1969.

2-322.44 TEMPERATURE RISE OF BUSES, ETC.

The temperature rise of buses, connecting straps and terminals above the ambient temperature shall not exceed 65°C, in accordance with Part 1-109 of NEMA Standards Publication No. ICS 1.

NEMA Standard 7-16-1969.

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MANUFACTURING

2-322.60 CONSTRUCTION

.01 Vertical Section

The function of the vertical section is to support the vertical and horizontal buses, the units, the doors and covers. Nominal installed height is 90 inches, excluding floor sills (or mounting channels).

The vertical section is self-supporting when properly bolted to the floor or otherwise secured. These sections may be assembled into a group to which additional sections may be readily added.

.02 Wiring Space

There shall be space for horizontal wiring between vertical sections at the top and/or bottom. There shall be vertical wiring space within each section for wiring to the units.

.03 Unit Mounting

Provision shall be made so that each combination motor control unit and feeder tap unit may be readily removed as a unit for rearrangement, replacement or repair. Exceptions may be made if the size or weight of the unit makes its removal impracticable.

Unit doors shall be hinged either to the vertical section or to the unit. If the door is mounted on the unit, removal of the unit shall not leave the bus so exposed that accidental contact with it is likely.

.04 Interlocking Of Doors

Access to each combination motor control unit or feeder tap unit shall be provided by a single separate hinged door, interlocked with its associated disconnecting device so that the door cannot be opened without first opening the disconnecting device. Where two sets of circuit disconnecting means are mounted in a single compartment to form a dual feeder tap unit, each disconnecting device shall be interlocked with its associated door. Provision shall be made for locking the disconnecting device in the open position when the door is closed.

When required by the particular application, a deactivating means (defeater) shall be provided to permit entry into the enclosure when the disconnecting device is closed.

.05 Spacings

Spacings of bare bus bars of the horizontal common power bus and of the bus extensions in the vertical sections, including stabs or bolted connectors, shall provide the following minimum clearances:

a. *To Parts of Opposite Polarity Through Air* – 1 inch.

b. *Between Live Parts and Ground Through Air or Across Surfaces* – 1 inch.

c. *To Parts of Opposite Polarity Across Surfaces* – 2 inches.

Spacings within units shall be in accordance with the basic requirements for industrial control equipment (see Part 1-111 of NEMA Standards Publication No. 1) or for such other devices as may be incorporated.

.06 Control Circuit Protection

a. Control circuits shall be protected in accordance with ICS 1-112.61.

b. A control circuit supplied by a source separate from the unit shall be considered to be an external source for purposes of overcurrent protection.

NEMA Standard 5-25-1988.

.07 Lighting Panel and Auxiliary Control Panel Protection

Lighting panels and auxiliary control panels, when connected directly to the common power bus, shall be protected for not less than the short-circuit current rating of the motor control center. When these panels are supplied from transformers in the motor control center, the transformer primaries shall be protected for not less than the short-circuit rating of the motor control center. Those panels connected to the secondary of such transformers shall be protected for not less than the maximum available short-circuit current of the transformer.

NEMA Standard 9-20-1972.

2-322.61 EQUIPMENT

A control center may contain any combination of equipment such as the following:

a. Full-voltage nonreversing combination motor control unit,

b. Full-voltage reversing combination motor control unit,

c. Full-voltage two-speed two-winding combination motor control unit,

d. Full-voltage two-speed single-winding combination motor control unit,

e. Part-winding nonreversing combination motor control unit,

f. Wye-delta nonreversing combination motor control unit,

g. Reduced-voltage single-step nonreversing combination motor control unit,

h. Lighting distribution panelboard,

i. Feeder tap units, and

j. Incoming-line fusible isolating switch.

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k. Incoming-line air circuit breaker,
l. Control transformer,
m. Lighting transformer, or
n. Special equipment assemblies.

NEMA Standard 7-16-1969.

The foregoing equipment may contain such items as: pushbuttons, selector switches, indicating lights, control transformers, control circuit fuses and electrical interlocks mounted as an integral part of the above units.

Authorized Engineering Information 7-7-1965.

2-322.62 MARKING

The bus structure, each motor control unit and each feeder tap unit shall be marked with its short-circuit current rating expressed in rms symmetrical amperes. This marketing supersedes any interrupting ratings shown on fuses or circuit breakers which are included in the units.

Fusible motor control units and fusible feeder tap units can be supplied with or without fuses. The short-circuit current rating of the unit shall be determined with the fuse installed. Information showing the various short-circuit current ratings based on the type of installed fuse shall be located in the fusible motor control unit or fusible feeder tap unit.

NEMA Standard 1-5-1977.

APPLICATION

2-322.80 TECHNICAL INFORMATION NEEDED TO ADEQUATELY SUPPLY A CONTROL CENTER

The technical information should include the following, as applicable.

a. Rating of supply:
    1. Voltage.
    2. Frequency.
    3. Number of Phases.
    4. Horizontal and vertical bus rating in amperes.
    5. Available fault current at the line terminals of the control center in symmetrical rms amperes.
b. Size, type (aluminum or copper), number and location of incoming cable, or busway.
c. Enclosure.
d. Types of combination motor control units, feeder tap units, main disconnect devices, etc., coordinated with step a.
e. Service entrance requirements per local codes, utilities, etc., for incoming line section.
f. Class and type of motor control center.
g. Preferred layout of units.
h. Special features.

Authorized Engineering Information 1-17-1974.

2-322.81 APPLICATION OF SHORT-CIRCUIT RATINGS

The motor control center short-circuit rating shall be the maximum available rms symmetrical current in amperes permissible at its line terminals. It shall be computed as the sum of the short-circuit current contributions of the motors connected to the motor control center and the maximum available current, including all other short-circuit current contributions of the supply system at the point of connection to the motor control center.

NEMA Standard 1-5-1977.

Some simplified methods of determining short-circuit currents treat all contributions to short-circuit current as due to motors and concentrated at the transformer terminals.

The maximum available current is taken as the sum of the maximum available current of the transformer and a motor contribution based on the transformer continuous current rating.

Such methods are not consistently applicable for motor control center installations. Under some conditions, as when the installation involves relatively long or high-impedance (possibly current-limiting) feeders, those methods may be unsafe. In such instances, the short-circuit current within the control centers may exceed the predicted value because the short-circuit current contributions of the motors connected to the control center are not diminished by the feeder impedance, as contemplated by the method.

In all circumstances, the maximum available current at the line terminals of the motor control center should be computed as the sum of the maximum available current of the system at the point of connection and the short-circuit current contribution of the motors con-

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nected to the control center.* The current thus determined must not exceed the short-circuit rating of the motor control center.

*In the absence of more precise information, it is usual to assume that the short-circuit current contribution of these motors equals four times the continuous current rating of the motor control center.

Authorized Engineering Information 1-5-1977.

2-322.82 HANDLING, INSTALLATION, OPERATION, AND MAINTENANCE

Refer to NEMA Standards Publication No. ICS 2.3 for recommended procedures.

Authorized Engineering Information 1-11-1984.

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Part ICS 2-324

AC GENERAL-PURPOSE MEDIUM VOLTAGE CONTACTORS AND CLASS E CONTROLLERS, 50 AND 60 HERTZ

Part ICS 2-324 applies to alternating current general-purpose contractors and Class E magnetic controllers rated 2001-7200 volts maximum, three phase, 50 and 60 hertz. The standards of Part ICS 2-110 apply to Part ICS 2-324. The definitions and standards of NEMA Standards Publications No. ICS 1 also apply to this part, unless otherwise specified.

GENERAL INFORMATION AND FEATURES

2-324.05 CLASSES OF CONTROLLERS

.01 Class E1 Controllers

Class E1 controllers employ their contacts for both starting and stopping the motor and interrupting short circuits or faults exceeding operating overloads.

.02 Class E2 Controllers

Class E2 controllers employ their contacts for starting and stopping the motor and employ fuses for interrupting short circuits or faults exceeding operating overloads.

NEMA Standard 7-16-1969.

RATINGS

2-324.20 MOTOR CURRENT AND INTERRUPTING RATINGS

.01 General

Motor current and fault interrupting ratings of controllers for nonplugging and nonjogging, reversing and nonreversing duty, when mounted in any type of enclosure and whether or not provided with running overcurrent (overload) protection or other auxiliary devices, shall be in accordance with Tables 2-324-1 and 2-324-2A and 2-324-2B. Table 2-324-1 lists motor current ratings of Class E controllers and line contactors; Table 2-324-2A lists interrupting ratings of Class E1 controllers; Table 2-324-2B lists voltage and interrupting ratings of Class E2 controllers.

NEMA Standard 11-17-1988.

Table 2-324-1
MOTOR CURRENT RATINGS OF CLASS E CONTROLLERS AND LINE CONTACTORS

Size of Controller and Contactor	Enclosed Current Ratings Amperes		**Horsepower Ratings at Utilization Voltages								
			2300 Volts, Three-Phase			4000 Volts Three-Phase			6600 Volts, Three-Phase		
				Synchronous Motors			Synchronous Motors			Synchronous Motors	
	Continuous	Service Limit*	Induction Motors	80% Power Factor	100% Power Factor	Induction Motors	80% Power Factor	100% Power Factor	Induction Motors	80% Power Factor	100% Power Factor
H2	180	207	700	700	900	1250	1250	1500	2000	2000	2500
H3	360	414	1500	1500	1750	2500	2500	3000	4000	4000	5000
H4	540	621	2250	2250	2500	4000	4000	4500	6000	6000	7500
H5	630	724	2500	2500	3000	4500	4500	5000	7000	7000	8250
H6	720	828	3000	3000	3500	5500	5500	6000	8000	8000	10000

* 1.15 times the continuous current.
**Horsepower ratings in Table 2-324-1 are shown only for reference.

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Table 2-324-2A
INTERRUPTING RATINGS OF CLASS E1 CONTROLLERS

	Class E1 Interrupting Ratings (Unfused)*	
Size of controller	Three-Phase Symmetrical MVA	Volts, Amperes
(1)	(2)	(3)
H2	25 or 50	**
H3	50	**
H4	60	**
H5	75	**
H6	Future	**

*Class E1 ratings may be specified from either column (2) or (3).
**To be specified by manufacturer.

Table 2-324-2B
VOLTAGE AND INTERRUPTING RATINGS OF CLASS E2 CONTROLLERS

Rated Insulation Voltage	Range of Utilization Voltages at which Interrupting Rating Applies		Class E2 Interrupting Ratings (Fused)	
Volts, RMS	Maximum	Minimum	Amperes (RMS), Symmetrical*	Three-Phase Symmetrical MVA at Nominal Utilization Voltage
(1)	(2)	(3)	(4) (5)	(6) (7)
2500	2500	2200	40,000 or 50,000	160 or 200 at 2300V
5000	5000	3800	40,000 or 50,000	280 or 350 at 4000V
5000	5000	3800	40,000 or 50,000	320 or 400 at 4600V
7200	7200	6200	40,000 or 50,000	460 or 570 at 6600V

*The asymmetrical interrupting rating is 1.6 times the symmetrical values shown.

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Class E controllers shall not be used with motors whose full-load current rating exceeds the continuous current rating given in Table 2-324-1. The continuous current ratings shown in Table 2-324-1 represent the maximum rms current, in amperes, which the controller may be expected to carry continuously without exceeding the temperature rises given in Part ICS 1-109 of NEMA Standards Publication No. ICS 1.

NEMA Standard 11-15-1984.

A motor controller intended for use with non-motor loads, such as capacitors or transformers, may require special consideration.

Authorized Engineering Information 11-17-1988.

.02 Service-Limiting Current Rating

The service-limit current ratings shown in Table 2-324-1 represent the maximum rms current, in amperes, which the controller may be expected to carry for protracted periods in normal service.

The ultimate trip current rating of overcurrent (overload) relays or of other motor protective devices used shall not exceed the service-limit rating of the controller.

NEMA Standard 11-15-1984.

When controllers are operated above the continuous current rating and up to the service-limit rating, temperature rises will exceed those obtained by testing the controller at its continuous current rating.

Authorized Engineering Information 11-15-1984.

2-324.21 BASIS OF INTERRUPTING RATING

The interrupting rating of a Class E controller is expressed in terms of the maximum available symmetrical MVA (megavoltamperes) or rms symmetrical fault current and specific line to line voltage, at the controller incoming line terminals.

The available symmetrical MVA is equal to the product of the available symmetrical rms short-circuit current, the line-to-line open-circuit voltage, and a phase factor which is 1.73×10^{-6} for three phase.

NEMA Standard 11-17-1988.

DESIGN TESTS AND PERFORMANCE

2-324.40 SUBSTANTIATION OF FAULT INTERRUPTING RATING

Tests made to substantiate the interrupting rating of a Class E controller shall be made over the range of 2200-2500 volts, 3800-5000 volts, or 6200-7200 volts, as applicable, and with an available symmetrical short-circuit MVA (megavoltamperes) at least equal to the interrupting rating of the controller. See ICS 2-324.41. The test shall be made in accordance with ICS 2-324.41 through 2-324.43. During the test, the controller shall meet the performance requirements of ICS 2-324.44.

Interrupting tests are intended to prove the interrupting performance of a given controller design and are not to be considered production tests.

NEMA Standard 11-15-1984.

2-324.41 FAULT INTERRUPTING RATING TEST CIRCUIT

.01 General

The test circuit (see Fig. 2-324-1 and 2-324-2), with the controller short-circuited at its line terminals, shall be capable of producing a three-phase short-circuit MVA based on the average of the currents in the three phases whose symmetrical value (i.e., omitting any direct current component) is at least equal to the interrupting rating of the controller. Also, the test circuit shall be capable of producing in one of the three phases a total rms current, including the direct current component, not less than shown in Table 2-324-3.

Table 2-324-3
DIRECT CURRENT COMPONENT CONTRIBUTION

Time after Initiation of Short Circuit, Cycle (60-cycles-per-second Fuse)	Ratio of Total Rms Current in the Phase with the Maximum Direct Current Component to the Rms Symmetrical Current Corresponding to the Interrupting Rating
½	1.6
1	1.4
2	1.2
3	1.1
4 or more	1.0

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The test circuit shall be capable of producing currents not less than those indicated in Table 2-324-3 from the instant of initiation of the short circuit to the instant of interruption.

The test circuit shall be permitted to include current-limiting reactors, resistors, and transformers in addition to the generating system. In setting up the test circuit, the leads between the reactors and the controllers shall be made as short as practicable so as to keep the capacitance to ground at the controller terminals small. No capacitance shall be added in the circuit.

The normal-frequency recovery voltage shall be not less than the rated voltage of the controller when measured in accordance with IEEE Standard C37.09, *Test Procedure for AC High Voltage Circuit Breaker Rated on a Symmetrical Current Basis.*

.02 Power Factor of Test Circuit

The power factor of the test circuit shall not exceed 15 percent lagging. The power factor shall be determined from the design constants of the generator and the measured alternating-current resistance and reactance of the remainder of the circuit, from oscillograph records, or by any other appropriate method. See Appendix 1 of IEC Publication No. 56, *High-Voltage Alternating-Current Circuit Breakers, Part 1: General and Definitions.*

NEMA Standard 7-16-1969.

2-324.42 FAULT INTERRUPTING RATING TESTS

.01 Test Preparation

a. *Calibration of Test Circuit*—The test circuit described in ICS 2-324.41 shall be used for the test. In order to obtain the total rms current specified in ICS 2-324.41, it may be necessary to use a larger symmetrical component than that corresponding to the symmetrical interrupting rating in MVA.

The circuit shall be tested and oscillograms shall be taken to record the three line currents and the three line-to-line voltages to assure compliance with ICS 2-324.41.

