NEMA Standards Publication ICS 2-2000

Industrial Automation Control Products and Systems:
Starters, Contactors, and Overload Relays
Rated not more than 2000 Volts AC or 750 Volts DC

Part 9-2002
AC Vacuum-Break Magnetic Controllers Rated 1500 Volts AC

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Foreword

This Standards Publication was prepared by a technical committee of the NEMA Industrial Automation Control Products and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes the indicated NEMA Standards Publication. This Standards Publication is an addition part to ICS 2-2000 and will be included into that standards publication when it is next revised.

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:

a. environmental conditions
b. system design
c. equipment selection and application
d. installation
e. operating practices
f. 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.

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To continue to serve the best interests of users of Industrial Control and Systems equipment, the Industrial Automation Control Products 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.

NEMA Standards Publications are subject to periodic review. They are revised frequently to reflect user input and to meet changing conditions and technical progress. Proposed revisions to this Standards Publication should be submitted to:

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This standards publication was developed by the Industrial Automation Control Products and Systems Section. Section Approval of the standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the Section was composed of the following members:

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Alstom Power Conversion—Pittsburgh, PA
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Section 1
GENERAL

1.1 SCOPE

The standards in this part apply to magnetically-operated, full-voltage vacuum-break, non-combination controllers rated 1500 volts for both motor and non-motor loads. The motor-rated controllers are full-voltage for use with squirrel-cage and wound-rotor induction motors. The non-motor loads may be single or three-phase transformer, capacitor, heating or lighting loads.

1.2 PURPOSE

The purpose of this part is to establish standard ratings, marking, construction, and performance requirements for Class V vacuum-break controllers and provide a means to evaluate other vacuum-break controllers which do not qualify for designation as a Class V controller.

1.3 NORMATIVE REFERENCES

The definitions and standards of ICS 1 and ICS 2, Part 1 apply to this Part unless otherwise specified. The test procedures and criteria of UL 508 and UL 486E apply to this Part.

Section 2
DEFINITIONS

available fault current: The calculated or measured short-circuit current, expressed in rms symmetrical amperes, that would flow at the point of installation (application) when the controller would be replaced by a conductor of negligible impedance. Available fault current is also known as prospective current.

Class V controller: An AC vacuum-break magnetic controller having a standard rating for service of 1500 volts or less, capable of interrupting operating overloads but not short circuits or faults beyond operating overloads, and meeting the requirements of this part.

jog (inch): A control function that provides for the momentary operation of a device for the purpose of accomplishing a small movement of the driven machine.

locked-rotor current: The steady-state current taken from the line with the rotor of a motor locked and with rated voltage (and rated frequency in the case of AC motors) applied to the motor. A locked-rotor current rating is often designated by the term "LRA".

NOTE—The maximum interrupt rating shall be the rated locked-rotor current. See Table 9-4-1 and Table 9-4-3.

plugging: A control function that provides braking by reversing the motor line voltage polarity or phase sequence so that the motor develops a counter-torque that exerts a retarding force.

rated continuous current: The maximum constant current that can be carried continuously without exceeding established temperature-rise limitations under prescribed test conditions.

rated insulation voltage (U_i): The value of voltage to which dielectric voltage tests, clearances and creepage distances are referred. In no case does the maximum value of the rated operational voltage exceed that of the rated insulation voltage.

rated operational current (I_e): The value of current which determines the application of the motor controller. Rated operational current is assigned by the manufacturer and takes into account the rated operational voltage and the rated supply frequency.

rated operational voltage (U_e): The value of voltage, assigned by the manufacturer, which, in combination with a rated operational current, determines the application of the motor controller.

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short-circuit protective device (SCPD): A device designed to provide protection against overcurrents that are greater than operating overloads, e.g. a fuse or circuit breaker.

short-circuit rating: The rating that defines the maximum potential fault conditions under which a non-combination controller may be installed in accordance with Article 110 of NFPA (70) NEC. The short-circuit withstand rating is expressed in terms of an available fault current, maximum nominal application voltage, and the designation of an associated short-circuit protective device (SCPD) required for the rating. This designation includes the type or class or specific brand of SCPD and its maximum current rating.

vacuum-break: A term applied to a device that interrupts an electric circuit in a vacuum.

vacuum contactor: A contactor with vacuum-break main contacts.

Section 3
CLASSIFICATIONS

A vacuum-break controller may be designated a NEMA Class V controller where it has a standard size designation and meets the requirements of this part.

Section 4
CHARACTERISTICS AND RATINGS

4.1 CURRENT RATINGS

4.1.1 Rated Continuous Current

The rated continuous currents of Class V controllers shall be as shown in Table 9-4-1 and Table 9-4-3.

4.1.2 Rated Operational Current

The rated operational current of a Class V motor controller is the motor full-load current corresponding to its horsepower rating at any given voltage. See Annex A.

Class V controllers are also rated in terms of motor full-load current (MFLC) and locked-rotor current (LRA).

These controllers may be assigned a number of combinations of rated operational voltage and rated operational current.

4.1.3 Rated Locked-Rotor Currents

The rated locked-rotor currents of vacuum-break controllers shall be eight times the rated continuous currents. See Table 9-4-1 and Table 9-4-3.

4.2 VOLTAGE RATINGS

4.2.1 Rated Operational Voltages

The rated operational voltages of Class V controllers shall be as shown in Table 9-4-2.

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4.2.2 Rated Insulation Voltage (U_i)

The rated insulation voltage of vacuum-break magnetic controllers shall be 1500 volts.

4.3 BASIS OF RATINGS

The ratings of Class V controllers are based on the use of three-pole contactors for three-phase loads and two-pole contactors for single-phase loads.

4.3.1 Horsepower Ratings

Class V controller horsepower ratings for limited plugging and limited jogging duty shall be in accordance with Table 9-4-1 and Table 9-4-3. These ratings also apply for non-plugging and non-jogging applications.

These ratings can be used for occasional jogging or plugging for limited time periods, such as pump clearing. 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.

A Class V controller shall not be used with a motor whose full-load current or locked-rotor current exceeds the controller ratings given in Table 9-4-1 and Table 9-4-3.

The manufacturer may assign equivalent kilowatt ratings at 50 hertz voltages.

Class V controllers may be used to control motors rated in terms of motor full-load current (MFLC) and locked-rotor current (LRA) where the MFLC and LRA do not exceed the MFLC and LRA ratings shown in Table 9-4-1 and Table 9-4-3.

4.3.2 Three-Phase Horsepower Ratings for Plug-Stop, Plug-Reverse, or Jogging Duty

The horsepower ratings of Class V controllers for three-phase 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 beyond that described in clause 4.3.1 shall be in accordance with Table 9-4-4. A Class V controller shall not be used with a motor whose full-load current, locked-rotor current, or horsepower rating exceeds the values given in Table 9-4-4.