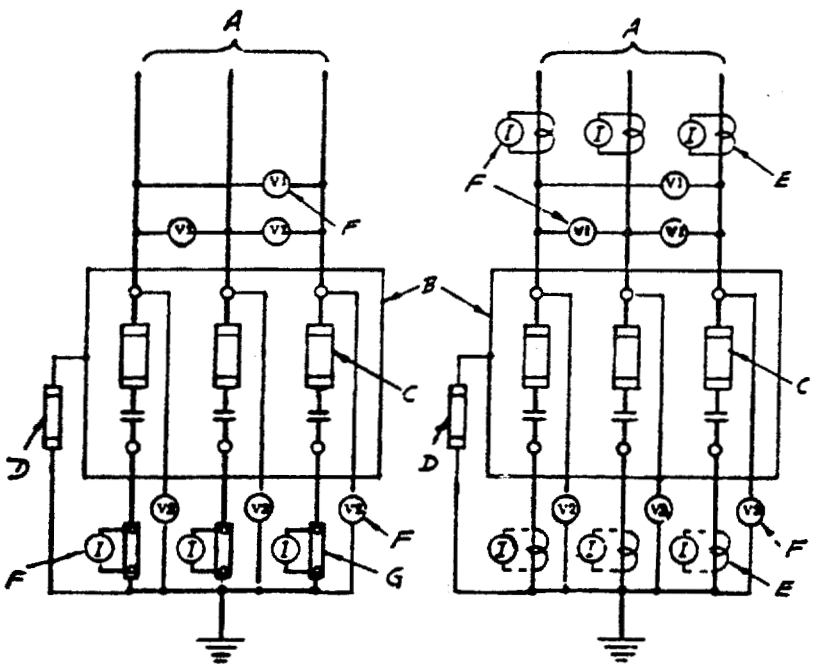


Fig. 2-324-1
UNGROUNDED SUPPLY TEST CIRCUIT

A = Power supply (current-limiting reactors, resistors or transformers are not shown).
B = Controller under test.
C = Main fuses (omitted in test of Class E1 controller).
D = 3-ampere 5000-volt fuse.
E = Current transformers (alternate location shown by dotted lines).
F = Oscillograph elements.
G = Current shunts.

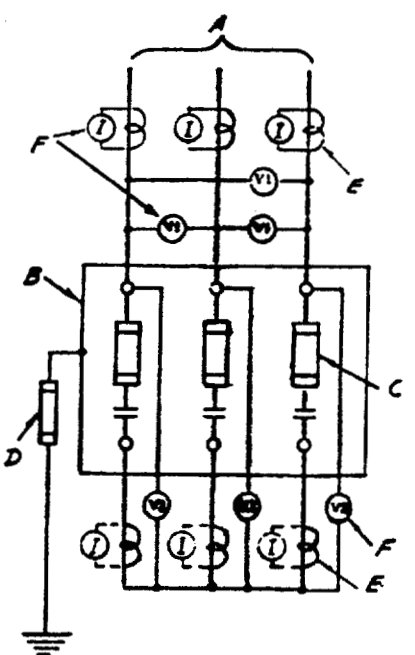


Fig. 2-324-2
NEUTRAL-GROUNDED SUPPLY TEST CIRCUIT

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Measurements of the currents shall be made on the calibration oscillograms at the "times" specified in Table 2-324-3. The available symmetrical short-circuit test current in each phase shall be the alternating-current component as determined by drawing the envelope of the current wave, measuring the peak-to-peak values at the appropriate instant, and dividing them by 2.828 as illustrated in IEEE Standard C37.09, *Test Procedure for AC High Voltage Circuit Breaker Rated on a Symmetrical Current Basis*. The total rms current at the "times" specified shall be determined in accordance with C37.09.

b. *Controller Test Circuit*—The controller test circuit shall be identical to the calibration test circuit, except that the short circuit shall be placed at the load terminals of the controller, and the circuit shall be interrupted by the controller.

c. *Grounding of Controller and Test Circuit*—The controller structure shall be grounded through a 3-ampere fuse or smaller of appropriate voltage rating.

d. *Size of Fuses Used in Test*—Class E2 controllers shall be tested with fuses of the highest current rating for which the controller is intended to be used.

.02 Measurements To Be Taken During Test

Measurements shall be made by oscillograph unless otherwise specified in the following paragraphs. Data giving the voltage and current values of the circuit and a description of the operation of the controller during and after the test shall be prepared.

Data to be recorded during the test shall include the following information:

a. *Measurements to be Made in Calibrating the Test Circuit:*

1. Open-circuit line-to-line voltages of all three phases by voltmeter of oscillograph immediately before short circuit is applied.
2. Short-circuit current in each line.

b. *Measurement to be Made with the Controller in the Circuit:*

1. Line-to-line voltages (V1) of all three phases before the short circuit by voltmeter.
2. Voltage, V2, between line and load controller terminals before, during, and immediately following the short circuit.
3. Currents through controller during test.

NEMA Standard 9-9-1970.

2-324.43 FAULT INTERRUPTING TEST CYCLE

A Class E controller shall be subjected to a test cycle consisting of a specified number of unit operations at stated intervals. A unit operation consists of a closing, followed immediately by an opening, of the circuit without purposely delayed action. This operation is designated by the letters CO signifying closing-opening. Random switching shall be used.

.01 Class E1 Controllers

The test cycle of a Class E1 controller shall be three CO unit operations at 2-minute intervals.

.02 Class E2 Controllers

The test cycle of a Class E2 controller shall be three CO unit operations separated by the interval required to a) renew the fuses and b) to inspect and, if necessary, replace any renewable contacts. Replacement of a vacuum, or any other sealed type, interrupter is not permitted.

NEMA Standard 7-13-88.

2-324.44 INTERRUPTING PERFORMANCE

The controller shall interrupt the short-circuit current,including any direct current component. (See ICS 2-324.43.)

At the end of any test cycle, the controller shall be in the following condition.

a. *Mechanical*—The controller, with the exception of the blowing of fuses, shall be in substantially the same mechanical condition as at the beginning.

b. *Electrical*—The controller shall be capable of withstanding rated voltage in the open position and of carrying rated current at rated voltage for a limited time but not necessarily without exceeding the rated temperature rise. After a test cycle at or near its interrupting rating, it is not to be inferred that the controller can again meet its interrupting rating without minor repairs such as the replacement of contacts.

c. *General*—A controller shall perform without the emission of flame or oil form its enclosure. On Class E2 controllers the welding of contactor tips under the specified test duty cycle shall not be considered a failure.

On class E2 controllers, it is not necessary for the contact tips to remain closed during the interrupting cycle.

Blowing of the 3-ampere fuse between the controller enclosure and ground shall be considered a failure.

NEMA Standard 7-16-1969.

2-324.45 FAULT WITHSTANDABILITY

A Class E controller shall withstand, without damage, except as noted in ICS 2-324.44.c, the thermal and electromagnetic effects imposed on it during the interval which the controller requires to open a short circuit on a system having the available short-circuit MVA at which the controller is rated.

NEMA Standard 7-17-1973.

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2-324.46 BASIC LIGHTNING IMPULSE INSULATION LEVEL (BIL) TESTS

Impulse dielectric tests on the controller high-voltage circuits shall be made with a full wave in accordance with Publication No. C68.1 of the American National Standards Institute.

The impulse dielectric test is intended to prove the Basic Insulation Level (BIL) rating of a given controller design and is not to be considered a production test.

The impulse dielectric tests are independent of the interrupting tests, and a controller is not required to meet the impulse dielectric tests after being subjected to interrupting tests.

.01 Impulse Test Voltage

Securing adequate insulation overvoltage protection depends upon a combination of good design practices with the selection of appropriate overvoltage protective devices. For more information on the application of surge arresters to safeguard electric power equipment against the hazards of abnormally high voltage surges of various origins, see ANSI C62.2, *Guide for Application of Valve-Type Lightning Arresters for Alternating Current Systems*, and IEEE Standard 141, *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants.*

The choice between Level A and Level B should be made considering the degree of exposure to lightning overvoltage, the type of system grounding, and the type and location of surge arrester on the source side.

Incoming surge voltages should be evaluated considering waveform variations and reflections. For approximating a worst case, multiply sparkover voltage of surge arrester by 260%.

For proper protective margin, the test voltage from the table below should be at least 20% more than the calculated worst case incoming surge voltage.

Authorized Engineering Information 11-15-1984.

IMPULSE TEST VOLTAGE

Controller Rating	Impulse Test Voltage, Crest Kilovolts		
Line-to-Line	Test 1 & 2		Test 3
R.M.S. Voltage	Level A	Level B	Levels A & B
2001-3600	30	45	For Test 3, apply a voltage equal to 110% of the voltage used for Test 1 and 2
3601-7200	45	60	

Suggested Standard for Future Design 11-15-1984.

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Following are example calculations for approximating a worst case, with resultant BIL levels leading to the selection of Level A and B BIL rated equipment.

ν Line-to-Line = 4.16KV (Grounded System)					
Type of Lightning Arrester	Arrester Continuous Voltage (KV-RMS)	Max. Discharge Voltage of Arrester ⚠ (KV Crest)	Arrester Discharge Voltage × 2.6 ⚠ (KV Crest)	Value of Column No. 4 × 1.2 ⚠ (KV Crest)	Required Equipment BIL Level
Station	2.54	6.4	16.6	20	Level A (45KV)
Intermediate	2.54	9.9	25.7	31	Level A (45KV)
Distribution	3.00	11	28.6	34.3	Level A (45KV)

ν Line-To-Line = 4.16KV (Ungrounded System)					
Type of Lightning Arrester	Arrester Continuous Voltage (KV-RMS)	Max. Discharge Voltage of Arrester ⚠ (KV Crest)	Arrester Discharge Voltage × 2.6 ⚠ (KV Crest)	Value of Column No. 4 × 1.2 ⚠ (KV Crest)	Required Equipment BIL Level
Station	4.20	10.4	27.0	32.0	Level A (45KV)
Intermediate	4.50	15.0	39.0	46.8	Level B (60KV)
Distribution	4.50	17.0	44.2	53.0	Level B (60KV)

⚠ Typical data for selected arrester.
⚠ Allowance for wavefront variations and reflected wave.
⚠ Additional allowance for temperature, humidity, aging, and contamination of insulation.

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.02 Test Sequence

a. *Test 1*—With the controller bus installed, the isolating means closed, the medium voltage motor circuit fuses (in case of Class E2 controllers) and control circuit fuses in place, and the contactor in the open position, the test voltage shall be applied between each electric circuit and grounded metal parts, and between each principle electric circuit and all other principle circuits, except that the impulse test need not be applied across the open tip gap of the contactor.

b. *Test 2*—Test 1 shall be repeated except that the contactor shall be closed.

c. *Test 3*—With the isolating means open, the impulse voltage shown in the foregoing table shall be applied in each phase individually between the contacts of the isolating means across the isolating gap. If the isolating means has provision for automatically grounding its load side when in the fully opened position, the test voltage shall be the value specified under Test 1 and 2.

.03 Test Procedure

The test samples shall be subjected to a sequence of tests in accordance with paragraph .02. In these tests, three positive and three negative impulses shall be applied to each phase individually (in accordance with paragraph .02) without causing disruptive damage or flashover.

Exception No. 1. If flashover occurs on only one test during any group of three consecutive tests, three more tests shall be made. If the equipment successfully withstands all three of the second group of tests, the flashover in the first group shall be considered as a random flashover and the equipment shall be considered as having successfully completed the test.

Exception No. 2. Flashover may occur at an integrally mounted surge arrester.

Suggested Standard for Future Design 11-15-1984.

Dry-type core and coil assemblies, such as reduced-voltage-starting reactors and autotransformers and control-circuit transformers, may be disconnected for this test.

Authorized Engineering Information 11-15-1984.

2-324.47 DIELECTRIC VOLTAGE WITHSTAND

.01 General

A controller shall be capable of withstanding for 1 minute without breakdown the application of a 60 (±2) hertz essentially sinusoidal potential as indicated in Table 2-324-4 in the following cases:

a. Between uninsulated live parts of each electric circuit and the grounded metal parts with the contacts opened and closed,

b. Between uninsulated line parts of each medium voltage circuit and all other medium voltage circuits,

c. Between terminals of opposite polarity with the contacts closed, or

d. Across the open contacts of the power circuit isolating means (See ICS 2-324.66.).

A transformer, a coil, or a similar device normally connected between lines of opposite polarity shall be disconnected from one side of the line during test between terminals of opposite polarity, item (c).

If a controller includes a meter or meters, such instruments shall be disconnected from the circuit. The meter or meters shall be tested separately for dielectric voltage withstand, with an applied potential of 1000 volts in the case of an ammeter, and 1000 volts plus twice rated voltage in the case of any other instrument having a potential circuit. The test potential shall be applied between live parts and the mounting panel, including the meter face, zero adjuster, and so forth.

.02 Test Procedures

Test procedures shall be in accordance with ICS 1-109.21 except for points of application (see 2-324.47.01). The controller shall be tested by means of a 500 volt-ampere or larger capacity transformer, whose output is essentially sinusoidal and can be varied. For definition of the applied wave shape see IEEE 4, *Standard Techniques for High Voltage Testing.*

NEMA Standard 11-15-1984.

Table 2-324-4
POWER FREQUENCY DIELECTRIC TEST VOLTAGES

Voltage Rating Volts (RMS)	Test Voltage (RMS)
0-600	1000 volts + (2 × nominal voltage rating)
601-7200	2000 volts + (2¼ × nominal voltage rating

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Care should be taken not to apply a test voltage across the open contacts of a vacuum type interrupter that exceeds the manufacturer's recommendation, to avoid generating harmful x-rays.

Authorized Engineering Information 7-13-1988.

.03 Basic Switching Impulse Insulation Level

Power frequency dielectric tests are related to basic switching impulse insulation level. See ICS 1-109.21.8.

Authorized Engineering Information 11-15-1984.

2-324.48 TEMPERATURE TEST

The temperature tests shall be in accordance with ICS 1-109.10 through 1-109.15.

NEMA Standard 11-15-1984.

2-324.49 RANGE OF OPERATING VOLTAGE TEST

Alternating current contactors shall withstand 110 percent of their rated voltage without injury to the operating coils and shall close successfully at 85 percent of their rated voltage.

For the test at 110 percent of rated control voltage, the operating coil shall be energized at 110 percent of rated control voltage until constant temperature is reached and then tested immediately to determine that full closure results when rated control voltage is reapplied.

For the test at 85 percent of rated control voltage, the operating coil shall be energized at rated control voltage until constant temperature is reached and then tested immediately to determine that full closure results when 85 percent or rated control voltage is applied.

When the contractors of an alternating current controller are operated from the secondary of a control-circuit transformer which has its primary winding connected to the controller supply circuit, the controller shall operate successfully at 90 percent of rated primary voltage.

NEMA Standard 11-15-1984.

2-324.50 MAKE AND BREAK CAPABILITY TEST

.01 A contactor that is part of a Class E controller, shall be capable of making and breaking the maximum current at which the overload relays alone cause interruption (cross-over point). The cross-over point shall be determined from the characteristic curves of the overload relays and the total clearing time curves of the medium voltage motor circuit fuses.

.02 To determine compliance with paragraph 2-324.50.01, a contactor shall be subjected to 10 make and break operations at the current indicated in paragraph 2-324.50.01 but not less than 10 times the continuous current rating of the contactor. The operations shall be conducted in a single continuous test without intervening maintenance or service.

.03 The contactor shall be operated at the rate of one operation per minute with an on time of not less than 0.1 seconds.

.04 Except as indicated in paragraphs 2-324.50.01 – 2-324.50.03, the conditions for this test shall be the same as for the overload test described in ICS 2-324.52.

.05 This test shall be permitted to be performed on a separate sample, or in combination with the overload ICS test in 2-324.52.

.06 When the make and break test is performed on a separate sample, the contactor shall be in substantially the same mechanical condition at the conclusion of the test as at the beginning and shall be capable of withstanding applied potentials in accordance with ICS 2-324.47 except that the applied potential shall be two times the rated voltage. The fuse specified in ICS 2-324.52.07 shall not have been opened.

.07 When the make and break test is combined with the overload test, the first 10 operations shall be performed in accordance with paragraphs ICS 2-324.50.01 and ICS 2-324.50.02 and the remaining 40 operations, without the contactor being serviced, shall be performed in accordance with ICS 2-324.52.

Suggested Standard for Future Design 7-13-1988.

2-324.51 SHORT-TIME CAPABILITY

A new contactor or controller shall be capable of meeting the requirements of ICS 2-110.42 at 15 times rated current for 1 second and 6 times rated current for 30 seconds.

For Class E2 controllers, the fuses shall be shunted during these tests.

Suggested Standard for Future Design 3-13-1974.

2-324.52 OVERLOAD TEST

.01 A contactor shall be capable of making and breaking 6 times its rated continuous current for 50 operations in a continuous test, without intervening maintenance or servicing, when combined with the Make and Break Capability Test. See ICS 2-324.50.07.