4.4 MAXIMUM CIRCUIT-CLOSING INRUSH CURRENTS

The maximum peak circuit-closing inrush currents for Class V controllers shall be as shown in Table 9-4-5. These circuit-closing currents are based on rated locked-rotor currents and the ratio of peak inrush current to rms current. The values are verified by the making and breaking capacity tests.

4.5 NON-MOTOR LOADS

4.5.1 Resistive and Lighting Loads

Vacuum-break controllers may be used to control tungsten and electrical discharge lighting loads and other resistive loads which do not exceed the rated continuous current of the controller.

4.5.2 Transformer Switching

Class V controller transformer switching ratings shall be in accordance with Tables 9-4-6A and 9-4-6B. A vacuum-break controller may be used to switch transformer loads where:

a. The transformer rated primary current does not exceed the rated continuous current of the controller,

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b. and the transformer inrush current (worst case peak) does not exceed the maximum circuit-closing inrush current of the controller. See Table 9-4-5 for Class V controller maximum peak circuit closing inrush capabilities.

4.5.3 Capacitor Switching

Class V controller capacitor switching ratings shall be in accordance with Tables 9-4-7A through 9-4-7F. A vacuum-break controller may be used to switch a capacitor where:

a. the rated continuous current of the controller is equal to or greater than 135 percent of the ampere rating of the capacitor as it is derived from the kVA rating, and,

b. the capacitor circuit has sufficient impedance to limit the capacitor inrush current to not more than the maximum circuit-closing inrush current rating for the controller selected. The capacitor inrush current can be limited by adding resistance or inductance to the capacitor circuit. For further information on capacitor bank switching see Clause 9 of ICS 2, Part 2.

4.6 SHORT-CIRCUIT RATINGS

The short-circuit ratings of non-combination vacuum-break controllers shall be expressed as a maximum available fault current (in rms symmetrical amperes), maximum nominal application voltage, and the designation of an associated short-circuit protective device (SCPD) required for the rating. This designation includes the type, or class, or specific brand of SCPD and its maximum current rating.

Vacuum-break controllers shall have the minimum short-circuit withstand current ratings shown in Table 9-4-8 and in addition, shall be permitted to have greater short-circuit withstand ratings in accordance with Table 9-4-9.

Section 5
PRODUCT MARKING, INSTALLATION, AND MAINTENANCE INFORMATION

5.1 PRODUCT MARKING

Each vacuum-break controller or the equipment that incorporates such a controller shall include in the form of a nameplate, label, or instruction material the following information:

5.1.1 Nameplate or Label Attached to Device

The following is shown on nameplate or label attached to the device:

a. manufacturer's name or trademark
b. catalog or type designation
c. NEMA size designation if the manufacturer claims compliance as a Class V controller
d. rated operational voltage
e. rated continuous current
f. rated frequency
g. horsepower rating

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5.1.2 Nameplate, Label, or Instruction Material Attached to or Packaged with Equipment

The following is shown on nameplate, label or instruction material attached to or packaged with the equipment:

a. auxiliary contact ratings
b. short-circuit withstand rating(s)
c. acceptable conductor sizes where lugs are provided
d. tightening torque
e. wire limitations, e.g., "for use with 75°C wire"
f. coil inrush VA
g. coil power and VA with armature sealed

5.1.3 Shown on or Adjacent to Coil

Shown on or adjacent to coil is the control voltage and frequency.

5.1.4 Shown on Auxiliary Contact

The following is shown on auxiliary contact:

a. manufacturer's name or trademark
b. catalog or type designation
c. contact rating

5.2 MARKING LIMITATIONS

No ratings or characteristics that conflict with this standard shall be shown.

5.3 INSTRUCTIONS FOR INSTALLATION, OPERATION, AND MAINTENANCE

Information shall be provided by the manufacturer for installation, operation, and maintenance of the controller during operation and measures to be taken with regard to the controllers in the event of a short circuit. See Annex B for example.

Section 6
SERVICE AND STORAGE CONDITIONS

See ICS 1, Clause 6 for service and storage conditions.

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Section 7
CONSTRUCTION

7.1 CLEARANCES AND CREEPAGE DISTANCES

Vacuum-Break controllers rated 1500 volts shall have the clearances and creepage distances specified in Table 9-7-1. Electrical clearance may optionally be verified by impulse testing in accordance with NEMA ICS 1, Annex A.

7.2 MULTI-POLE OPERATION

The moving contacts of vacuum-break controllers shall be so mechanically coupled that all poles make and break substantially together whether operated manually or magnetically.

7.3 TERMINALS AND WIRING

7.3.1 Terminals

Class V and other vacuum-break controllers shall be permitted to be supplied with or without wire connectors (lugs). Where wire connectors are furnished with Class V controllers they shall accommodate the copper conductor sizes specified in Table 9-7-2.

Where wire connectors are not supplied, the manufacturer shall:

a. Recommend by catalog designation or equivalent, the wire connectors to be used.

b. Provide instructions regarding maintaining the required minimum spacings specified in Table 9-7-1.

7.3.2 Terminal Identification and Connections for Full-Voltage Single-Speed Class V Motor Controllers

Class V controllers shall be marked and wired in accordance with Table 9-7-3, where applicable. Additional power circuit terminal markings in accordance with IEC standards are permitted.

The sequence of line and load terminal markings shall be L1, L2, L3 and T1, T2, T3, reading from left to right when looking at the front of the controller. Where the leads come in to the left or right of the controller, the sequence of lead numbering shall be the same as if the controller were rotated to these positions.

The primary of the control circuit transformer, where used, shall be connected between L1 and L2. Control circuit devices, such as push-buttons, master switches, relays and interlocks, shall be connected between the ungrounded line of the control circuit and the coil. Exceptions include control circuits controlled by double-pole contacts opening both sides of a circuit, and motor running over-current device contacts.

A control circuit step-down transformer, that requires an overcurrent protective device, shall be protected in accordance with NFPA 70 (NEC). See Figure 2-7-1 of ICS 2, Part 2.

Where 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 2-7-3 of ICS 2, Part 2.

Control circuit markings for reversing controllers shall be 1, 2, 3, 4, 5, 6 and 7 and in accordance with Figure 2-7-4 of ICS 2, Part 2.

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7.3.3 Wiring Space

Enclosures for vacuum-break controllers shall be built in such a manner as to provide no less than the minimum wire bending space shown in Annex C. The wiring space is measured from each line terminal to the enclosure wall towards which the wire will be directed upon leaving the lug or connector.