.02 The test shall be performed at the rated maximum voltage and at a lagging power factor not greater than 0.35.

.03 The controller shall be mounted with the door or cover closed. Any other openings, except intentional ventilation openings, shall be closed.

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Open contactors shall be mounted in an enclosure whose dimensions shall be permitted to be approximately 150% of the dimensions of the contactor, or the contactor shall be permitted to be mounted in an enclosure whose dimensions are representative of the size enclosure in which the contactor will be mounted in actual service.

.04

The controller shall be connected as shown in Figure 2-324-1 or 2-324-2. All or part of the limiting impedance shall be permitted to be connected on the load side. The test circuit shall be permitted to include current-limiting reactors, resistors and transformers in addition to the generating system. No capacitance shall be added in the circuit.

NEMA Standard 7-13-1988.

In setting up the test circuit, the leads between the reactors and the controller should be made as short as practicable so as to keep the capacitance to ground at the controller terminals small.

Authorized Engineering Information 7-13-1988.

.05 Reactive components shall be permitted to be paralleled if of the air-core type but no reactance shall be connected in parallel with resistances except that an air-core reactor(s) in any phase shall be permitted to be shunted by resistance, the volt-ampere loss of which is approximately 0.6 percent of the reactive volt-amperes in the air core reactor(s) in that phase.

NEMA Standard 7-13-1988.

.06 With reference to paragraph ICS 2-324.52.05, the shunting resistance used with an air-core reactor having negligible resistance may be calculated from the formula:

$$R = 167 \frac{E}{I}$$

where E is the voltage across the air-core reactor with current I flowing as determined by oscillographic measurement during the short-circuit calibration or, by proportion, from meter measurements at some lower current.

Authorized Engineering Information 7-13-1988.

.07 The controller structure and enclosure shall be grounded through a 3-A or smaller fuse of appropriate voltage rating or the equivalent, connected as shown in Figure 2-324-1 or 2-324-2.

.08 The medium voltage motor circuit fuses shall be permitted to be shunted or replaced with dummy fuses.

.09 The open-circuit voltage of the supply circuit shall be not less than 100 percent of the rated maximum voltage of the controller.

.10 The closed-circuit voltage is not specified, but the normal-frequency recovery voltage shall be not less than the rated voltage of the controller when measured in accordance with the *Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis,* ANSI/IEEE C37 .09.

.11 Circuit characteristics shall be determined using either laboratory type meters or oscillographic means. When oscillographic means are employed, the method indicated in the *Standard Guide for Methods of Power Factor Measurement for Low-Voltage Inductive Test Circuits,* IEEE C37.26, shall be used for determining power factor.

.12 The controller shall be operated at the rate of one operation per minute. These operations shall be permitted to be conducted in groups of 5 with 15 minutes maximum between groups.

.13 During each operation the on time shall be not less than 4 electrical cycles before contact parting commences as determined by oscillographic or equivalent measurements.

.14 For a reversing controller, the on period shall consist of a forward operation immediately followed by a reverse operation. The on time for each operation (forward and reverse) shall comply with paragraph ICS 2-324.52.13.

.15 When the reversing circuit arrangement is such that both operating coils can be energized simultaneously, 10 additional test cycles of operation shall be conducted with both coils energized simultaneously.

.16 At the conclusion of the overload test, the controller shall be in substantially the same mechanical condition as at the beginning and the medium voltage motor circuit fuses, if used, and the fuse specified in paragraph ICS 2-324.52.07 shall not have opened.

NEMA Standard 7-13-1988.

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MANUFACTURING

2-324.60 CONSTRUCTION

Class E controllers shall be wired and assembled as complete, totally-enclosed and self-supporting units.

Controllers shall be provided with means for connection to ground; such means shall have contact with the bare metal of the permanent portion of the cubicle.

NEMA Standard 11-15-1984.

2-324.61 POWER-CIRCUIT ISOLATING MEANS

Externally-operable gang-operated medium-voltage isolating means with position indication shall be included and shall be capable of interrupting the no-load current of the control-circuit transformer supplied with the controller. The isolating means can be any one of the following:

a. Three-pole isolating switch,
b. Three-pole isolating switch in mechanical combination with current-limiting fuses, or
c. Drawout contactor.

NEMA Standard 11-15-1984.

2-324.62 INTERLOCKING

Interlocking shall be provided by mechanical means or by combination of mechanical and electrical means and shall provide the following features:

a. Prevent the isolating means from being opened or closed unless all line contactors are open,
b. Prevent the opening of a medium-voltage-compartment* door when the isolating means is closed, and
c. Prevent the isolating means from being closed when any medium-voltage-compartment* door of the controller is open.

The reversing contactors of reversing controllers shall be electrically and mechanically interlocked. When required by the particular application, interlocking functions such as current or potential interlocking shall be provided to guard against short circuit through the arcs at the contacts.

When required by the particular application, means shall be provided to permit locking the medium-voltage-compartment doors closed.

When a dynamic braking contactor of the normally open type is used, the dynamic braking contactor shall be mechanically or electrically interlocked with the line contactor or contactors. If the dynamic braking contactor is normally closed, it shall be mechanically interlocked with the line contactor or contactors.

*Medium-voltage-compartment refers to a compartment containing medium -voltage components (2001-7200 volts). (This sentence has been approved as Authorized Engineering Information.)

When means for circumventing the interlock is provided for inspection or maintenance purposes, some degree of difficulty shall be required to bypass the interlock in ICS 2-324.62.b. The degree of difficulty shall involve a minimum of two separate and distinct operations. Turning a knob, or moving a lever, or removal of a single bolt, or the like, shall not be considered to provide the required degree of difficulty.

NEMA Standard 7-13-1988.

2-324.63 ARRANGEMENT FOR FIELD INSPECTION

When required for the particular application, provisions shall be made to operate the controllers for testing only with the medium-voltage isolating means open. The interlocking shall be so arranged for this test that power cannot be applied to the motor. Also, the control circuit shall be disconnected from the normal control transformer and connected to a separate source of control power supplied by the user. Should it be necessary to defeat the mechanical interlock in order to close the contactor on test power, the isolating means shall be prevented from being closed until the interlock mechanism has been restored to normal.

NEMA Standard 11-15-1984.

2-324.64 EQUIPMENT PROTECTION

Medium-voltage Class E controllers shall be provided with the following protective features.

a. Alternating current under-voltages protection, or under voltage release (two-wire control), except for latched contactors in special applications.
b. A minimum of three motor-running overcurrent protective units.
c. The control-circuit transformer shall be provided with primary overcurrent protection. The transformer secondary shall be insulated from the primary and provided with an overcurrent device in each ungrounded leg to which the control circuit devices, e.g., push buttons, limit switches, and so forth, are connected.
d. Instrument potential transformers shall be provided with primary overcurrent protection.
e. Class E1 controllers shall be provided with instantaneous fault overcurrent protection in each ungrounded conductor of the power supply in addition to the foregoing motor-running overload protection.
f. Class E2 controllers shall be provided with fuses for interrupting faults exceeding operating overloads.

NEMA Standard 11-15-1984.

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2-324.65 MARKING

Class E controllers shall be legibly marked with the following:

a. Manufacturer's Name or Trademark,
b. Catalog or Manufacturer's Identification,
c. Class E1 or E2 Controller, as appropriate,
d. Number of Phases,
e. Frequency,
f. Continuous Current Rating, RMS Amperes,
g. Interrupting Rating (MVA or Volts, RMS Symmetrical Amperes),
h. Maximum Voltage,
i. Power Fuse Size for Class E2 Controller,
j. Continuous Current Rating of Horizontal Bus, if supplied,
k. BIL Test Level,
l. Control Voltage, and
m. Volt-ampere rating or the equivalent of any operating coil circuit which requires a remote control device with a sealed rating or more than 125 volt-amperes.

Suggested Standard For Future Design 11-15-1984.

Marking is not required to be located on the outside of an enclosure provided it is readily visible by opening a door or removing a cover after installation.

Other markings may be used to meet other applicable requirements.

Authorized Engineering Information 11-15-1984.

2-324.66 POWER FREQUENCY DIELECTRIC TEST

Production dielectric tests on controllers shall be made at power frequency in accordance with ICS 1-109.21 except for points of application which shall be in accordance with ICS 2-324.47.

NEMA Standard 11-15-1984.

2-324.67 INSPECTION AND TESTING

(Under Consideration)

APPLICATION

2-324.80 PREVENTIVE MAINTENANCE

.01 General

Basic preventive maintenance should be planned and executed in accordance with ICS 1.3 or ICS 1, Part 1-115.

.02 Precautions

All maintenance should be performed by trained, qualified personnel, using safety practices and protective equipment applicable to systems over 600 Volts.

.03 Condensation

If moisture condensation occurs inside an enclosure, corrective action, such as the installation of a space heater, should be taken. Refer to the manufacturer for the recommended heater size for the circuit.

.04 Contacts

Contact wear allowance (overtravel) and contact spring pressures should be checked against the manufacturer's recommendation in the specific instruction literature.

Vacuum bottles in a vacuum contactor should be checked for adequate vacuum level periodically by performing a dielectric test across the open contacts in accordance with the manufacturer's recommendations.

Authorized Engineering Information 7-13-1988.

2-324.81 METHODS OF MOTOR STARTING

(Under Consideration)

2-324.82 COORDINATION WITH POWER SYSTEMS

(Under Consideration)

2-324.83 INSTALLATION AND STORAGE

(Under Consideration)

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Part ICS 2-325

AC GENERAL-PURPOSE CONTROLLERS FOR SYNCHRONOUS MOTORS

Part ICS 2-325 covers magnetic controllers for use with synchronous motors rated up to 7200 volts, 50 and 60 hertz. In addition to the provisions of Part ICS 2-325, all of Part ICS 2-324 with the exception of Table 2-324-1 applies to high-voltage synchronous motor control. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

GENERAL INFORMATION AND FEATURES

2-325.05 TYPICAL METHODS OF CONNECTING AC WINDINGS FOR SYNCHRONOUS MOTOR STARTING

Typical methods of starting alternating-current synchronous motors are shown in Figures 2-325-1 through 2-325-5. An "X" in the contactor sequence chart indicates closed contacts.

Authorized Engineering Information 5-21-1962.

2-325.06 DETERMINATION OF SYNCHRONOUS MOTOR STARTING CURRENT

The starting current values for the various methods of motor starting as shown in Figures 2-325-1 through 2-325-5 may be determined as follows.

a. *With Full-voltage Starting* (Fig. 2-325-1) – The starting current is equal to the locked-rotor current at full voltage.

b. *With Reactor or Resistor Starting* (Fig. 2-325-2) – The starting current is determined from the sum of the impedances of the starting reactor or resistor and of the motor under locked-rotor conditions.

c. *With Autotransformer Reduced-voltage Starting* (Sketches H, I, J, K, L and M in Fig. 2-325-3) –

1. The starting current drawn from line = $1 \times p^2 + .025\ I_m$.
2. The starting current taken by the motor = $I \times p$.
3. The autotransformer neutral current = $1 \times p - (I \times p^2 + 0.25\ I_m)$.

where –

I = Locked-rotor amperes at full voltage.
p = Transformer tap used (fraction of full voltage).
I_m = Rated full-load current of motor. The term "$0.25\ I_m$" is introduced to allow for transformer magnetizing current.

d. *With Part-winding Starting* (Fig. 2-325-4) – The starting current is the locked-rotor current of the motor connected for starting.

e. *With Wye-delta Starting* (Fig. 2-325-5) – The starting current on the wye connection is equal to 0.33 times the locked-rotor current on the delta connection.

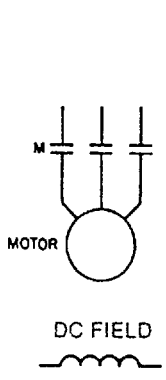
Authorized Engineering Information 9-20-1972.

2-325.07 GENERAL FEATURES

The controller shall include the following general features for either low- or high-voltage synchronous motor control.

a. One start-and-stop pushbutton station integrally mounted on enclosed controllers. Provision for connecting one separately mounted start-and-stop pushbutton station when required by the particular application.
b. Necessary current transformers.
c. Alternating-current line ammeter.
d. Means which automatically applies field excitation at the proper time.
e. Direct-current field ammeter.

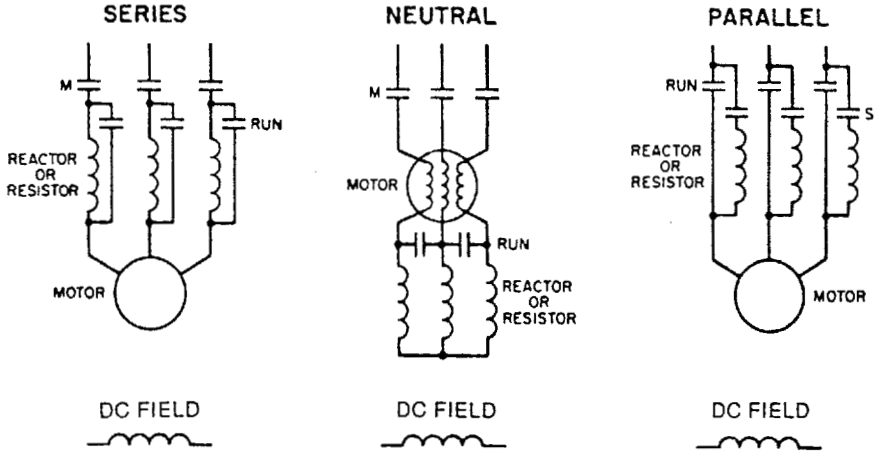
NEMA Standard 7-16-1969.



CONTACTOR SEQUENCE	
CONTACTOR	START AND RUN
M	X

Fig. 2-325-1
FULL VOLTAGE STARTING

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CONTACTOR SEQUENCE		
CON-TACTOR	START	RUN
M	X	X
RUN		X

CONTACTOR SEQUENCE		
CON-TACTOR	START	RUN
M	X	X
RUN		X

CONTACTOR SEQUENCE			
CON-TACTOR	START	TRAN-SITION	RUN
S	X	X	X*
RUN		X	X

* OPEN OR CLOSED

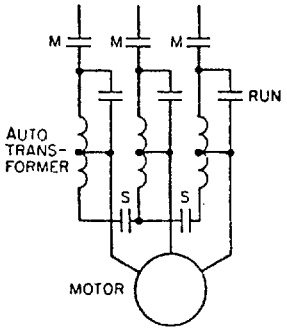
Fig. 2-325-2
REDUCED VOLTAGE—REACTOR OR RESISTOR STARTING