7.4 LOCATION OF OVERLOAD RELAY CONTACTS IN CIRCUIT

The contacts of overload relays are located as shown in Figure 2-7-3 and 2-7-4 of ICS 2, Part 2 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.

Analysis of Figure 2-7-4 of ICS 2, Part 2 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.

The foregoing applies to the control circuit shown in Figure 2-7-3 of ICS 2, Part 2 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.

7.5 MECHANICAL INTERLOCKING OF MAGNETIC CONTACTORS

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

7.6 ELECTRICAL INTERLOCKING OF MAGNETIC CONTACTORS

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

7.7 THE INSULATION RATING OF CURRENT TRANSFORMERS USED WITH CLASS V CONTROLLERS

The insulation rating of current transformers used with Class V controllers shall be 1500 volts.

Section 8
PERFORMANCE REQUIREMENTS AND TESTS

8.1 TYPE TESTS

Vacuum-break controllers rated 1500 volts shall meet the applicable test and performance requirements of Table 9-8-1 and referenced subclauses.

Type tests are intended to verify compliance of the design of vacuum-break controllers with this standard. They comprise the verification of:

a. temperature-rise limits (8.3.2)
b. dielectric properties (8.3.3)
c. rated making and breaking capacity (8.3.4.)

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d. endurance performance (8.3.5)
e. performance under short-circuit conditions (8.3.6)
f. terminal performance (8.3.8)
g. short-time operating capability (8.3.9)
h. operation and operating limits (8.3.10)

8.2 ROUTINE TESTS

Routine tests are intended to detect faults in materials and workmanship and to ascertain proper functioning of the equipment. They shall be made on each individual piece of equipment under the same, or equivalent, conditions as those specified to type tests.

Routine tests for vacuum-break controllers comprise:

a. operation and operating limits (8.3.10)
b. dielectric tests (8.3.3)

8.3 COMPLIANCE WITH PERFORMANCE REQUIREMENTS

8.3.1 Test Sequences

Each test sequence is made on a new sample; however, more than one test sequence or all test sequences may be conducted on one sample. The sequence of tests shall be as shown in Table 9-8-1.

8.3.2 Temperature Rise

The standards of ICS 1 apply. The temperature rise of current-carrying parts of a new controller shall be measured while enclosed when carrying a current corresponding to its rated continuous current on all poles. Conductors shall be selected in accordance with ICS 1, Clause 8. The enclosure shall be the smallest practicable enclosure that provides minimum wire bending space (See Annex C) for the device. The device shall have passed the test if the temperature rise limits of ICS 1, Clause 8 are not exceeded.

An open type device shall be mounted in an enclosure considered representative of the intended use. The maximum enclosure dimensions are to be determined by one of the following methods:

a. 150 percent of the dimensions of the device—that is, length, width, and height.

b. The intended enclosure, which may be larger than indicated in item a, provided the size is marked on the device, or on instruction material attached to, or packaged with, the controller and the enclosure includes the minimum wire bending space specified in Annex C.

8.3.3 Dielectric Properties

The power frequency dielectric test procedures of ICS 1, Clause 8 apply. The test voltage shall be 5375 volts (2000 volts plus 2.25 times 1500 volts). The test shall be considered to have been passed if there is no puncture, flashover, or indication of breakdown.

8.3.4 Making and Breaking Capacity

A vacuum-break controller rated 1500 volts shall be capable of making and breaking currents without failure under the conditions stated in Table 9-8-2 when wired in accordance with the appropriate diagram of Figure 9-8-1. Diagrams A and B show connections for a device for three-phase and single-phase loads.

See Annex A for full-load currents corresponding to horsepower ratings.

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For the test, equipment shall be mounted in an appropriate enclosure and wired so as to represent the intended use.

The contacts shall open completely and close completely when the controller is operated magnetically at rated control voltage.

During the test there shall be no permanent arcing, no flashover between poles, no blowing of the fusible element in the simulated ground circuit and no welding of the contacts.

8.3.5 Endurance

A vacuum-break controller rated 1500 volts shall be capable of making and breaking current without failure under the conditions stated in Table 9-8-4.

For the test, equipment shall be mounted in an appropriate enclosure and wired so as to represent the intended use, per the appropriate diagram of Figure 9-8-1.

During the test there shall be no permanent arcing, no flashover between poles, no opening of the fusible element in the simulated ground circuit and no welding of the contacts.

8.3.6 Ability to Make and Withstand Short-Circuit Currents

Vacuum-break controllers shall be so constructed as to be capable of withstanding the thermal, dynamic and electrical stresses resulting from short-circuit currents under the conditions specified in this standard.

8.3.6.1 Procedure

The controller, circuit breaker or disconnect switch and fuses shall be mounted as in service, in the smallest enclosure specified, in clean and new condition. Any enclosure opening normally closed in service shall be closed for the test.

Non-combination controllers shall be tested with the specified SCPD mounted separate from the controller.

Combination controllers shall be tested with the SCPD mounted in the same enclosure as the controller Where the test is conducted with dummy fuses and current limiters or fuses, the dummy fuses shall be in the same enclosure as the controller and the current limiters or fuses shall be mounted separate from the controller.

The controller SCPD combination shall be connected to the test circuit using 4 ft (1.2 m) conductor attached to each terminal. Where the SCPD is mounted separate from the controller, the conductor length between the SCPD and controller, shall be included in the 4 ft (1.2 m) length. The conductors shall be routed through a 10-12 in. (25-30 cm) length of conduit installed on the controller enclosure.

NOTE 1—The conductors may exceed 4 ft (1.2 m) in length if the excess length is in the test circuit during calibration.

NOTE 2—For controllers rated more than 400 amperes the conductors may be replaced with bus bars equivalent in cross-sectional area.

NOTE 3—Conductors 1/0 or larger may be connected in parallel.

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8.3.6.2 Conductor Type and Size

The conductor shall be copper, the ampacity shall be 125 percent of the motor full load current and the cross-section shall be selected from Table 9-8-5. Reference Annex D.

8.3.6.3 Controller Operation

Controllers shall be operated as in normal service. Electromagnetic controllers shall be operated from a separate supply source with rated values 100% of coil voltage.

8.3.6.4 Test Circuit

The test circuit and its calibration shall be in accordance with UL 508.

8.3.6.5 Overload Relays

Controllers equipped with interchangeable overload relays, or heaters shall be tested with the highest impedance and lowest impedance overload relay or heater and the corresponding SCPDs.

8.3.6.6 Standard Short-Circuit Ratings

The short-circuit tests shall be conducted with the available current according to Table 9-4-8, selected according to the controller current rating.

8.3.6.6.1 Number of Operations

The number of operations for each controller shall be according to Table 9-8-6.

a. Three phase controllers shall be tested with three poles and three overload relays.
b. Single phase controllers shall be tested with:
    1. Two Poles and two overload relays, if supplied, or
    2. Two poles and one overload relay.
c. A separate sample may be used for each operation of the short-circuit test.

8.3.6.6.2 Short-Circuit Withstand Test

The controller shall be in the closed position and the circuit connected to the test sample with a separate switching device. Instantaneous-trip circuit breakers shall be adjusted to their maximum setting, or seventeen times the full load current, if the maximum setting exceeds this value.

8.3.6.6.3 Test Results

The controller will have passed the test when the following conditions are met:

8.3.6.6.4 All Devices

a. The SCPD successfully interrupted the fault current.
b. The fuse between the live pole and the enclosure has not opened.
c. The door or cover shall not be blown open, and it shall be possible to open the door or cover. Deformation of the enclosure is acceptable. To reduce the likelihood of unintentional contact that may involve risk of electric shock from an un-insulated live part, electrical energy – high current levels, or injury to persons from a moving part, an opening in an enclosure shall comply with either (1) or (2).

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1. For an opening that has a minor dimension (the diameter of the largest cylindrical probe that can be inserted through the opening) less than 1 inch (25.4 mm), such a part or wire shall not be contacted by the UL or IEC articulated probe (reference Fig 7.4 and 7.5 of UL 508).

2. For an opening that has a minor dimension of 1 inch (25.4 mm) or more, such a part or wire shall be spaced from the opening as specified in the table below:

MINIMUM ACCEPTABLE DISTANCE FROM AN OPENING TO A PART THAT MAY INVOLVE A RISK OF ELECTRICAL SHOCK, ELECTRICAL ENERGY-HIGH CURRENT LEVEL, OR INJURY TO PERSONS

Minor Dimension of Opening *†		Minimum Distance from Opening to Part †	
Inches	(mm)	Inches	(mm)
1	(25.4)	6-1/2	(165.0)
1-1/2	(38.1)	8-3/8	(212.7)
2	(50.8)	11-5/8	(295.3)
Over 2 but not more than 3	(Over 50.8 but not more than 76.2)	30	(762.0)

NOTES—

* The minor dimension of an opening is the diameter of the largest cylindrical probe that can be inserted through the opening.

† Interpolation is to be used to determine a value between values specified in the table.

d. There is no damage to the conductors and terminals and the conductors have not separated from the terminals.

e. There is no cracking or breaking of an insulating base to the extent that the integrity of mounting of a live part is impaired.

f. Discharge of parts or any risk of fire shall not occur.

g. Burnout of flexible leads has not occurred.

8.3.6.6.5 Motor control devices

h. The load switching function of the motor control device may be inoperative at the conclusion of the test. The contacts of the motor control device may weld but shall not disintegrate or evaporate.

8.3.6.6.6 Overload relays

i. The current elements have not burned out and have not been damaged and will perform according to the requirements of ICS 2, Part 4.

j. All electronic overloads shall be operable immediately after the test and will perform according to the requirements of ICS 2, Part 4.

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8.3.6.6.7 Combination motor controllers

k. The disconnecting means of the combination motor controller shall be capable of being opened manually with the operating handle. The contacts of the disconnecting means shall not weld.

l. When provided as part of the equipment, neither end of a protective device—such as a fuse, current limiter, or motor short-circuit protector—shall be completely separated from the mounting means, and the line end of a fuse, current limiter, or motor short-circuit protector shall not bridge from the mounting means to dead metal.

8.3.6.7 Short-Circuit Test Covering Fuses and Circuit Breakers

When the tests are performed for three electrical cycles the test is considered to cover the requirements for fuses and circuit breakers.

8.3.6.8 Short-Circuit Ratings—High Capacity

The short-circuit tests shall be conducted with available current according to Table 9-4-9.

8.3.6.8.1 Test Circuit

For the three phase test the test circuit and its calibration shall be in accordance with UL 508.

8.3.6.8.2 Short-Circuit Test

The controller, circuit breaker or disconnect switch shall be in the closed position and the test circuit connected to the test sample with a separate switching device. The test consists of one operation.

Three phase controllers shall be tested with three poles and three overload relays. The three phase test is considered to cover single phase test.

8.3.6.8.3 Test Results

The controller will have passed the test if the following conditions are met:

8.3.6.8.4 All Devices

a. The SCPD successfully interrupted the fault current.

b. The solid AWG wire connected between the live pole and the enclosure shall not open.

c. The door or cover shall not be blown open, and it shall be possible to open the door or cover. Deformation of the enclosure is acceptable. To reduce the likelihood of unintentional contact that may involve risk of electric shock from an un-insulated live part, electrical energy—high current levels, or injury to persons from a moving part, an opening in an enclosure shall comply with either (1) or (2).

1. For an opening that has a minor dimension (the diameter of the largest cylindrical probe that can be inserted through the opening) less than 1 inch (25.4 mm), such a part or wire shall not be contacted by the UL or IEC articulated probe (reference Fig 7.4 and 7.5 of UL 508).
2. For an opening that has a minor dimension of 1 inch (25.4 mm) or more, such a part or wire shall be spaced from the opening as specified in the table below:

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MINIMUM ACCEPTABLE DISTANCE FROM AN OPENING TO A PART THAT MAY INVOLVE A RISK OF ELECTRICAL SHOCK, ELECTRICAL ENERGY-HIGH CURRENT LEVEL, OR INJURY TO PERSONS

Minor Dimension of Opening *†		Minimum Distance from Opening to Part †	
Inches	(mm)	Inches	(mm)
1	(25.4)	6-1/2	(165.0)
1-1/2	(38.1)	8-3/8	(212.7)
2	(50.8)	11-5/8	(295.3)
Over 2 but not more than 3	(Over 50.8 but not more than 76.2)	30	(762.0)

NOTES—

* The minor dimension of an opening is the diameter of the largest cylindrical probe that can be inserted through the opening

† Interpolation is to be used to determine a value between values specified in the table

d. There is no damage to the conductors and terminals and the conductors have not separated from the terminals.

e. There is no cracking or breaking of an insulating base to the extent that the integrity of mounting of a live part is impaired

f. Discharge of parts or any risk of fire shall not occur

g. Burnout of flexible leads has not occurred.

8.3.6.8.5 Motor Control Devices

h. The load switching function of the motor control device may be inoperative at the conclusion of the test. The contacts of the motor control device may weld but shall not disintegrate or evaporate.

8.3.6.8.6 Overload Relays

i. The current elements have not burned out and have not been damaged and will perform according to the requirements of ICS 2, Part 4.

j. All electronic overloads shall be operable immediately after the test and will perform according to the requirements of ICS 2, Part 4.