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THREE-COIL TRANSFORMER

SERIES
CLOSED TRANSITION

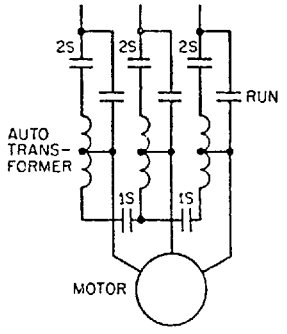


A

CONTACTOR SEQUENCE			
CON-TACTOR	START	TRAN-SITION	RUN
M	X	X	X
S	X		
RUN			X

CLOSED TRANSITION

PARALLEL
OPEN OR CLOSED TRANSITION

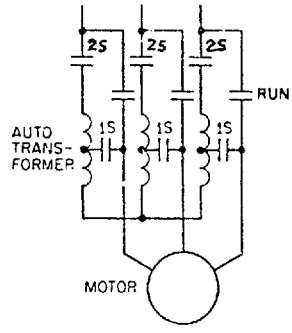


B

CONTACTOR SEQUENCE					
CON-TACTOR	START	OPEN TRAN-SITION	CLOSED TRAN-SITION		RUN
			1	2	
1S	X				
2S	X		X	X	
RUN				X	X

FOR OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR

PARALLEL
OPEN TRANSITION



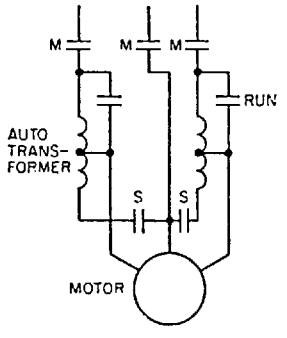
C

CONTACTOR SEQUENCE		
CONTACTOR	START	RUN
1S	X	
2S	X	
RUN		X

OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR

TWO-COIL TRANSFORMER

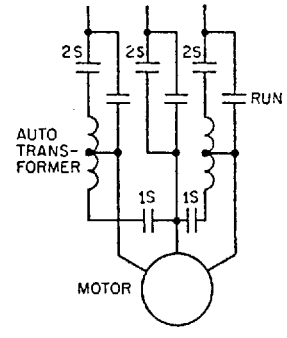
SERIES
CLOSED TRANSITION



D

CONTACTOR SEQUENCE			
CON-TACTOR	START	TRAN-SITION	RUN
M	X	X	X
S	X		
RUN			X

PARALLEL
OPEN OR CLOSED TRANSITION

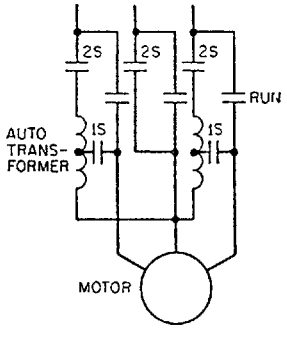


E

CONTACTOR SEQUENCE					
CON-TACTOR	START	OPEN TRAN-SITION	CLOSED TRAN-SITION		RUN
			1	2	
1S	X				
2S	X		X	X	
RUN				X	X

FOR OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR

PARALLEL
OPEN TRANSITION



F

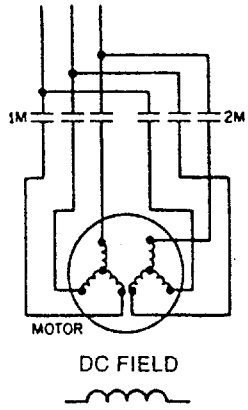
CONTACTOR SEQUENCE		
CONTACTOR	START	RUN
1S	X	
2S	X	
RUN		X

OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR

Fig. 2-325-3
REDUCED VOLTAGE AUTOTRANSFORMER STARTING

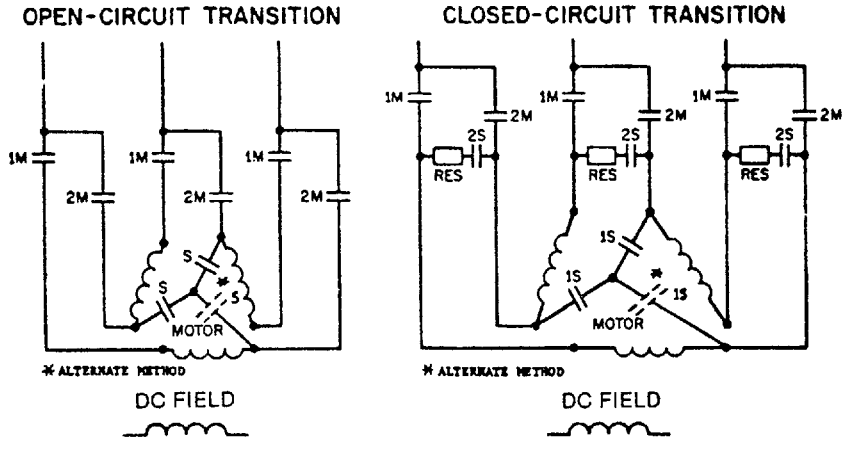
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CONTACTOR SEQUENCE		
CONTACTOR	START	RUN
1M	X	X
2M		X

Fig. 2-325-4
PART WINDING STARTING



CONTACTOR SEQUENCE				
CON-TACTOR	START		TRAN-SITION	RUN
1M		X	X	X
2M				X
S	X			

CONTACTOR SEQUENCE						
CON-TACTOR	START		TRANSITION			RUN
			1	2	3	
1M		X	X	X	X	X
2M					X	X
1S	X		X			
2S			X	X	X	

Fig. 2-325-5
WYE-DELTA STARTING

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2-325.08 PROTECTIVE FEATURES

Protective features for synchronous motor controllers shall be as follows.

a. Means to automatically remove field excitation in event of pull-out.

NEMA Standard 7-16-1969.

b. When required by the particular application, field-loss protection shall be included to disconnect the motor from the line in the event of excitation failure.

Field-loss protection is recommended for motors provided with controllers arranged for re-synchronizing when pull-out conditions are encountered.

Authorized Engineering Information 5-21-1962.

c. Means to protect the field against excessive induced voltage during normal operation out of synchronism.

d. Means to protect the squirrel-cage windings during operation out of synchronism.

e. Means to automatically disconnect the motor from the line in case of pull-out when required by the particular application.

f. A minimum of two motor running overcurrent (overload) protective units unless the motor, the motor control apparatus, and the branch-circuit conductors are otherwise adequately protected.

g. Instantaneous undervoltage protection. When required by the particular application, time-delay undervoltage protection shall be included in lieu of instantaneous undervoltage protection.

h. When required by the particular application, the direct-current control bus supplying field excitation shall have suitable two-pole disconnect means and short-circuit protection. Field-discharge means shall be permanently connected across the load side of this protective device and disconnecting means.

NEMA Standard 7-16-1969.

2-325.09 ADDITIONAL FEATURES

Additional features, when required by the particular application, shall include the following.

a. Dynamic-braking contactor(s), when required for emergency stop, shall be normally closed and magnetically opened and mechanically interlocked with the line contactor(s).

b. Dynamic-braking contactor(s), when used for non-emergency dynamic braking stops, shall be normally open and magnetically closed or normally closed and magnetically opened, and mechanically or electrically interlocked with the line contactor(s).

c. Dynamic braking, when provided for emergency stopping, shall be effective under all normal* conditions of operation and for all stops.

d. Provision for connecting a two-pole emergency stop switch. When tripped, this switch shall open both sides of the control circuit.

e. Means to prevent restarting of the motor during an emergency stop until the dynamic-braking cycle has been complete and field excitation removed.

f. Drilling for exciter field rheostat.

g. Mounting provision for a tapped resistor for the motor field.

h. Means to re-synchronize in event of pull-out.

i. An exciter rectifier unit for the motor field.

*CAUTION – Dynamic braking will be ineffective under conditions of field failure. (This sentence has been approved as Authorized Engineering Information.)

NEMA Standard 7-16-1969.

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RATINGS

2-325.20 HORSEPOWER AND CURRENT RATINGS OF LOW-VOLTAGE CONTROLLERS FOR SYNCHRONOUS MOTORS FOR NONPLUGGING AND NON-JOGGING DUTY

These controllers shall not be used with synchronous motors whose full-load currents or horsepower ratings exceed the values given in Table 2-325-1.

The accelerating contactor of single-step primary-resistor, autotransformer and reactor-type controllers shall have the same rating as the line contactor when the controller has a continuous rating of 135 amperes of less. When a controller has a rating of 270 amperes or more, an accelerating contactor having the next lower rating than the line contactor may be used. The ratings of accelerating contactors of multiple-step starters shall be in accordance with Part ICS 2-210.

NEMA Standard 5-21-1962.

2-325.21 HORSEPOWER AND CURRENT RATINGS OF HIGH-VOLTAGE CLASS E CONTROLLERS

These controllers shall not be used with synchronous motors whose full-load currents or horsepower ratings exceed the values given in Table 2-325-2.

NEMA Standard 5-21-1962.

On certain duty-cycle applications and when the controller is used with motors having a high inrush current, the horsepower rating of Class E controllers may be less than the values given in Table 2-325-2.

Authorized Engineering Information 5-21-1962.

Table 2-325-1
RATINGS FOR LOW-VOLTAGE CONTROLLERS FOR SYNCHRONOUS MOTORS FOR NONPLUGGING AND NONJOGGING DUTY

Size of Controller	Continuous Current Rating, Amperes	Horsepower Ratings			
		230 Volts		460 or 575 Volts	
		Power Factor		Power Factor	
		1.0	0.8	1.0	0.8
2	45	20	15	30	25
3	90	40	30	60	50
4	135	60	50	125	100
5	270	125	100	250	200
6	540	250	200	500	400
7	810	350	300	700	600
8	1215	500	450	1000	900
9	2250	1000	800	2000	1600

Table 2-325-2
RATINGS FOR HIGH-VOLTAGE CLASS E CONTROLLERS FOR SYNCHRONOUS MOTORS

Size of Controller	Horsepower Ratings				Continuous Current Rating, Amperes
	2200–2400 Volts Three Phase		4000–4600 Volts Three Phase		
	Power Factor		Power Factor		
	100 Percent	80 Percent	100 Percent	80 Percent	
H2	900	700	1500	1250	180
H3	1750	1500	3000	2500	360

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Part ICS 2-327

AC GENERAL-PURPOSE CLASS A MAGNETIC CONTROLLERS FOR INDUCTION MOTORS, RATED IN FULL-LOAD AND LOCKED-ROTOR CURRENT, 600 VOLTS AND LESS, 50 AND 60 HERTZ

Part ICS 2-327 applies to Class A magnetic controllers for squirrel cage and wound-rotor induction motors rated in full load and locked rotor current for application at 600 volts and less, 50 and 60 hertz. The standards of Part ICS 2-110 and Part ICS 2-222 also apply to Part ICS 2-327. See Part ICS 2-321 for magnetic controllers for induction motors rated in horsepower, types of controllers, and for methods of motor starting.

The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

GENERAL INFORMATION AND FEATURES

2-327.05 TYPICAL METHODS OF MOTOR STARTING

Typical methods of motor starting are shown in Fig. 2-321-1 through Fig. 2-321-5.

Authorized Engineering Information 1-13-1965.

2-327.06 DETERMINATION OF MOTOR-STARTING LINE CURRENT

See ICS 2-321.06.

RATINGS

2-327.20 RATINGS AND APPLICATIONS – GENERAL

.01 Continuous Current Ratings

The continuous current ratings shown in Part ICS 2-327 represent the maximum rms current, in amperes, which the controller shall be permitted to carry continuously without exceeding the temperature rises permitted by Part 1-109 of NEMA Standards Publication No. ICS 1.

.02 Service-limit Current Ratings

The service-limit current ratings shown in Part ICS 2-327 represent the maximum rms current, in amperes, which the controller shall be permitted to carry for protracted periods in normal service. At service-limit current ratings, temperature rises shall be permitted to exceed those obtained by testing the controller at its continuous current rating. The current rating of overload relays or trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

NEMA Standard 1-13-1965.

2-327.21 BASIS OF CONTROLLER CURRENT RATINGS

The current ratings of alternating-current general-purpose controllers are based on the use of three-pole contactors for two- and three-phase motors and of two-pole contactors for single-phase motors.

NEMA Standard 1-13-1965.

2-327.22 RATINGS OF FULL-VOLTAGE CONTROLLERS FOR NON-PLUGGING AND NONJOGGING DUTY

The ratings of full-voltage single-speed magnetic controllers for nonplugging and nonjogging duty requiring five or less openings or closings per minute and not in excess of 10 in a 10-minute period, when mounted in any type of enclosure and whether or not provided with running over-current (overload) protection or other auxiliary devices, shall be:

a. In accordance with Table 2-327-1 for three-phase controllers, and
b. In accordance with Table 2-327-2 for single-phase controllers.

These controllers shall not be used with motors whose full-load current ratings exceed the continuous current rating or whose locked-rotor current ratings exceed the locked-rotor current rating given in Table 2-327-1 and 2-327-2.

The current rating of overload relays or trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

NEMA Standard 5-17-1971.

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Table 2-327-1
RATINGS FOR THREE-PHASE SINGLE-SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR NONPLUGGING AND NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	Locked-rotor Current, Amperes at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 Volts	60 Hertz 575 Volts	Service-limit Current Rating,* Amperes
00	9	46	40	30	25	20	11
0	18	74	70	64	53	42	21
1	27	152	140	107	88	70	32
2	45	255	255	255	210	168	52
3	90	500	500	500	418	334	104
4	135	835	835	835	835	668	156
5	270	1670	1670	1670	1670	1334	311
6	540	3340	3340	3340	3340	2670	621
7	810	5000	5000	5000	5000	4000	932
8	1215	7500	7500	7500	7500	6000	1400
9	2250	13400	13400	13400	13400	10700	2590

* See ICS 2-327.20.

Table 2-327-2
RATINGS FOR SINGLE-PHASE SINGLE-SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR NONPLUGGING AND NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	50 and 60 Hertz Locked-rotor Current, Amperes at 115 Volts	230 Volts	Service-limit Current Rating,* Amperes
00	9	50	45	11
0	18	80	65	21
1	27	130	90	32
1P	36	140	135	42
2	45	200	200	52

* See ICS 2-327.20.

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2-327.23 RATINGS OF FULL-VOLTAGE SINGLE-SPEED MAGNETIC CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE AND JOGGING DUTY

The rating of full-voltage single-speed magnetic controllers 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 that described in ICS 2-327.22, shall be in accordance with Table 2-327-3.

These controllers shall not be used with motors whose full-load current ratings exceed the continuous current rating or whose locked-rotor current ratings exceed the locked-rotor current rating given in Table 2-327-3.

The current rating of overload relays or trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

NEMA Standard 5-17-1971.

Table 2-327-3
RATINGS FOR THREE-PHASE SINGLE-SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE AND JOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	Locked-rotor Current, Amperes at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 Volts	60 Hertz 575 Volts	Service-limit Current Rating,* Amperes
0	18	46	40	30	25	20	21
1	27	74	70	63	52	42	32
2	45	175	175	154	127	102	52
3	90	335	335	300	250	200	104
4	135	500	500	500	500	400	156
5	270	1250	1250	1250	1250	1000	311
6	540	2500	2500	2500	2500	2000	621
7	810	3750	3750	3750	3750	3000	932
8	1215	5625	5625	5625	5625	4500	1400
9	2250	10000	10000	10000	10000	8000	2590

* See ICS 2-327.20.

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2-327.24 RATINGS OF REDUCED-VOLTAGE GENERAL PURPOSE CONTROLLERS

Reduced-voltage controllers include primary-resistor controllers, autotransformer controllers, and reactor controllers.

NEMA Standard 1-13-1965.

The ratings of reduced-voltage non-plugging and non-jogging controllers, when mounted in any type of enclosure and whether or not provided with running overcurrent (overload) protection or other auxiliary devices, shall be:

a. In accordance with Table 2-327-4 for three-phase controllers, and
b. In accordance with Table 2-327-5 for single-phase controllers.

These controllers shall not be used with motors whose full-load current ratings exceed the continuous current rating or whose locked-rotor current ratings exceed the locked-rotor current rating given in Tables 2-327-4 and 2-327-5. The current rating of overload relays or trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

The accelerating contactor of single-step two-point controllers shall be of the same size as the line contactor when the line contactor is Size 4 or smaller. When the line contactor is Size 5 or larger, an accelerating contactor of the next smaller size may be used.

Accelerating contactors for automatic multistep controllers and for increment (network) controllers shall be selected so that the 8-hour rating for each resistor step will be not less than one-sixth times the maximum rms current for that step.

For the temperature test for primary resistor controllers, see Part ICS 2-213.

For the temperature test for primary reactor and autotransformer controllers, see Part ICS 2-214.

Resistors for controllers with automatic acceleration shall be Class Number 116 except where the application requires the use of other duty resistors. See Part ICS 2-213.

For refrigeration and air-conditioning applications, the controller shall be suitable for a duty cycle of:

a. *For Primary Resistor- and Reactor-type Controllers* — One start per hour not to exceed 30 seconds.
b. *For Autotransformer-type Controllers* —

Tap, Percent	Start After 5 Hours or Longer Shutdown, Not to Exceed	One Start per Hour, Not to Exceed
50 to 65	90 seconds	60 seconds
80	45 seconds	30 seconds

NEMA Standard 5-17-1971.

2-327.25 RATINGS OF WYE-DELTA MAGNETIC CONTROLLERS

Ratings of wye-delta magnetic controllers shall be in accordance with Table 2-327-6.

NEMA Standard 7-17-1973.

2-327.26 RATINGS OF PART-WINDING CONTROLLERS

Ratings for full-voltage part-winding controllers shall be in accordance with Table 2-327-7.

Ratings for reduced-voltage part-winding controllers shall be in accordance with Table 2-327-8.

NEMA Standard 7-17-1974.