8.3.6.8.7 Combination Motor Controllers

k. The disconnecting means of the combination motor controller shall be capable of being opened manually with the operating handle. The contacts of the disconnecting means shall not weld. Following high fault short circuit tests only, the disconnecting means shall be subjected to the voltage withstand test per paragraph 8.3.7.

l. When provided as part of the equipment, neither end of a protective device—such as a fuse, current limiter, or motor short-circuit protector—shall be completely separated

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from the mounting means, and the line end of a fuse, current limiter, or motor short-circuit protector shall not bridge from the mounting means to dead metal.

8.3.7 Dielectric Re–Verification

A controller that has been subjected to the high capacity short circuit test in 8.3.6.8.2 shall withstand without breakdown the test potential of twice the maximum rated voltage (3000 volts):

a. Between the line and load terminals of the circuit breaker or disconnect switch, with the circuit breaker tripped and the disconnect switch in the open position.

b. Between opposite polarity terminals with the circuit breaker or disconnect switch contacts closed.

c. Between live parts of the circuit breaker or disconnect switch and the enclosure when the contacts are open or closed.

NOTE—The controller may be disconnected during the test.

8.3.7.1 Short-Circuit Closing Test

When the controller is tested with a circuit breaker or disconnect switch, a separate closing test shall be performed. The circuit breaker or disconnect switch shall be closed on the test circuit. The test consists of one operation.

Three phase controllers shall be tested with three poles and three overload relays. The three-phase test is considered to cover single phase test.

8.3.7.2 Test Results

The controller will have passed the test if the requirements in 8.3.6.8.3 are met.

8.3.8 Performance of Terminals

Terminals of vacuum-break controllers shall comply with the requirements of ICS 1 and UL 486E.

8.3.9 Short-Time Capability

8.3.9.1 Maximum Overload

A new vacuum-break contactor shall be capable of withstanding a current ten times its rated continuous current for 20 seconds. All poles of the contactor are simultaneously subjected to one test at any convenient voltage, at room temperature.

A new vacuum-break starter shall be capable of withstanding a current eight times the current rating of its highest rated overload relay for the time necessary for the overload relay to trip. The eight times current rating corresponds to ten times motor full-load current for a service factor 1.15 motor protected at 125 percent. All poles of the controller are simultaneously subjected to one test at any convenient voltage, at room temperature.

8.3.9.2 Short-Time Surge Capability

A new vacuum-break contactor shall be capable of withstanding a current that is 15 times its rated continuous current for one second. All poles of the contactor are simultaneously subjected to one test at any convenient voltage, at room temperature.

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A new vacuum-break starter shall be capable of withstanding a current that is 12 times the current rating of its highest rated overload relay for one second or for the time necessary for its overload relay to trip, whichever is shorter. The 12 times current rating corresponds to 15 times motor full-load current for a service factor 1.15 motor protected at 125 percent. All poles of the controller are simultaneously subjected to one test at any convenient voltage, at room temperature.

A separate source of power shall be permitted to be used to supply coil voltage.

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

8.3.9.3 Short-Time Capability Evaluation

At the end of the short-term capability tests, the controller shall be capable of withstanding the dielectric test described in 8.3.3 at full test values as specified, and in addition from line to load terminals with the contacts open. The contacts must be capable of being opened by normal operation.

8.3.10 Operation and Operating Limits

8.3.10.1 Pickup Voltage

Immediately after the Temperature Rise Test, the contactor shall pick-up and go to the fully sealed position without hesitation when 85 percent of the lowest rated AC coil voltage is applied suddenly. The contactor shall pick-up and go to the fully-sealed position without hesitation when 80 percent of the lowest rated DC coil voltage is applied suddenly. See ICS 1, Clause 8.

8.3.10.2 Dropout Voltage

Immediately after the test described in 8.3.10.1, the contactor shall remain in the fully-sealed position at 75 percent or less of the lowest rated coil voltage, when the voltage is decreased slowly from a pickup at 85 percent of the lowest rated coil voltage. Any movement from the fully sealed position shall be to the fully opened position without hesitation.

The contactor shall drop-out at or above 10 percent of the lowest rated coil voltage where the coil current is DC and at or above 20 percent of the lowest rated coil voltage where the coil current is AC.

Section 9
APPLICATION, TYPICAL METHODS OF STARTING MOTORS

Typical methods of starting motors and determining motor-starting line current for vacuum-break controllers are the same as for Class A controllers. See ICS 2, Part 2.

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Table 9-4-1
HORSEPOWER (HP) AND LOCKED–ROTOR CURRENT (LRA) RATINGS FOR THREE-PHASE, SINGLE SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR LIMITED PLUGGING AND JOGGING DUTY

NEMA Size desig-nation	Rated continuous current (enclosed)	Maximum full-load current	Rated locked-rotor current	Three-phase horsepower								
	Amperes	Amperes	Amperes	200V 60 Hz	230V 60 Hz	400V 50 Hz	460V 60 Hz	575V 60 Hz	800V 60 Hz	1000V 50 Hz	1100V 60 Hz	1500V 60 Hz
V50	50	50	400	10	15	25	30	40	50	75	75	100
V80	80	80	640	20	25	40	50	60	75	100	125	175
V120	120	120	960	30	40	60	75	100	125	175	175	250
V160	160	160	1280	50	60	100	125	150	200	250	300	400
V200	200	200	1600	60	75	125	150	175	250	300	350	500
V250	250	250	2000	75	100	150	175	200	300	400	400	600
V320	320	320	2560	100	125	200	250	300	400	500	600	900
V450	450	450	3600	125	150	250	350	400	500	700	700	1000
V600	600	600	4800	200	200	375	500	600	800	1100	1100	1600
V800	800	800	6400	--	300	450	600	700	900	1250	1500	2000
V1000	1000	1000	8000	--	--	--	800	1000	1250	1600	1750	2250

NOTE—Horsepower ratings are based on nominal motor full-load currents shown in Annex A. It should be recognized that under some overload conditions, where the trip current of the overload protective device is greater than the continuous rating of the controller, the temperature rise of some current-carrying parts may exceed that specified in this standard for what is considered to be a temporary condition.

Table 9-4-2
RATED OPERATIONAL VOLTAGES FOR CLASS V CONTROLLERS 50 OR 60 HERTZ

Motor loads	Non-motor loads
200	208
230	240
400	480
460	600
500	830
575	1040
800*	1500
1000*	
1100*	
1500*	

*Specific voltage ratings for motors have not been standardized.