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Table 2-327-4
RATINGS FOR THREE-PHASE REDUCED-VOLTAGE MAGNETIC CONTROLLERS FOR NONPLUGGING AND NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	Locked-rotor Current, Amperes at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 Volts	60 Hertz 575 Volts	Service-limit Current Rating,* Amperes
1	27	152	140	107	88	70	32
2	45	255	255	255	210	163	52
3	90	500	500	500	418	334	104
4	135	835	835	835	835	668	156
5	270	1670	1670	1670	1670	1334	311
6	540	3340	3340	3340	3340	2670	621
7	810	5000	5000	...	5000	4000	932
8	1215	7500	7500	...	7500	6000	1400
9	1250	13400	13400	...	13400	10700	2590

* See ICS 2-327.20.

Table 2-327-5
RATINGS FOR SINGLE-PHASE REDUCED-VOLTAGE MAGNETIC CONTROLLERS FOR NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	Locked-rotor Current, Amperes at 115 Volts	230 Volts	Service-limit Current Rating,* Amperes
1	27	130	90	32
1P	36	140	100	42
2	45	190	190	52

* See ICS 2-327.20.

Table 2-327-6
RATINGS FOR THREE-PHASE WYE-DELTA NONPLUGGING AND NONJOGGING MAGNETIC CONTROLLERS FOR EITHER OPEN- OR CLOSED-CIRCUIT TRANSITION

Size of Controller	Continuous Current Rating,* Amperes	Contactor Size 1M and 2M†	S or 1S	2S	Locked-rotor Rating, Amperes at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 Volts	60 Hertz 575 Volts	Service-limit Current Rating,* Amperes
1YD	47	1	1	‡	263	242	185	152	121	55
2YD	78	2	2	‡	441	441	441	363	291	90
3YD	156	3	3	‡	866	866	866	725	578	179
4YD	233	4	4	‡	1445	1445	1445	1445	1155	270
5YD	467	5	4	‡	2510	2510	2510	2510	2000	538
6YD	935	6	5	‡	5020	5020	5020	5020	4000	1075
7YD	1400	7	6	‡	8660	8660	8660	8660	6930	1610
8YD	2100	8	7	‡	13000	13000	13000	13000	10400	2420
9YD	3900	9	8	‡	23200	23200	23200	23200	18500	4480

* See ICS 2-327.20.
† Each contactor 1M and 2M carries only 0.577 times the motor line current when the motor is switched to the delta (running) connections. See ICS 2-321.06.03 and Fig. 2-321-2.
‡ Contactor 2S shall be capable of interrupting the current in the transition resistor circuit.

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Table 2-327-7
RATINGS FOR NONPLUGGING, NONJOGGING FULL-VOLTAGE POLYPHASE MAGNETIC CONTROLLERS FOR MOTORS SUITABLE FOR PART-WINDING STARTING

Size of Controller	Continuous Current Rating per Winding,* Amperes	Contactor Size Line† (1 M and 2 M)	Locked-Rotor Rating per Winding Amperes at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 Volts	60 Hertz 575 Volts	Service-Limit Current Rating per Winding,* Amperes
1PW	27	1	152	140	107	88	70	32
2PW	45	2	255	255	255	210	168	52
3PW	90	3	500	500	500	418	334	104
4PW	135	4	835	835	835	835	668	156
5PW	270	5	1670	1670	1670	1670	1334	311
6PW	540	6	...	3340	3340	3340	2670	621
7PW	810	7	...	5000	5000	5000	4000	932
8PW	1215	8	...	7500	...	7500	6000	1400
9PW	2250	9	...	13400	...	13400	10700	2590

* See ICS 2-327.20.
† Contactors 1M and 2M are each intended to carry one half of the motor running line current. See ICS 2-321.06.04 and Figure 2-321-4.

NOTE: These ratings are established on a per-winding basis because, on part-winding starting, the locked-rotor current is considerably in excess of 50 percent of the total locked-rotor current rating of the motor. The percentage varies over a wide range, depending on motor design. (This note has been approved as Authorized Engineering Information.)

Table 2-327-8
RATINGS FOR NONPLUGGING NONJOGGING REDUCED-VOLTAGE POLYPHASE MAGNETIC CONTROLLERS FOR MOTORS SUITABLE FOR PART-WINDING STARTING

Size of Controller	Continuous Current Rating per Winding,* Amperes	Contactor Size Line† (1M and 2 M)	Contactor Size Accelerating	Locked-Rotor Rating per Winding Amperes at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 Volts	60 Hertz 575 Volts	Service-Limit Current Rating per Winding,* Amperes
1PW	27	1	1	152	140	107	88	70	32
2PW	45	2	2	255	255	255	210	168	52
3PW	90	3	3	500	500	500	418	334	104
4PW	135	4	4	835	835	835	835	668	156
5PW	270	5	4‡	1670	1670	1670	1670	1334	311
6PW	540	6	5‡	...	3340	3340	3340	2670	621
7PW	810	7	6‡	...	5000	5000	5000	4000	932
8PW	1215	8	7‡	...	7500	...	7500	6000	1400
9PW	2250	9	8‡	...	13400	...	13400	10700	2590

* See ICS 2-327.20.
† Contactors 1M and 2M are each intended to carry one half of the motor running line current. See ICS 2-321.06.04 and Figure 2-321-4.
‡ The use of one size smaller accelerating contactor on sizes 5PW and larger is suitable when the contactor is shunted by its associated line contactor. (This sentence is approved as Authorized Engineering Information.)

NOTE: These ratings are established on a per-winding basis because, on part-winding starting, the locked-rotor current is considerably in excess of 50 percent of the total locked-rotor current rating of the motor. The percentage varies over a wide range, depending on motor design. (This note has been approved as Authorized Engineering Information.)

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DESIGN TESTS AND PERFORMANCE

2-327.40 GENERAL

Class A controllers shall meet the applicable test and performance requirements of Part ICS 2-110.

NEMA Standard 1-17-1974.

2-327.41 SHORT-TIME OPERATING CAPABILITY

.01 A new Class A controller with overload relay(s) shall be capable of meeting the requirements of ICS 2-110.42 at 6.4 times the current rating of its highest rated overload relay for the time necessary for its overload relay to trip.

NEMA Standard 5-25-1988.

6.4 x current rating corresponds to 8 x MFLC for a service factor 1.15 motor protected at 125 percent.

Authorized Engineering Information 5-25-1988.

.02 A new Class A controller without overload relays shall be capable of meeting the requirements of ICS 2-110.42 at 1.33 times (8/6) the maximum locked rotor current rating for 20 seconds.

NEMA Standard 5-25-1988.

2-327.42 PERFORMANCE TESTS

Motor controllers shall be evaluated in accordance with Underwriters Laboratories Inc. Publication No. UL 508.

NEMA Standard 5-12-1975.

2-327.43 SHORT-TIME SURGE CAPABILITY

.01 A new Class A controller with overload relay(s) shall be capable of meeting the requirements of ICS 2-110.42 at 12 times the current rating of its highest rated overload rating for 1 second or for the time necessary for its overload relay to trip, whichever is shorter.

NEMA Standard 5-25-1988.

12 x current rating corresponds to 15 x MFLC for a service factor 1.15 motor, protected at 125 percent.

Authorized Engineering Information 5-25-1988.

For convenience of testing, the duration of the surge capability test shall be permitted to be shortened (to not less than 0.9 seconds) in order to suit the available test current provided that the value of the I^2t (Joule Integral) is maintained.

NEMA Standard 5-25-1988.

.02 A new Class A controller without overload relays shall be capable of meeting requirements of ICS 2-110.42 at 15 times rated continuous current for 1 second.

For convenience of testing, the duration of the surge capability test shall be permitted to be shortened (to not less than 0.9 seconds) in order to suit the available test current provided that the value of the I^2t (Joule Integral) is maintained.

NEMA Standard 5-25-1988.

MANUFACTURING

2-327.60 WIRING AND CONNECTIONS FOR FULL-VOLTAGE SINGLE-SPEED MAGNETIC CONTROLLERS

See ICS 2-321.60.

2-327.61 TERMINAL MARKINGS FOR PART-WINDING MAGNETIC CONTROLLERS

.01 Controllers With Three-pole Contactors

For controllers having three-pole contactors, the controller terminal markings shall be as follows:

a. For the section of the motor winding first connected to the supply lines—T1, T2, T3.

b. For the other section of the motor winding—T7, T8, T9.

.02 Controllers with a Four-pole and Two-pole Contactor

For controllers having a four-pole contactor and two-pole contactor, the controller terminal markings shall be as follows:

a. For the section of the motor winding first connected to supply lines—A, B, C, D.

b. For the other section of the motor winding—E, F.

NEMA Standard 7-15-1970.

APPLICATION

2-327.70 APPLICATION CONSIDERATIONS

See Part ICS 2-321.

2-327.100 PREVENTIVE MAINTENANCE GUIDE

See Part ICS 1-115, of NEMA Standards Publication ICS 1, for general maintenance instructions.

Authorized Engineering Information 5-25-1988.

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Part ICS 2-328

AC GENERAL-PURPOSE CLASS A MANUALLY OPERATED AND MOTOR OPERATED CONTROLLERS FOR INDUCTION MOTORS RATED IN HORSEPOWER

Part ICS 2-328 applies to Class A manually operated and motor operated controllers for squirrel-cage and wound-rotor induction motors for application at 600 volts and less, 50 and 60 hertz. The standards of Part ICS 2-110 also apply to Part ICS 2-328.

The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

RATINGS

2-328.20 RATINGS OF MANUALLY OPERATED FULL-VOLTAGE SINGLE-SPEED CONTROLLERS FOR INTEGRAL-HORSEPOWER INDUCTION MOTORS

The ratings of non-reversing and reversing full-voltage controllers, with or without motor running overcurrent protection or other auxiliary devices and when mounted in any type of enclosure, shall be as shown in Table 2-328-1.

NEMA Standard 5-17-1971.

2-328.21 RATINGS OF MANUALLY OPERATED FULL-VOLTAGE CONTROLLERS FOR FRACTIONAL-HORSEPOWER MOTORS

For full-voltage manually operated controllers, single or double pole, provided with or without running overcurrent protection and enclosed in any type of enclosure for use with fractional-horsepower single-phase motors, the rating shall be 1 horsepower at alternating-current voltages of 115 and 230 volts.

NEMA Standard 5-18-1964.

2-328.22 RATINGS FOR MANUALLY OPERATED FULL-VOLTAGE SINGLE-SPEED CONTROLLERS FOR GROUP SHORT-CIRCUIT PROTECTION

The horsepower ratings of full-voltage manually operated controllers designed for group fusing or group circuit breaker protection shall be as shown in Table 2-328-2.

Table 2-328-1
RATINGS OF NONREVERSING AND REVERSING FULL-VOLTAGE CONTROLLERS

	Horsepower at				
	Three Phase			Single Phase	
	60 Hertz		60 Hertz	50 or 60 Hertz	
Size of Controller	200 or 230 Volts	50 Hertz 380 Volts	460 or 575 Volts	115 Volts	230 Volts
M-0	3	5	5	1	2
M-1	7-1/2	10	10	2	3
M-1P	...	...	...	3	5

NEMA Standard 5-17-1971.

Table 2-328-2
RATINGS OF GROUP PROTECTED MOTOR CONTROLLERS

	Horsepower at				
	Three Phase			Single Phase	
	60 Hertz		60 Hertz	50 or 60 Hertz	
Size of Controller	200 or 230 Volts	50 Hertz 380 Volts	460 or 575 Volts	115 Volts	230 Volts
M-0	3	5	5	1	2

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These controllers shall be capable of meeting the tests given for group fusing in the Underwriters Laboratories Inc., Publication No. UL 508.

NEMA Standard 5-17-1971.

2-328.23 RATINGS OF DRUM CONTROLLERS FOR FULL-VOLTAGE SINGLE-SPEED AND MULTISPEED MOTORS

The ratings of drum controllers for single-speed and multispeed induction motors (other than wound-rotor) shall be as shown in Table 2-328-3.

NEMA Standard 9-20-1972.

2-328.24 RATINGS OF MANUALLY OPERATED DRUM CONTROLLERS FOR WOUND-ROTOR MOTORS

The horsepower ratings and the number of control points of enclosed alternating-current drum controllers for wound-rotor motors shall be as shown in Tables 2-328-4 and 2-328-5. Drum switches shall include a provision for conduit connections. Continuous ratings apply in all cases where any point on the drum switch will be used for any period exceeding 5 minutes. Intermittent ratings shall be used for crane, hoist or other duty where the running time is not more than 50 percent of the total time and the maximum running time is not more than 5 minutes.

Table 2-328-3
RATINGS OF DRUM CONTROLLERS

Size of Controller	Horsepower at Three Phase* 200 or 230 Volts	Horsepower at Three Phase* 460 or 575 Volts	Horsepower at Single Phase 115 Volts	Horsepower at Single Phase 230 Volts
D-0	2	2	1	1-1/2
D-1	5	7-1/2	1-1/2	3

* Does not include three-phase constant-horsepower multispeed motors. For these motors, use the ratings given in the single-phase column.

Table 2-328-4
RATINGS OF MANUALLY OPERATED DRUM CONTROLLERS FOR WOUND-ROTOR MOTOR PRIMARY AND SECONDARY CONTROL*

8-hour Rating, Amperes	Number of Control Points	Horsepower Rating Continuous Duty 230 Volts	Horsepower Rating Continuous Duty 460 or 575 Volts	Horsepower Rating Intermittent Duty 230 Volts	Horsepower Rating Intermittent Duty 460 or 575 Volts	Service-limit Current Rating Amperes
50	5 or 6	15	25	15	25	58
100	6 or 7	30	50	40	75	115
150	7 or 8	50	100	60	125	173
300	9 or 10	100	200	150	300	345

* Drum Controllers shall open all ungrounded lines of a three-phase primary circuit.

Table 2-328-5
RATINGS OF MANUALLY OPERATED DRUM CONTROLLERS FOR WOUND-ROTOR MOTOR, SECONDARY CONTROL ONLY*

8-hour Rating, Amperes	Number of Control Points	Horsepower Ratings at 230, 460 or 575 Volts	Service-limit Current Rating, Amperes
100	11	50	115
150	11	100	173
300	11	300	345
600	11	750	690

* Drum controllers for starting duty only.

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For starting duty only, the number of control points shall be permitted to be from 8 to 10, and the ampere and horsepower ratings for the 100- to 300-ampere sizes shall be permitted to be doubled provided a contactor of the proper rating is used to shunt the controller on the final point. Under similar conditions for the 600-ampere size, the rating shall be permitted to be increased to 1000 amperes and 1250 horsepower.

NEMA Standard 5-18-1964.

2-328.25 RATINGS OF RESISTORS FOR MOTOR SECONDARY CIRCUITS

Resistors for the secondary circuits of wound-rotor motors used with manually operated controllers, shall be rated as follows:

a. *50 Horsepower and Less* – Class No. 114 or 115 (see Part ICS 2-213).

b. *More than 50 Horsepower* – Class No. 132, 133, 134 or 135 (see Part ICS 2-213).

NEMA Standard 5-18-1964.

2-328.26 RATINGS OF MOTOR OPERATED DRUM CONTROLLERS FOR SECONDARY CIRCUITS OF WOUND-ROTOR MOTORS

The ratings of alternating-current motor operated drum controllers for use in the secondary circuits of wound-rotor motors shall be as shown in Table 2-328-6, all speed points being balanced.

NEMA Standard 5-18-1964.

Table 2-328-6
RATINGS OF MOTOR OPERATED DRUM CONTROLLERS FOR SECONDARY CIRCUITS OF WOUND ROTOR MOTORS

8-hour Rating, Amperes	Number of Speed-regulating Points	Service-limit Current Rating, Amperes
300	13	345
300	20	345
600	13	690
600	20	690

MANUFACTURING

2-328.60 CURRENT CARRYING CAPACITY OF RESISTOR WIRES

See Part ICS 2-213.

2-328.61 FACE-PLATE-TYPE CONTROLLERS

Face-plate-type controllers shall be enclosed.

NEMA Standard 5-18-1964.

2-328.62 DRUM CONTROLLER CONDUIT CONNECTIONS

See ICS 2-328.24.

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Part ICS 2-329
AC GENERAL-PURPOSE CLASS A MANUALLY OPERATED FULL-VOLTAGE CONTROLLERS FOR SINGLE-SPEED INDUCTION MOTORS RATED IN FULL-LOAD AND LOCKED-ROTOR CURRENT FOR NONPLUGGING AND NONJOGGING DUTY

Part ICS 2-329 applies to Class A manually operated controllers for squirrel-cage and wound-rotor induction motors for application at 600 volts and less, 50 and 60 hertz. The standards of Part ICS 2-110 also apply to Part ICS 2-329. The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

RATINGS

2-329.20 CONTROLLER RATINGS

Ratings for three-phase manually operated controllers shall be in accordance with Table 2-329-1. Ratings for single-phase manually operated controllers shall be in accordance with Table 2-329-2.

NEMA Standard 5-17-1971.

2-329.100 PREVENTIVE MAINTENANCE GUIDE

See Part ICS 1-115, of NEMA Standards Publication ICS 1, for general maintenance instructions.

Authorized Engineering Information 5-25-1988.

Table 2-329-1
RATINGS FOR THREE-PHASE SINGLE-SPEED FULL-VOLTAGE MANUAL CONTROLLERS FOR NONPLUGGING AND NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	Locked-rotor Current, Amperes at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 Volts	60 Hertz 575 Volts	Service-limit Current Rating,* Amperes
M-0	18	74	70	64	53	42	21
M-1	27	152	140	107	88	70	32

* See ICS 2-327.20.

Table 2-329-2
RATINGS FOR SINGLE-PHASE SINGLE-SPEED FULL-VOLTAGE MANUAL CONTROLLERS FOR NONJOGGING DUTY

Size of Controller	Continuous Current Rating,* Amperes	50 and 60 Hertz Locked-rotor Current, Amperes at 115 Volts	230 Volts	Service-limit Current Rating,* Amperes
M-0	18	80	65	21
M-1	27	130	90	32
M-1P	36	140	135	42

* See ICS 2-327.20.

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Part ICS 2-331

DC GENERAL-PURPOSE CONSTANT-VOLTAGE CLASS B CONTROLLERS

Part ICS 2-331 covers manual and magnetic controllers used with direct-current motors rated 600 volts and less.
Part ICS 2-110 applies to this part unless otherwise specified.
The definitions and standards of NEMA Standards Publication No. ICS 1 also apply to this part.

GENERAL INFORMATION AND FEATURES

2-331.05 TYPES OF FULL-VOLTAGE CLASS B MAGNETIC CONTROLLERS

The types of full-voltage Class B magnetic controllers shall be:

a. An enclosed non-reversing controller consisting of a two-pole line contactor and an overload relay and with provision for separate mounting of the pushbutton.
b. An enclosed non-reversing controller consisting of a two-pole line contactor and an overload relay and with the pushbutton mounted in the cover.
c. An enclosed reversing controller consisting of a two-pole line contactor and an overload relay and with provision for separate mounting of the pushbutton.
d. An enclosed reversing controller consisting of a two-pole line contactor and with provision for separate mounting of the pushbutton.

NEMA Standard 1-22-1954.

2-331.06 REDUCED-VOLTAGE CLASS B MAGNETIC CONTROLLERS FOR GENERAL-PURPOSE APPLICATIONS

An enclosed nonjogging non-reversing Class B controller for motors having a 2 to 1, or less, speed range by field control and having a maximum rating of 5 horsepower at 115 volts and 10 horsepower at 230 volts shall include:

a. A single-pole line contactor.
b. Necessary accelerating means.
c. A single-element overload relay.
d. A starting resistor (Class 115 or 116).
e. Provision for a separately mounted pushbutton.

NEMA Standard 9-18-1957.

2-331.07 REDUCED-VOLTAGE CLASS B MAGNETIC CONTROLLERS FOR MACHINE TOOL APPLICATIONS

Class B controllers for machine tool applications vary by range of field control.

.01 For Motors having a 2 to 1 or Less Speed Range by Field Control

An enclosed jogging-duty controller, Sizes 1 through 9 (see ICS 2-331.23), for motors having a 2 to 1 or less speed range by field control shall include:

a. *For Non-reversing Controllers Without Dynamic Braking:*
    1. A single-pole line contactor.
    2. One to seven accelerating contactors with accelerating means.
    3. A single-element overload relay.
    4. A starting resistor (Class 135 or 136).
    5. Provision for a separately mounted pushbutton.
b. *For Non-reversing Controllers With Dynamic Braking:*
    1. The same equipment as the controller described in par. a.
    2. A dynamic-braking contactor or the equivalent.
    3. A dynamic-braking resistor.
c. *For Reversing Controllers With Dynamic Braking:*
    The same equipment as the controller described in par. b, but with a set of reversing contactors instead of the line contactor.

.02 For Motors having a Speed Range in Excess of 2 to 1 by Field Control

An enclosed jogging-duty controller, Sizes 1 through 9 (see ICS 2-331.23) for motors having a speed range in excess of 2 to 1 by field control shall include:

a. *For Non-reversing Controllers Without Dynamic Braking:*
    1. A single-pole line contactor.

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2. One to seven accelerating contactors with accelerating means.
3. A single-element overload relay.
4. A starting resistor (Class 135 or 136).
5. Means for full-field starting.
6. Field acceleration means.
7. Provision for a separately mounted pushbutton.

b. *For Non-reversing Controllers With Dynamic Braking:*
1. The same equipment as the controller described in par. a.
2. A dynamic-braking contactor or the equivalent.
3. A dynamic-braking resistor.

c. *For Reversing Controllers With Dynamic Braking:* The same equipment as the controller described in par. b, but with a set of reversing contactors instead of the line contactor.

NEMA Standard 9-18-1957.

2-331.08 NUMBER OF ACCELERATING CONTACTORS FOR REDUCED VOLTAGE CONTROLLERS

The number of accelerating contactors provided in reduced voltage magnetic controllers shall be in accordance with Table 2-331-4.

NEMA Standard 9-18-1957.

RATINGS

2-331.20 HORSEPOWER RATINGS OF DC DRUM SWITCHES

The ratings of reversing and non-reversing drum switches shall be in accordance with Table 2-331-1.

Eight-hour ratings shall be used in all cases where any point on the drum switch is in the circuit for any period exceeding 5 minutes. Intermittent ratings shall be used for crane, hoist or other duty where the running time does not exceed 50 percent of the total time and the maximum running time does not exceed 5 minutes.

See Part 1-112 of NEMA Standards Publication No. ICS 1.

NEMA Standard 8-10-1949.

Table 2-331-1
DC DRUM SWITCH RATINGS

8-hour Rating, Amperes	8-hour Ratings		Intermittent-duty Ratings	
	Horsepower Rating at		Horsepower Rating at	
	115 Volts	230 Volts	115 Volts	230 Volts
50	5	10	7.5	15
100	10	25	15	30
150	20	40	25	50
300	40	75	50	100

2-331.21 HORSEPOWER RATINGS OF FULL-VOLTAGE MANUALLY OPERATED DC CONTROLLERS

The horsepower ratings of full-voltage manually operated controllers (including reversing starter controllers), with or without overload relay or other auxiliary devices and enclosed in any type of enclosure, shall be in accordance with Table 2-331-2.

NEMA Standard 11-12-1953.

Table 2-331-2
MANUALLY OPERATED DC CONTROLLER RATINGS

Size of Controller	8-hour Open Rating, Amperes	Horsepower at	
		115 Volts	230 Volts
0	15	1	1-1/2
1	25	1-1/2	2

2-331.22 HORSEPOWER RATINGS OF FULL-VOLTAGE DC MAGNETIC CONTROLLERS

The horsepower ratings of full-voltage magnetic controllers shall be in accordance with Table 2-331-3.

NEMA Standard 1-22-1954.

Table 2-331-3
FULL-VOLTAGE MAGNETIC DC CONTROLLER RATINGS

Size of Controller	8-hour Open Rating, Amperes	Horsepower at	
		115 Volts	230 Volts
0	15	1	1
1	25	1-1/2	2

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2-331.23 HORSEPOWER RATINGS OF REDUCED-VOLTAGE DC MAGNETIC CONTROLLERS

The horsepower ratings and the number of accelerating contactors of the controllers described in ICS 2-331.07 shall be in accordance with Table 2-331-4.

NEMA Standard 5-12-1975.

DESIGN TESTS AND PERFORMANCE

2-331.40 SHORT-TIME SURGE CAPABILITY FOR CLASS B CONTROLLERS

A new Class B controller shall be capable of meeting the requirements of ICS 2-110.42 at 15 times the current corresponding to the horsepower rating for 1 second.

For convenience of testing, the duration of the surge capability test shall be permitted to be shortened (to not less than 0.9 seconds) in order to suit the available test current provided that the value of the I^2t (Joule Integral) is maintained.

Suggested Standard for Future Design 1-11-1983.

2-331.41 CIRCUIT OPENING TEST

Class B controllers and direct-current manual starting rheostats shall be capable of opening the circuit on the first point with the motor at rest.

NEMA Standard 8-10-1949.

Table 2-331-4
REDUCED VOLTAGE MAGNETIC DC CONTROLLER RATINGS

Size of Controller and Contactor	8-hour Open Rating, Amperes	115 Volts		230 Volts		550 Volts	
		Horse-power Rating	Number of Accelerating Contactors	Horse-power Rating	Number of Accelerating Contactors	Horse-power Rating	Number of Accelerating Contactors
1	25	3	1	5	1	...	...
2	50	5	2	10	2	20	2
3	100	10	2	25	2	50	2
4	150	20	2	40	2	75	3
5	300	40	3	75	3	150	4
6	600	75	3	150	4	300	5
7	900	110	4	225	5	450	6
8	1350	175	4	350	5	700	6
9	2500	300	5	600	6	1200	7

When a motor has different horsepower ratings at different speeds, the controller rating shall apply to the maximum horsepower rating of the motor.

Line, reversing and final-accelerating direct-current contactors shall be selected in accordance with the above table.

Intermediate accelerating contactors shall be selected so that the 8-hour open rating will be not less than 0.25 × the accelerating peak.

These controllers may be used at their rating with motors of comparable rating provided that the motor is operated within its name plate rating or within a service factor rating not greater than 1.15 times its nameplate rating. If the motor is to be operated at a service factor rating in excess of 1.15 but within standard NEMA service factors, it is recommended that a controller having the next higher horsepower rating be used. (This paragraph has been approved as Authorized Engineering Information.)

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MANUFACTURING

2-331.60 MANUAL CONTROLLERS

Face-plate-type manual controllers shall be enclosed.

NEMA Standard 8-10-1949.

2-331.61 MANUAL SPEED REGULATORS

Face-plate-type manual speed regulators shall have enclosed face plates.

NEMA Standard 8-10-1949.

2-331.62 RESISTOR CLASSIFICATION FOR MANUAL CONTROLLERS

Resistor classifications for dc manual controllers shall be:

a. *For Controllers Rated 50 Horsepower and Less* – Class No. 114 or 115 (see Part ICS 2-213), and

b. *For Controllers Rated More than 50 Horsepower* – Class No. 132, 133, 134 or 135 (see Part ICS 2-213).

NEMA Standard 8-10-1949.

APPLICATION

2-331.80 FIELD PROTECTION

Some motor fields may not be able to withstand continuous excitation at full voltage with the motor at rest. In this case, a field protective (economizer) relay is recommended.

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Part ICS 2-447

AC AUTOMATIC TRANSFER SWITCHES

Part ICS 2-447 covers electromechanical automatic transfer switches rated 600 volts or less, 60 hertz, for use on single-phase and polyphase alternating-current circuits.

The definitions and standards of NEMA Standards Publication No. ICS 1, except for Parts 1-111 and 1-112 as indicated, also apply to this part.

DEFINITIONS

2-447.05 DEFINITIONS

AUTOMATIC TRANSFER SWITCH

An automatic transfer switch is self-acting equipment for transferring one or more load conductor connections from one power source to another.

NEMA Standard 1-14-1975.

BYPASS/ISOLATION SWITCH

A bypass/isolation switch is a manually operated device used in conjunction with an automatic transfer switch to provide a means of directly connecting load conductors to a power source, and of disconnecting the automatic transfer switch.

NEMA Standard 5-19-1986.

CONTACT TRANSFER TIME

Contact transfer time is the time measured from the parting of one set of main contacts to the closing of a second set of main contacts on an alternate power source.

NEMA Standard 1-14-1975.

MONITORED SOURCE DEVIATION

Monitored source deviation is a variation in the power source being monitored that signals the transfer switch to operate.

NEMA Standard 1-14-1975.

a. Typical variations which can be detected are changes in voltage and frequency.
b. "Normal source failure" is a term often used to describe the loss or reduction of voltage supplied by the normal power source. It is one type of monitored source deviation.
c. "Transfer signal" is a term used to describe the signal which is initiated by the monitored source deviation and which signals the automatic transfer switch to operate.

Authorized Engineering Information 1-14-1975.

OPERATING TRANSFER TIME

Operating transfer time is the time measured from the instant of the monitored source deviation to the closing of main contacts on an available alternate power source exclusive of any purposely introduced time delay.

NEMA Standard 1-14-1975.

TOTAL SYSTEM TRANSFER TIME

Total system transfer time is the time measured from the instant of the monitored source deviation in one power source to the closing of main contacts on another power source, including any purposely introduced time delays and engine-generator start-up time. Total system transfer time is a parameter of the total system and not solely of the automatic transfer switch.

NEMA Standard 1-14-1975.

TRANSFER SWITCH

A transfer switch is a device for transferring one or more load conductor connections from one power source to another.

NEMA Standard 1-14-1975.

GENERAL INFORMATION AND FEATURES

2-447.10 CLASSIFICATION OF AUTOMATIC TRANSFER SWITCHES

Automatic transfer switches are classified Type A or Type B as follows:

Type A (PC): An automatic transfer switch that is not intended to provide required overcurrent protection.

Type B (CB): An automatic transfer switch that is intended to automatically provide required overcurrent protection.

NEMA Standard 5-19-1986.

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RATINGS

2-447.20 SYSTEM VOLTAGE RATINGS

The system voltage rating of an automatic transfer switch shall be 120, 208, 240, 480 or 600 volts, single phase or polyphase.

NEMA Standard 1-14-1975.

2-447.21 CONTINUOUS CURRENT RATING

The continuous current rating of an automatic transfer switch shall be in the range of 30 to 4000 amperes, based on an ambient temperature of 40°C.

NEMA Standard 1-14-1975.

2-447.22 RATING BASED ON LOAD CHARACTERISTICS

Automatic transfer switches shall be rated for one or more of the following types of loads:

a. Total system load consisting of any combination of motors, electric discharge lamps, electric heating (resistive) loads and tungsten lamp loads, provided the latter do not exceed 30 percent of the continuous current rating of the transfer switch.
b. Tungsten lamp load consisting entirely of tungsten lamps.
c. Electric discharge lamp load consisting entirely of electric discharge lamps, including fluorescent lamps.
d. Resistive load consisting of heater and other non-inductive loads in which the inrush current does not exceed 150 percent of the continuous current rating of the switch.

NEMA Standard 1-14-1975.

2-447.23 WITHSTAND AND CLOSING RATINGS

Transfer switches shall have withstand and closing ratings, expressed in maximum available fault current (rms symmetrical amperes) at maximum rated voltage, and marked in accordance with UL 1008 and ICS 2-447. The type and rating of any associated protective devices necessary to meet the requirements of UL 1008 shall also be marked on the transfer switch equipment.

The withstand and closing current rating shall be one of the values specified in Column 1 of Table 2-447-1.

NEMA Standard 5-15-1989.

Table 2-447-1
AVAILABLE FAULT CURRENTS AND RESPECTIVE TEST POWER FACTORS AND CORRESPONDING X/R RATIOS

Withstand and Closing Current Rating (RMS Symmetrical Amperes)	Maximum Test Power Factor*	Minimum Corresponding X/R Ratio*
5,000	0.50	1.73
7,500	0.50	1.73
10,000	0.50	1.73
14,000	0.30	3.18
18,000	0.30	3.18
22,000	0.20	4.90
25,000	0.20	4.90
30,000	0.20	4.90
35,000	0.20	4.90
42,000	0.20	4.90
50,000	0.20	4.90
65,000	0.20	4.90
85,000	0.20	4.90
100,000	0.20	4.90
125,000	0.20	4.90
150,000	0.20	4.90
200,000	0.20	4.90

*Columns 2 and 3 of Table 2-447-1 are approved as Authorized Engineering Information.