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Table 9-4-3

HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR SINGLE-PHASE, FULL-VOLTAGE MAGNETIC CONTROLLERS FOR LIMITED PLUGGING AND JOGGING DUTY

NEMA Size designation	Rated continuous current (enclosed)	Maximum full-load current	Rated locked-rotor current	Single-phase horsepower at 60 Hertz		
	Amperes	Amperes	Amperes	115 Volts	200 Volts	230 Volts
V50	50	50	400	3	7.5	7.5
V80	80	80	640	5	10	15
V120	120	120	960	10	20	25
V160	160	160	1280	15	25	30

NOTE—Horsepower ratings are based on nominal motor full-load currents shown in NFPA 70 (NEC). It should be recognized that under some overload conditions, where the trip current of the overload protective device is greater than the continuous rating of the controller, the temperature rise of some current-carrying parts may exceed that specified in this standard for what is considered to be a temporary condition.

NOTE—For voltages over 230 volts apply controllers on the basis of maximum allowable full-load current and locked-rotor current rating.

Table 9-4-4

HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR THREE-PHASE, SINGLE-SPEED, FULL-VOLTAGE MAGNETIC CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE, OR JOGGING

NEMA Size designation	Rated continuous current (enclosed)	Maxi-mum full-load current	Rated locked-rotor current	Three-phase horsepower								
	Amperes	Amperes	Amperes	200 Volts 60 Hz	230 Volts 60 Hz	400 Volts 50 Hz	460 Volts 60 Hz	575 Volts 60 Hz	800 Volts 60 Hz	1000 Volts 50 Hz	1100 Volts 60 Hz	1500 Volts 60 Hz
V50	50	33	264	7.5	10	15	20	25	30	50	50	60
V80	80	53	424	15	15	25	30	40	50	60	75	125
V120	120	80	640	20	25	40	50	60	75	125	125	175
V160	160	107	856	30	40	60	75	100	150	175	200	300
V200	200	134	1072	40	60	75	100	125	175	200	250	375
V250	250	167	1336	60	75	125	125	150	200	300	300	450
V320	320	214	1712	75	100	150	175	200	300	375	450	700
V450	450	302	2416	100	125	175	250	300	375	500	500	750
V600	600	402	3216	150	150	300	375	450	600	800	800	1200
V800	800	536	4288	--	200	350	450	500	700	1000	1100	1500
V1000	1000	670	5360	--	--	--	600	750	1000	1200	1300	1750

NOTE—Horsepower ratings are based on nominal motor full-load currents shown in Annex A and limited to values not greater than 67% of the rated continuous current.

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Table 9-4-5
MAXIMUM CIRCUIT-CLOSING CURRENT RATINGS

NEMA Size designation	Rated locked-rotor current Amperes, rms	Ratio of peak current to RMS current*	Maximum circuit-closing inrush current amperes peak, including offset
V50	400	1.754	702
V80	640	1.754	1123
V120	960	1.895	1819
V160	1280	1.895	2426
V200	1600	1.895	3032
V250	2000	1.895	3790
V320	2560	1.895	4851
V450	3600	1.895	6822
V600	4800	1.895	9096
V800	6400	1.895	12128
V1000	8000	1.895	15160

* Multiplier is based on the power factor used in making and breaking capacity test, 0.45 for sizes V50 and V80, and 0.35 for larger sizes.

Table 9-4-6A
RATINGS OF ENCLOSED CLASS V CONTROLLERS FOR TRANSFORMER PRIMARY SWITCHING THREE-PHASE KVA

NEMA Size designation	Rated continuous current enclosed	Maximum circuit-closing inrush current	Transformer having inrush currents (worst case peak) of not more than 20 times peak of continuous–current rating					
	Amperes	Amperes	240V	480V	600V	800V	1100V	1500V
V50	50	702	9	19	24	34	47	64
V80	80	1123	15	30	38	55	76	103
V120	120	1819	25	49	61	89	123	167
V160	160	2426	33	65	82	119	163	223
V200	200	3032	41	82	102	149	204	278
V250	250	3790	51	102	128	186	255	348
V320	320	4851	65	131	164	238	327	446
V450	450	6822	92	184	230	334	459	627
V600	600	9096	123	246	307	446	613	835
V800	800	12128	164	327	409	594	817	1114
V1000	1000	15160	205	409	511	743	1021	1392

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Table 9-4-6B
RATINGS OF ENCLOSED CLASS V CONTROLLERS FOR TRANSFORMER PRIMARY SWITCHING, THREE-PHASE KVA

NEMA Size designation	Rated continuous current enclosed	Maximum circuit-closing inrush current	Transformer having inrush currents (worst case peak) of over 20 through 40 times peak of continuous–current rating					
	Amperes	Amperes	240V	480V	600V	800V	1100V	1500V
V50	50	702	5	9	12	17	24	32
V80	80	1123	8	15	19	28	38	52
V120	120	1819	12	25	31	45	61	84
V160	160	2426	16	33	41	59	82	111
V200	200	3032	20	41	51	74	102	139
V250	250	3790	26	51	64	93	128	174
V320	320	4851	33	65	82	119	163	223
V450	450	6822	46	92	115	167	230	313
V600	600	9096	61	123	153	223	306	418
V800	800	12128	82	164	205	297	408	557
V1000	1000	15160	102	205	256	371	511	696

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Table 9-4-7A
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 230 VOLTS 50 AND 60 HERTZ

NEMA Size designation	Rated continuous current enclosed	Maximum capacitor rated current	Maximum circuit-closing inrush current amp - peak, including offset	Three-phase ratings of capacitor maximum size of three-phase capacitor in kVar for available current* in amperes RMS symmetrical					
	Amperes	Amperes		3000	5000	10,000	14,000	18,000	22,000
V50	50	40	702	16	16	8	6	5	4
V80	80	64	1123	25	25	21	16	12	10
V120	120	96	1819	38	38	38	38	31	26
V160	160	128	2426	50	50	50	50	50	45
V200	200	160	3032	63	63	63	63	63	63
V250	250	200	3790	79	79	79	79	79	79
V320	320	256	4851	101	101	101	101	101	101
V450	450	360	6822	143	143	143	143	143	143
V600	600	480	9096	191	191	191	191	191	191
V800	800	640	12128	254	254	254	254	254	254
V1000	1000	800	15160	318	318	318	318	318	318

* - Available at capacitor terminals

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Table 9-4-7B
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 460 VOLTS 50 AND 60 HERTZ