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Standard withstand and closing ratings are based on transfer switch testing conducted at maximum allowable test circuit power factors and corresponding minimum X/R ratios specified in Table 2-447-1 . When applying transfer switches, consideration should be given to both available fault current and circuit X/R ratio at the point of application.

Authorized Engineering Information 5-15-1989.

2-447.24 INTERRUPTING RATING

Current interrupting ratings shall be expressed in rms symmetrical amperes.

NEMA Standard 5-19-1986.

2-447.25 MOTOR STARTER RATING

Transfer switches intended for a load consisting of a single motor may include overload relays and may be rated in horsepower or in full-load and locked-rotor current.

Authorized Engineering Information 1-14-1975.

DESIGN TESTS AND PERFORMANCE

2-447.40 DESIGN TESTS

Automatic transfer switches shall be capable of meeting the performance tests specified in Underwriters Laboratories Inc. Publication No. UL 1008.

NEMA Standard 1-14-1975.

Bypass/isolation switches shall be capable of meeting the performance tests specified in UL 1008.

NEMA Standard 5-19-1986.

2-447.41 TEST SEQUENCE

The tests referred to in ICS 2-447.40 are usually conducted on enclosed automatic transfer switches in the following order.

a. Normal operation test to verify the correct functioning of controls for automatic and test operation.
b. Overvoltage test to verify the ability of coils to withstand 110 percent of rated voltage for the maximum time during which they are normally energized.
c. Undervoltage test to verify the ability of phase-voltage-sensing relay coils to withstand 95 percent of rated pull-in voltage with the relay armatures open.
d. Overload test to verify the ability of the switch to interrupt specified loads at rated voltage.
e. Temperature test to verify the ability of the switch to carry rated current. (As an alternative, this test may be run after the endurance test.)
f. Endurance test to verify the ability of the switch to operate for a prescribed number of operations under specified conditions. The endurance test requirements for switches used in standby systems are less severe than those for switches used in emergency systems.
g. Dielectric test to verify the ability of the switch to withstand the prescribed dielectric test.
h. Withstand test to verify the ability of the switch, with the contact initially closed, to withstand the prescribed level and duration of available short circuit current.
i. Circuit closing test to verify the ability of the switch to close onto and withstand the prescribed level and duration of available short circuit current.

   Type A transfer switches for which the manufacturer has not assigned a conditional short circuit rating shall withstand the level and duration of available short circuit current for which they are rated.

   Type A transfer switches for which the manufacturer has assigned a conditional short circuit rating shall withstand the available short circuit current for which they are rated until the protective device clears the short circuit.

   Type B transfer switches shall be capable of automatically interrupting the available short circuit current for which they are rated.

   NEMA Standard 5-19-1986.
j. Repeated dielectric test to verify the ability of the switch to withstand a reduced dielectric test after the withstand and circuit closing tests.

   One sample is used to complete the overload, temperature, endurance and dielectric tests. A previously untested sample may be used for the withstand, circuit closing and repeated dielectric tests. When automatic transfer switches are rated for multiple specific loads as listed in ICS 2-447.22, additional samples may be used.

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MANUFACTURING

2-447.60 UNDERVOLTAGE MONITOR

Unless otherwise specified, an automatic transfer switch shall have provision for initiating the transfer of load conductor connections to an alternate power source when the voltage on any phase of the normal power source falls below 70 percent of rated voltage. Provision shall also be made for transferring the connections back to the normal power source when the voltage on all phases of the normal power source returns to at least 90 percent of rated voltage.

NEMA Standard 1-14-1975.

Voltage critical loads may require adjustable voltage-monitoring means.

Authorized Engineering Information 1-14-1975.

2-447.61 TEST SWITCH

An external test switch or terminals for connection to an external test switch shall be provided. Such a test switch shall be connected so that operation of the test switch simulates a failure of the normal power source.

NEMA Standard 1-14-1975.

2-447.62 INTERLOCK

a. The operating mechanism of a transfer switch shall have a mechanical or electromechanical interlock to prevent simultaneous connection of the load to both the normal and alternate power sources.

NEMA Standard 5-19-1986.

b. Bypass/isolation switches shall be provided with necessary interlocks to prevent the unintentional simultaneous connection of two power sources. In addition, bypass/isolation switches provided with overlapping contacts shall be provided with a means of interlocking to prevent the opening of nonload break contacts under load.

NEMA Standard 5-19-1986.

2-447.63 SPACINGS

Except as otherwise specified in the following paragraphs, spacings in automatic transfer switches and bypass/isolation switches shall be not less than those shown in Table 2-447-2.

a. The spacings on printed wiring assemblies may be as small as 0.031 inch if the power to the printed wiring assembly is limited and transient voltages are controlled as specified in Part 1-111 of NEMA Standards Publication No. ICS 1.

b. The spacings given in Table 2-447-2 do not apply to snap switches, lampholders and similar wiring devices which are used as a part of automatic transfer switches.

c. In a circuit involving potentials of not more than 50 volts, the spacings at field-wiring terminals may be 0.125 inch through air and 0.250 inch over the surface, and the other spacings may be 0.063 inch through air and over the surface, provided that insulation and clearances between the low-potential circuit and any high-potential circuit are in accordance with the requirements that are applicable to the high-potential circuit.

NEMA Standard 5-19-1986.

2-447.64 MARKINGS

.01 Automatic Transfer Switches

The nameplate markings for automatic transfer switches shall include the following.

a. Name of manufacturer and catalog number, or the equivalent serial number.
b. Voltage and frequency ratings.
c. Continuous current rating.

Additional markings shall be those required by UL 1008 and shall include the following, where applicable:

d. Suitability for emergency or standby service as defined by the *National Electrical Code.*
e. Suitability for specific loads. See ICS 2-447.22.
f. Suitability for use as service equipment.
g. Interrupting or short circuit ratings.

Type A: Short circuit rating or conditional short circuit rating with the type and rating of the additionally required short circuit protective device.

Type B: Interrupting rating.

h. Horsepower or locked-rotor current ratings at selected voltages for transfer switches intended for use with a single motor only.
i. Cautions or warnings, or both.

.02 Bypass Isolation Switches

The nameplate markings for bypass/isolation switches shall include the following.

a. Name of manufacturer and catalog number, or the equivalent serial number.
b. Voltage and frequency ratings.
c. Continuous current rating.

Additional markings shall be those required by UL 1008 and shall include the following, where applicable:

d. Suitability for emergency or standby service as defined by the *National Electrical Code.*

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e. Interrupting rating or withstandability rating along with the type of short circuit protection necessary to achieve the rating.
f. Cautions or warnings, or both.
g. Operating instructions.

NEMA Standard 5-19-1986.

2-447.65 SERVICE EQUIPMENT

Automatic transfer switches which are designed to suitable for use as service equipment shall:

a. Have spacings in accordance with Table 2-447-2, item .2.
b. Have accessible means to disconnect, independently, both the normal and alternate power sources.
c. Be marked "suitable for use as service equipment."
d. If provided with a neutral, have provision for connection of the service grounding conductor to the neutral terminal in accordance with Table 2-447-3.
e. Be provided with ground fault protection when applied on solidly grounded Wye electrical services of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase for each service disconnect rated 1000 amps or more.
   1. The maximum setting of the ground fault protection shall be 1200 amps.
   2. The maximum time delay shall be one second for ground fault currents equal to or greater than 3000 amperes.
   3. In health care facilities, the GFP on the service disconnect must be coordinated with the GFP on the next downstream feeder to ensure 100% selectivity such that the feeder device and not the service disconnect shall open on ground faults on the load side of the feeder device. A minimum time separation between tripping bands of 6 cycles is required.
   4. The alternate source for emergency systems shall not be required to have ground fault protection of equipment.

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TABLE 2-447-2
SPACINGS

		Minimum Spacings, Inches Nominal Operating Voltage		
		51–150 Volts	151–300 Volts	301–600 Volts
.1 Power Circuits Rated Not More Than 400 Amperes and Control Circuits				
(a) Between any uninsulated live part and (1) an uninsulated live part of the opposite polarity or (2) an uninsulated grounded part other than the enclosure or an exposed metal part	through air or	0.125*	0.250	0.375
	oil over surface	0.250	0.375	0.500
(b) Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable†	shortest distance	0.500	0.500	0.500
.2 Power Circuits Rated Over 400 Amperes and Service				
(a) Between any uninsulated live part and an uninsulated live part of the opposite polarity	through air or	0.500	0.750	1.000
	oil over surface	0.750	1.250	2.000
(b) Between any uninsulated live part and an uninsulated grounded part, exposed metal part, or the walls of a metal enclosure, including fittings for conduit or armored cable†	through air or	0.500	0.500	1.000 ‡
	oil over surface	0.500	0.500	1.000

* The spacing between wiring terminals of opposite polarity and the spacing between a wiring terminal and a grounded part shall be not less than 0.250 inch if short-circuiting or grounding of such terminals may result from projecting strands of wire.
† For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce spacings between the metal piece and uninsulated live parts.
‡ The through-air spacing may be not less than 0.500 inch (1) at the main terminals and (2) between grounded dead metal and the neutral of a 277/480-volt, 3-phase, 4-wire transfer switch.

TABLE 2-447-3
SIZE OF GROUNDING CONDUCTORS

Size of Largest Service Conductor or Equivalent Size of Multiple-conductor Cables*		Size of Grounding Conductor	
Copper	Aluminum	Copper	Aluminum
2 AWG or smaller	0 AWG or smaller	8 AWG	6 AWG
1 or 0 AWG	2/0 or 3/0 AWG	6 AWG	4 AWG
2/0 or 3/0 AWG	4/0 AWG or 250 MCM	4 AWG	2 AWG
Over 3/0 AWG to 350 MCM	Over 250 to 500 MCM	2 AWG	0 AWG
Over 350 to 600 MCM	Over 500 to 900 MCM	0 AWG	3/0 AWG
Over 600 to 1100 MCM	Over 900 to 1750 MCM	2/0 AWG	4/0 AWG
Over 1100 MCM	Over 1750 MCM	3/0 AWG	250 MCM

* The equivalent size for multiple-conductor cables shall be the sum of the circular-mil areas of the individual conductors.

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APPLICATION

2-447.80 EMERGENCY AND LEGALLY REQUIRED SYSTEMS

a. Emergency systems meet the requirements of Articles 517 and 700 of the *National Electrical Code* and the National Fire Protection Association Publication No. 99, *Standard for Health Care Facilities*. Emergency systems are those legally required to automatically supply alternate power within 10 seconds of power interruption—to a number of prescribed functions essential for safety to human life.

b. Legally required standby systems meet the requirements of Article 701 of the *National Electrical Code*. These systems are intended to automatically supply power to selected loads (other than those classed as emergency systems) in the event of failure of the normal source.

Authorized Engineering Information 5-19-1986.

2-447.81 OVERCURRENT PROTECTION

Each service, feeder and branch circuit should have the appropriate short circuit, ground-fault and overload protection, provided either as an integral part of the automatic transfer switch or externally.

Authorized Engineering Information 1-14-1975.

2-447.82 MOTOR TRANSFER

Motors rated approximately 50 horsepower and greater are susceptible to damage if, in an on-off-on operation, they are switched before the residual motor voltage has decayed to a safe level. The high abnormal currents which may result from the out-of-phase relationship between the motor's residual voltage and the voltage of the reconnected power source may also trip overcurrent protective devices and, therefore, should be avoided. Consideration should be given to including controls in an automatic transfer switch to minimize these abnormal currents.

Authorized Engineering Information 1-14-1975.

For a fuller treatment of motor transfer, see NEMA Standards Publication MG-1, *Motors and Generators:* Bus Transfer or Reclosing.

2-447.83 SELECTION OF AUTOMATIC TRANSFER SWITCHES

The following characteristics of normal and alternate power sources should be specified in order to properly match the automatic transfer switch to the system:

a. Voltage.
b. Number of phases.
c. Number of wires.
d. Frequency.
e. Number of switched poles.
f. Type of load as defined in ICS 2-447.22.
g. Continuous current or horsepower, or both, requirements of the load.
h. Available fault current.
i. Whether the switch is intended for emergency or standby service.
j. Whether it is necessary to disconnect the load from both power sources simultaneously.
k. Whether the switch is to be suitable for use as service equipment.
l. Whether the switch is to include integral overcurrent protection.
m. Whether it is necessary to provide a bypass/isolation switch in conjunction with the automatic transfer switch.

Note: When a bypass/isolation switch is provided, it should be compatible with the automatic transfer switch.

n. Features required for particular applications (see ICS 2-447.84).

Authorized Engineering Information 5-19-1986.

2-447.84 FEATURES FOR PARTICULAR APPLICATIONS

Some conditions or requirements of particular applications may make additional features necessary. These may include the following.

a. *Time Delay to Override Monitored Source Deviation*—A fixed or adjustable time delay which delays all signals for operation. This time delay prevents starting of the engine and/or the transfer of the load from the normal power source to the alternate power source during momentary voltage dips or disturbances of the normal power source.*

b. *Time Delay Before Transfer to Alternate Power Source*—A fixed or adjustable time delay which delays the transfer of the load to an available alternate power source. This delay allows an engine-generator time to stabilize at rated voltage and frequency before accepting the load.*

c. *Time Delay Before Transfer to Normal Power Source*—An adjustable time delay which transfers the load back to the normal power source. This delay allows the normal power source time to stabilize before accepting the load. The time delay may be automatically nullified if the alternate power source fails and power is available at the normal power source.

*Applicable to installations where the alternate power source is an engine-generator set.

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d. *Time Delay Before Engine Shutdown* – A fixed or adjustable time delay which delays the shutdown of the engine-generator (alternate power source) after the load is transferred back to the normal power source. This delay allows the engine to run at no load and thereby minimizes the possibility of shutdown due to an increase in the temperature of the cooling water. It also permits the immediate transfer of the load back to the engine-generator in the event that the normal power source has not fully stabilized.*

e. *Time Delay to Limit Cranking* – A fixed or adjustable time delay to limit the cranking time of the engine-generator if the engine fails to start when the normal power source fails.*

f. *Engine Exerciser* – A programmable time switch to initiate the starting of the engine-generator for a preset period of time at preset intervals without transferring the load from the normal to the alternate power source.*

Caution: No-load operation may be detrimental to the engine, and the engine generator manufacturer should be consulted. Paragraph g. should be considered.

g. *Alternate System Exerciser* – A programmable time switch to initiate the starting of the engine-generator and to transfer the load from the normal to the alternate power source for a preset period of time at preset intervals. The load is transferred back to the normal power source at the end of the exercise period.*

Note: Provision should be made for the initiation of immediate retransfer to the normal source in the event of an engine-generator failure during the exercise period.

h. *Auxiliary Contact* – A contact, other than the power contacts, that is part of an automatic transfer switch and is available for connection by the user. The number of contacts, mode of operation and function of the auxiliary contact(s) should be specified.

i. *Engine Start Contact* – A contact that closes if the normal power source fails to initiate cranking of the engine-generator.*

j. *Alternate Source Monitor* – A device(s) that monitors voltage and/or frequency of the load from the normal to the alternate power source until the voltage and/or frequency of the alternate power source reach specified levels.*

k. *Test Switch* – A switch to simulate failure of the normal power source, causing transfer of the load to the alternate power source.

*Applicable to installations where the alternate power source is an engine-generator set.

l. *Close Differential Protection* – A device(s) that monitors all lines of the normal power source and initiates transfer of the load from the normal power source to the alternate power source when any line of the normal power source drops below a predetermined value of voltage; it initiates transfer of the load back to the normal power source when all lines of the normal power source return to within specified limits. This feature is generally used for installations where only a limited reduction in voltage can be tolerated.

m. *Time Delay By-pass Switch* – A momentary contact switch which initiates immediate transfer of the load back to the normal power source, bypassing any optional time delays.

n. *Manual Return-to-normal Switch* – A momentary contact switch which initiates transfer from the alternate to the normal power source where automatic transfer is not desired.

o. *Overcurrent Protection* – The addition of elements to permit the automatic transfer switch to provide running overcurrent protection for a single motor.

p. *Service Equipment* – See ICS 2-447.65.

q. *In-phase Monitor* – A device that monitors the relative voltage and phase angle between the power source to be transferred to and the power from which the transfer is to be made, and initiates transfer when acceptable values of voltage and phase angle are present. Such a device may function on the transfer from either power source.

r. *Delayed Transition* – Provides a timed disconnect of the load from the power sources during transfer primarily to allow decay of motor residual voltage.

s. *Load Disconnect Device* – A device that initiates opening of a pilot contact prior to transfer from either power source and timed closure after transfer. It is used primarily to allow decay of motor voltage, without affecting the speed of transfer.

t. *Closed Transition Switch* – An automatic transfer switch providing momentary paralleling of both power sources during transfer in either direction. The closed transition is possible only when the sources are properly interfaced and synchronized.

u. *Bypass/isolation Switch* – A switch that may provide any of the following features and function:

1. Load break contacts,
2. Overlapping contacts,
3. Combination of 1. and 2.,
4. Single Source Bypass,
5. Dual Source Bypass,
6. Total isolation of the automatic transfer switch for purpose of maintenance, testing, modification, or repair, and

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7. A means by which the bypass/isolation switch can function as an independent non-automatic transfer switch.

Authorized Engineering Information 5-19-1986.

2-447.85 MAINTENANCE OF AUTOMATIC TRANSFER SWITCHES

A maintenance program and schedule should be established for each particular installation to assure minimum down time. The program should include periodic testing, tightening of connections, inspection for evidence of overheating and excessive contact erosion, removal of dust and dirt, and replacement of contacts when required.

Authorized Engineering Information 1-14-1975.

For additional information, see ICS 1-115.

Authorized Engineering Information 1-11-1989.

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Part ICS 2-448

AC AUTOMATIC COMBINATION OIL FIELD CONTROLLERS

Part ICS 2-448 covers alternating-current 50- and 60-hertz full-voltage specific-purpose magnetic controllers and related control equipment to meet the specific requirements of that portion of the petroleum industry concerned with automatic oil field operation.

The definitions and standards of NEMA Standards Publication No. ICS 1, except for Part 1-111 as indicated, also apply to this part.

RATINGS

2-448.20 CONTROLLER RATINGS

The ratings of combination oil field controllers shall be the same as those shown in Part ICS 2-321 for sizes 00 through 5, for voltages of 230 through 575, three phase.

NEMA Standard 8-20-1962.

MANUFACTURING

2-448.60 DISCONNECTING MEANS

Each controller shall be provided with a motor-circuit switch or circuit breaker which can be opened under load to isolate the circuit.

NEMA Standard 8-20-1962.

2-448.61 CLEARANCE AND CREEPAGE DISTANCES FOR DISCONNECTING MEANS SUITABLE FOR SERVICE EQUIPMENT

Clearance and creepage distances for disconnecting means and the line side of short-circuit protective devices of industrial control, where such disconnecting means and/or short-circuit protective devices are used as service entrance equipment, shall be in accordance with Table 2-448-1.

Table 2-448-1
CLEARANCE AND CREEPAGE DISTANCES OF DISCONNECTING MEANS SUITABLE FOR SERVICE EQUIPMENT

Voltage Between Parts Involved, Volts	Minimum Spacing, Inches			
	Between Uninsulated Live Metal Parts of Opposite Polarity		Between Uninsulated Live Metal Parts and Any Grounded Dead Metal	
	Over Surface	Through Air	Over Surface	Through Air
0–125	3/4	1/2	1/2	1/2
126–250	1-1/4	3/4	1/2	1/2
251–600	2	1	1	1/2

These clearances do not apply to the internal spacings of circuit breakers and interrupters which are designed to the applicable standards of Underwriters Laboratories Inc.

NEMA Standard 1-11-1984.

2-448.62 SHORT-CIRCUIT PROTECTION

Each controller shall be provided with circuit breakers or provisions for fuses of appropriate size to protect the motor branch circuit against overcurrent due to short circuits or grounds.

NEMA Standard 8-20-1962.

2-448.63 LIGHTNING ARRESTERS

Lightning arresters connected to the line side of the disconnecting means shall be provided for all phases in each controller.

NEMA Standard 8-20-1962.

2-448.64 CONTACTORS

Each controller shall be provided with a three-pole magnetic contactor.

NEMA Standard 8-20-1962.

2-448.65 UNDERVOLTAGE RELEASE

Each controller shall be provided with undervoltage release.

NEMA Standard 8-20-1962.

2-448.66 STARTING OPEN-PHASE PROTECTION

Each controller shall be provided with starting open-phase protection.

NEMA Standard 8-20-1962.

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2-448.67 OVERLOAD PROTECTION

Each controller shall be provided with three overload relays, unless equivalent protection of the motor is otherwise provided. The overload relays, or equivalent protection, if located in the controller or operating through the controller, shall be manually reset.

NEMA Standard 8-20-1962.

2-448.68 PROGRAM TIMER

When required by the particular application, a program time switch shall be provided with a 24-hour dial, having a minimum "ON" interval of not more than 15 minutes and minimum "OFF" interval of not more than 30 minutes. A day omission feature shall be provided when required by the particular application.

NEMA Standard 8-20-1962.

2-448.69 SEQUENCE STARTING PROVISION

When required by the particular application, the controller shall be provided with a means of delaying starting after power restoration, following a power failure. This feature is intended to prevent multiple simultaneous starting and permits normal voltage recovery before starting the motor.

NEMA Standard 8-20-1962.

2-448.70 SELECTOR SWITCH

Each controller shall include a three-position selector switch marked "HAND-OFF-AUTOMATIC" to permit a choice of manually controlled operation or automatic operation.

NEMA Standard 8-20-1962.

2-448.71 GROUNDING PROVISION

A grounding stud (1/4 inch or larger) or lug shall be provided on each enclosure.

NEMA Standard 8-20-1962.

2-448.72 ENCLOSURE

Each controller shall be enclosed in an enclosure that is suitable for outdoor applications (see NEMA Standards Publication No. ICS 6) and equipped with a threaded conduit hub at the top and knockouts at the bottom. If ventilating louvers are provided, the openings shall be protected by a mesh screen having a wire gauge in the range of 14 to 18 AWG, or the equivalent.

The enclosure shall be provided with a hinged door, interlocked with the disconnecting means. There shall be provision for locking this door.

Each controller shall have provision for mounting either on a flat surface or on a pole.

NEMA Standard 8-20-1962.

2-448.73 WIRING DIAGRAMS

Wiring diagrams shall be attached to or placed in a pocket of the controller enclosure.

NEMA Standard 8-20-1962.

2-448.74 OVERLOAD RELAY CURRENT ELEMENT TABLE

When overload relays are provided, an overload relay current element selection table shall be attached to the enclosure. This table shall be based on operation in the sun at an ambient temperature of 104°F, as measured by a shaded thermometer.

NEMA Standard 8-20-1962.

2-448.100 PREVENTIVE MAINTENANCE GUIDE

See Part ICS 1-115, of NEMA Standards Publication ICS 1, for general maintenance information.

Authorized Engineering Information 5-25-1988.

2-448.101 SPECIFIC MAINTENANCE INSTRUCTIONS

For lightning arresters, follow manufacturer's instructions.

Authorized Engineering Information 5-25-1988.

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Part ICS 2-449

AC AUTOMATIC COMBINATION IRRIGATION PUMP CONTROLLERS

Part ICS 2-449 covers alternating-current 50- and 60-hertz full-voltage specific-purpose magnetic controllers and related control equipment to meet the specific requirements for automatic irrigation pump controllers.

The definitions and standards of NEMA Standards Publication No. ICS 1, except for part 1-111 as indicated, also apply to this part.

RATINGS

2-449.20 CONTROLLER RATINGS

The ratings of combination irrigation pump controllers shall be the same as those shown in Part ICS 2-321 for motors rated in horsepower or in Part ICS 2-327 for motors rated only in full-load and locked-rotor current for Sizes 1 through 5, for 600 volts and less.

NEMA Standard 11-17-1966.

MANUFACTURING

2-449.60 DISCONNECTING MEANS

Each controller shall be provided with an externally operable motor-circuit switch* or circuit breaker which may be opened under load to disconnect the motor and control from the power source.

NEMA Standard 11-17-1966.

*When required by the particular application, the switch should meet the requirements for service entrance equipment.

Authorized Engineering Information 11-17-1966.

2-449.61 CLEARANCE AND CREEPAGE DISTANCES FOR DISCONNECTING MEANS SUITABLE FOR SERVICE EQUIPMENT

Clearance and creepage distances for disconnecting means and the line side of short-circuit protective devices of industrial control, where such disconnecting means and/or short-circuit protective devices are used as service entrance equipment, shall be in accordance with Table 2-449-1.

These clearances do not apply to the internal spacings of circuit breakers and interrupters which are designed to the applicable standards of Underwriters Laboratories Inc.

NEMA Standard 1-11-1984.

2-449.62 SHORT-CIRCUIT AND GROUND-FAULT PROTECTION

Each controller shall be provided with a circuit breaker or provisions for fuses of appropriate size to protect the motor branch circuit against overcurrent due to short circuits or grounds.

NEMA Standard 11-17-1966.

2-449.63 OVERLOAD PROTECTION

Each controller shall be provided with three overload relays unless equivalent protection of the motor is otherwise provided.

NEMA Standard 1-11-1984.

Table 2-449-1
CLEARANCE AND CREEPAGE DISTANCES OF DISCONNECTING MEANS SUITABLE FOR SERVICE EQUIPMENT

Voltage Between Parts Involved, Volts	Minimum Spacing, Inches			
	Between Uninsulated Live Metal Parts of Opposite Polarity		Between Uninsulated Live Metal Parts and Any Grounded Dead Metal	
	Over Surface	Through Air	Over Surface	Through Air
0–125	3/4	1/2	1/2	1/2
126–250	1-1/4	3/4	1/2	1/2
251–600	2	1	1	1/2

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2-449.64 OVERLOAD RELAY CURRENT ELEMENT TABLE

When overload relays using interchangeable current elements are provided, an element selection table shall be attached to the enclosure.

NEMA Standard 11-17-1966.

2-449.65 CONTROL CIRCUIT

The control circuit shall provide the necessary connections for either three-wire or two-wire control. There shall be mounted on the enclosure a three-position selector switch to provide for manual or automatic operation, and an OFF position.

NEMA Standard 11-17-1966.

2-449.66 GROUNDING PROVISION

A grounding stud (1/4 inch or larger) or lug shall be provided on each enclosure.

NEMA Standard 11-17-1966.

2-449.67 ENCLOSURE

Each controller shall be enclosed in an enclosure which is suitable for outdoor applications (see NEMA Standards Publication No. ICS 6) and equipped with a threaded conduit hub at the top and knockouts at the bottom. If ventilation is required, the openings shall be so protected as not to permit rain to reach live parts.

The enclosure shall be provided with a hinged door, interlocked with the disconnecting means. There shall be provision for locking this door. When required by the particular application, space shall be provided in the enclosure for equipment such as pressure switch, back spin timer, and lightning arresters.

Each controller shall have provision for mounting either on a flat surface or on a pole.

NEMA Standard 11-17-1966.

2-449.68 WIRING DIAGRAMS

Wiring diagrams shall be attached to or placed in a pocket of the controller enclosure.

NEMA Standard 11-17-1966.

2-449.100 PREVENTIVE MAINTENANCE GUIDE

See Part ICS 1-115, of NEMA Standards Publication ICS 1, for general maintenance information.

Authorized Engineering Information 5-25-1988.

2-449.101 SPECIFIC MAINTENANCE INSTRUCTIONS

When lightning arresters are used, follow manufacturer's instructions.

Authorized Engineering Information 5-25-1988.

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Appendix A

REFERENCED STANDARDS

In this publication reference is made to the following standards listed below. Copies are available from the indicated sources.

I
American National Standards Institute
1430 Broadway
New York, NY 10018

C37.90-1978	*Relays and Relay Systems Associated with Electrical Power Apparatus*
C62.2-1987	*Guide for the Application of Gapped Silicon-Carbide Surge Arresters for Alternating Current Systems*

II
American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103

B 8-1986	*Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*

III
Association of Iron and Steel Engineers
Three Gateway Center
Suite 2350
Pittsburgh, PA 15222

AISE Std. No. 1-1968	*DC Mill Motor Standard*
AISE Std. No. 1-A-1964	*AC Mill Motor Standard*
AISE Std. No. 6-1969	*Cranes*
AISE Std. No. 11-1972	*Brake Standards for Mill Motors*

IV
Crane Manufacturers Association of America
1326 Freeport Road
Pittsburg, PA 15238

CMAA No. 70-1983	*Cranes – Service Classes*

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V
Electronic Industries Association
2001 Eye Street, NW
Washington, DC 20006

RS 232-D-1987*	*Interface between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange*
RS 422-A-1978	*Electrical Characteristics of Balanced Voltage Digital Interface Circuits*

VI
Institute of Electrical and Electronic Engineers
345 East 47th Street
New York, NY 10017

C37.09-1979*	*Test Procedure for AC High Voltage Circuit Breaker Rated on a Symmetrical Current Basis*
C37.26-1972(R 1978)	*Guide for Methods of Power Factor Measurement for Low-Voltage Induction Test Circuits*
IEEE 4-1978	*Standard Techniques for High Voltage Testing*
IEEE 100-1988	*Standard Dictionary of Electrical and Electronics Terms*
IEEE-141-1986	*Recommended Practice for Electric Power Distribution for Industrial Plants*
IEEE 344-1987*	*Recommended Practice for Seismic Qualification of Class I Electric Equipment for Nuclear Power Generating Stations*

VII
International Electrotechnical Commission
(copies available from ANSI, 1430 Broadway, New York, NY 10017)

IEC 56 1987	*High-Voltage Alternating-Current Circuit Breakers, Part 1: General and Definitions*

VIII
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

AB 1-1986	*Molded Case Circuit Breakers*
CP1-1988	*Shunt Capacitors*
DC 2-1982 (R 1988)	*Quick Connect Terminals*

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ICS 1-1988	*General Standards for Industrial Control and Systems*
ICS 2.3-1983 (R 1988)	*Instructions for Handling, Installation, Operation, and Maintenance of Motor Control Centers*
ICS 3-1988	*Industrial Systems*
ICS 6-1988	*Enclosures for Industrial Controls and Systems*
MG 1-1987*	*Motors and Generators*
MG 2-1983	*Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators*
WC 5-1973 (R 1979, 1985) (ICEA S-61-402, 3rd Ed.)	*Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy*
	Guide for Development of Metric Standards

IX
National Fire Protection Association
Batterymarch Park
Quincy, MA 02269

NFPA 70-1987*	*National Electrical Code*
99-1987*	*Standard for Health Care Facilities*
NFPA 79-1987*	*Electrical Standard for Industrial Machinery*

X
National Fluid Power Association
3333 North Mayfair Road
Milwaukee, WI 53222

NFPA T3.29.2M-1976 (R 1982)	*Pressure Switch Pressure Rating Supplement #3 to NFPA Recommended Standard for Verifying the Fatigue and Static Pressure Rating of the Pressure Containing Envelope of a Metal Fluid Power Component*

XI
Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 353-1974*	*Limit Controls*
UL 486A-1980*	*Wire Connectors and Soldering Lugs for Use with Copper Conductors*

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UL 486E-1988*	*Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors*
UL 506-1979*	*Specialty Transformers*
UL 508-1984*	*Industrial Control Equipment*
UL 674-1978*	*Electric Motors and Generators for Use in Hazardous Locations, Class I, Groups C and D, Class II, Groups E, F, and G*
UL 698-1984*	*Industrial Control Equipment for Use in Hazardous (Classified) Locations*
UL 845-1988*	*Motor Control Centers*
UL 873-1988*	*Temperature-indicating and -regulating Equipment*
UL 1008-1989*	*Automatic Transfer Switches*

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status, are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below.

Purpose of Standards

National Electrical Manufacturers Association standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist purchasers in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard. *(Standardization Policies and Procedures, p. 1)*

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p.8)

Categories of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.

(Standardization Policies and Procedures, pp. 7 & 16)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment, and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 7 & 16)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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INDUSTRIAL CONTROL AND SYSTEMS SECTION OF THE NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

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Milwaukee, WI 53201

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Entrelec Division
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Amerace Corporation
Livingston, NJ 07039

Asea Controls
Wichita Falls, TX 76302

Automatic Switch Company
Florham Park, NJ 07932

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Florence, KY 41042

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Raleigh, NC 27609

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Arrow-Hart Components Products
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Control Device Operation
Standish, ME 04084

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