NEMA Size designation	Rated continuous current enclosed	Maximum capacitor rated current	Maximum circuit-closing inrush current amp - peak, including offset	Three-phase ratings of capacitor maximum size of three-phase capacitor in kVar for available current* in amperes RMS symmetrical					
	Amperes	Amperes		3000	5000	10,000	14,000	18,000	22,000
V50	50	40	702	32	32	17	13	10	8
V80	80	64	1123	51	51	43	32	25	21
V120	120	96	1819	76	76	76	76	63	53
V160	160	128	2426	101	101	101	101	101	91
V200	200	160	3032	127	127	127	127	127	127
V250	250	200	3790	159	159	159	159	159	159
V320	320	256	4851	203	203	203	203	203	203
V450	450	360	6822	286	286	286	286	286	286
V600	600	480	9096	382	382	382	382	382	382
V800	800	640	12128	509	509	509	509	509	509
V1000	1000	800	15160	637	637	637	637	637	637

* - Available at capacitor terminals

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TABLE 9-4-7C
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 575 VOLTS 50 AND 60 HERTZ

NEMA Size designation	Rated continuous current enclosed	Maximum capacitor rated current	Maximum circuit-closing inrush current amp - peak, including offset	Three-phase ratings of capacitor Maximum size of three-phase capacitor in kVar for available current* in amperes RMS symmetrical					
	Amperes	Amperes		3000	5000	10,000	14,000	18,000	22,000
V50	50	40	702	39	39	22	16	12	10
V80	80	64	1123	63	63	54	39	32	26
V120	120	96	1819	95	95	95	95	67	67
V160	160	128	2426	127	127	127	127	127	114
V200	200	160	3032	159	159	159	159	159	159
V250	250	200	3790	199	199	199	199	199	199
V320	320	256	4851	254	254	254	254	254	254
V450	450	360	6822	358	358	358	358	358	358
V600	600	480	9096	477	477	477	477	477	477
V800	800	640	12128	637	637	637	637	637	637
V1000	1000	800	15160	796	796	796	796	796	796

* - Available at capacitor terminals

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Table 9-4-7D
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 800 VOLTS 50 AND 60 HERTZ

NEMA Size designation	Rated continuous current enclosed	Maximum capacitor rated current	Maximum circuit-closing inrush current amp - peak, including offset	Three-phase ratings of capacitor Maximum size of three-phase capacitor in kVar for available current* in amperes RMS symmetrical					
	Amperes	Amperes		3000	5000	10,000	14,000	18,000	22,000
V50	50	40	702	55	55	30	22	17	14
V80	80	64	1123	88	88	74	55	44	37
V120	120	96	1819	133	133	133	133	88	88
V160	160	128	2426	177	177	177	177	177	133
V200	200	160	3032	221	221	221	221	221	221
V250	250	200	3790	277	277	277	277	277	277
V320	320	256	4851	354	354	354	354	354	354
V450	450	360	6822	498	498	498	498	498	498
V600	600	480	9096	664	664	664	664	664	664
V800	800	640	12128	886	886	886	886	886	886
V1000	1000	800	15160	1107	1107	1107	1107	1107	1107

* - Available at capacitor terminals

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Table 9-4-7E
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 1100 VOLTS 50 AND 60 HERTZ

NEMA Size designation	Rated continuous current enclosed	Maximum capacitor rated current	Maximum circuit-closing inrush current amp - peak, including offset	Three-phase ratings of capacitor Maximum size of three-phase capacitor in kVar for available current* in amperes RMS symmetrical					
	Amperes	Amperes		3000	5000	10,000	14,000	18,000	22,000
V50	50	40	702	76	76	42	31	24	20
V80	80	64	1123	121	121	103	77	61	51
V120	120	96	1819	182	182	182	182	152	128
V160	160	128	2426	243	243	243	243	243	219
V200	200	160	3032	304	304	304	304	304	304
V250	250	200	3790	380	380	380	380	380	380
V320	320	256	4851	487	487	487	487	487	487
V450	450	360	6822	685	685	685	685	685	685
V600	600	480	9096	913	913	913	913	913	913
V800	800	640	12128	1218	1218	1218	1218	1218	1218
V1000	1000	800	15160	1523	1523	1523	1523	1523	1523

* - Available at capacitor terminals

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Table 9-4-7F
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 1500 VOLTS 50 AND 60 HERTZ

NEMA Size designation	Rated continuous current enclosed	Maximum capacitor rated current	Maximum circuit-closing inrush current amp - peak, including offset	Three-phase ratings of capacitor Maximum size of three-phase capacitor in kVar for available current* in amperes RMS symmetrical					
	Amperes	Amperes		3000	5000	10,000	14,000	18,000	22,000
V50	50	40	702	103	103	58	42	33	27
V80	80	64	1123	166	166	140	103	83	69
V120	120	96	1819	249	249	249	249	208	174
V160	160	128	2426	332	332	332	332	332	299
V200	200	160	3032	415	415	415	415	415	415
V250	250	200	3790	519	519	519	519	519	519
V320	320	256	4851	664	664	664	664	664	664
V450	450	360	6822	934	934	934	934	934	934
V600	600	480	9096	1246	1246	1246	1246	1246	1246
V800	800	640	12128	1661	1661	1661	1661	1661	1661
V1000	1000	800	15160	2077	2077	2077	2077	2077	2077

* - Available at capacitor terminals

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Table 9-4-8
MINIMUM SHORT-CIRCUIT WITHSTAND CURRENT RATINGS
OF VACUUM-BREAK CONTROLLERS

Continuous current rating (amperes)	Available current in RMS symmetrical (amperes)	Test circuit power factor
0 - 50	5,000	0.70 to 0.80
51 - 200	10,000	0.70 to 0.80
201 - 400	18,000	0.25 to 0.30
401 - 600	30,000	0.20 or less
601 - 850	42,000	0.20 or less
851 - 1500	85,000	0.20 or less
1501 or more	100,000, 150,000 or 200,000	0.20 or less

Table 9-4-9
HIGH CAPACITY SHORT-CIRCUIT CURRENT RATINGS
OF VACUUM-BREAK CONTROLLERS

Available current RMS symmetrical amperes	Test circuit power factor
10,000	0.70 to 0.80
14,000	0.25 to 0.30
18,000	0.25 to 0.30
22,000	0.20 or less
25,000	0.20 or less
30,000	0.20 or less
42,000	0.20 or less
50,000	0.20 or less
65,000	0.20 or less
85,000	0.20 or less
100,000	0.20 or less
125,000	0.20 or less
150,000	0.20 or less
200,000	0.20 or less

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Table 9-7-1
MINIMUM SPACINGS IN INCHES (MM)

Rated insulation voltage	Between uninsulated live parts of opposite polarity*		Between uninsulated parts and any dead metal	
	Clearance (spacing through air)	Creepage distance (spacing over surface)	Clearance (spacing through air)	Creepage distance (spacing over surface)
1500 volts	0.700 (17.8)	1.200 (30.5)	1.200 (30.5)	1.650 (41.9)

*Also applies between live parts of the power circuit and live parts of the control circuit.

Table 9-7-2
TERMINAL CAPACITY MINIMUM RANGE OF CONDUCTOR SIZES FOR 75°C

Size of controller	Conductor insulation rated 75 C AWG
V50	14 - 4
V80	6 - 1
V120	3 - 1/0
V160	1 - 3/0
Larger sizes	Not specified

Table 9-7-3
TERMINAL CONNECTION AND MARKINGS

	Single Phase	Three Phase
Line terminal markings on controller	L1, L2	L1, L2, L3
Load terminal markings on controller	T1, T2	T1, T2, T3
Ground connector when used	L2	L2
Interchanged for reversing,	---	L1, L3
Location of motor running over-current protection	T1	T1, T2, T3
Source of control circuit power	L1, L2	L1, L2

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Table 9-8-1
SEQUENCE OF TESTS FOR VACUUM-BREAK CONTROLLERS

Test	Subclause	Test Sequence			
		I	II	III	IV
Temperature rise	8.3.2	X			
Making & breaking capacity	8.3.4		X		
Endurance	8.3.5		X		
Ability to withstand short-circuit currents	8.3.6			X	
Short-time capability	8.3.9				X
Operation and operating limits	8.3.10	X			
Dielectric properties	8.3.3	X	X		X
Reverification of dielectric properties	8.3.7			X	
Performance of terminals	8.3.8				X

Table 9-8-2
CONDITIONS FOR VERIFICATION OF MAKING AND BREAKING CAPACITY[(a)]

I/I_c	Test Voltage (Volts)	Power Factor	Minimum On-Time (Seconds) (c)	Maximum Off-Time Seconds	Number Of Operating Cycles (d)
8.0	1500	(b)	0.05	9 (e)	50

NOTES—The making current is expressed in rms symmetrical values but it is understood that the peak value of the asymmetrical current corresponding to the power factor of that circuit will assume a higher value.

I = Test current made and broken, expressed in rms symmetrical values.

I_c = Rated continuous current, enclosed.

(a) Conductors selected in accordance with ICS 1, Clause 8.

(b) Power factor is 0.45 for I_c equal or less than 100 A, 0.35 for I_c greater than 100 A.

(c) ON time shall be permitted to be less than 0.05 seconds provided the contacts are allowed to become properly seated before reopening. For reversing controllers each device will be ON for 0.05 seconds.

(d) 25 operations @110% + 25 operations @ 85% coil voltage in that order.

For reversing starters incorporating two contactors, the two contactors A and B shall be wired as used for normal application. The sequence of the 50 operating cycles shall be:

Close A - Open A - Close B – Open B - OFF.

Ten additional cycles of operation with both coils energized simultaneously are required for reversing controllers. This test is to be conducted after the 50 cycles of operation.

(e) The OFF time for equipment conducting a test current of 500 to 1499 amperes is to be no more than 120 seconds, and for devices conducting a test current more than 1499 amperes the OFF time is to be no more than 240 seconds.

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Table 9-8-3
TEST CYCLE FOR MOTOR CONTROLLERS

Type of controller	Test current (amperes)	Time on [a], Second	Maximum time off, seconds
Nonreversing	Less than 200	0.05	½
	200 – 499	0.05	1
	500 – 1499	0.05	120
	1500 or more	0.05	240
Reversing	Less than 200	0.05 forward 0.05 reverse	1
	200 – 499	0.05 forward 0.05 reverse	2
	500 – 1499	0.05 forward 0.05 reverse	120
	1500 or more	0.05 forward 0.05 reverse	240

NOTE—
[a] ON time shall be permitted to be less than 0.05 second provided the contacts are allowed to become properly seated before reopening.

Table 9-8-4
CONDITIONS FOR VERIFICATION OF ENDURANCE CAPABILITY *

	I/I_c	Test Voltage	Power Factor	Minimum ON-Time Seconds †	Maximum OFF-Time Seconds ‡	Number of Operations		
						With Current	Without Current	Total Operating Cycles
Across-the line AC Motor Starting	2.0	1500	**	0.05		1000	5000	6000

NOTES—

I = Test current made and broken, expressed in AC rms symmetrical values.

I_c = Rated continuous current, enclosed.

* Conductors selected in accordance with ICS 1, Clause 8.

** Power factor is 0.45 for I_c equal or less than 100 A, 0.35 for I_c greater than 100 A.

† ON time shall be permitted to be less than 0.05 second provided the contacts are allowed to become properly seated before reopening.

‡ See Table 9-8-3 For OFF time.

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Table 9-8-5
AMPACITIES OF INSULATED COPPER CONDUCTORS[a,b]

Wire Size AWG (mm²)	60°C (140°F)	75°C (167°F)
24 (0.2)	2	-
22 (0.3)	3	-
20 (0.5)	5	-
18 (0.8)	7	-
16 (1.3)	10	-
14 (2.1)	15	15
12 (3.3)	20	20
10 (5.3)	30	30
8 (8.4)	40	50
6 (13.3)	55	65
4 (21.2)	70	85
3 (26.7)	85	100
2 (33.6)	95	115
1 (42.4)	110	130
1/0 (53.5)	-	150
2/0 (67.4)	-	175
3/0 (85.0)	-	200
4/0 (107.2)	-	230
Kcmil		
250 (127)	-	255
300 (152)	-	285
350 (177)	-	310
400 (203)	-	335
500 (253)	-	380
600 (304)	-	420
700 (355)	-	460
750 (380)	-	475
800 (405)	-	490
900 (456)	-	520
1000 (506)	-	545
1250 (633)	-	590
1500 (760)	-	625
1750 (887)	-	650
2000 (1013)	-	665

a) For multiple-conductors of the same size (1/0 AWG or larger) at a terminal, the ampacity is equal to the value in Table 9-8-5 for that conductor multiplied by the number of conductors that the terminal will accommodate.

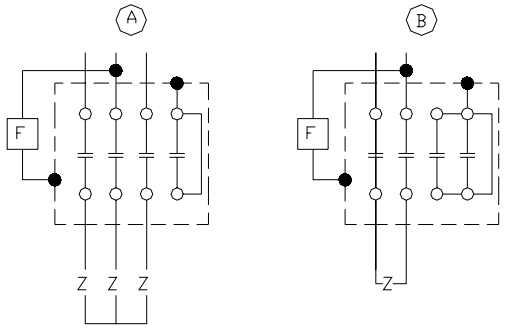
b) These values of ampacity apply only if not more than three conductors will be field-installed in the conduit. If four or more conductors, other that a neutral that carries the unbalanced current,m will be installed in a conduit (as may occur because of the number of conduit hubs provided in outdoor equipment, the number of wires necessary in certain polyphase systems, or other reasons), the ampacity of each of the conductors is: 80% of these values if 4-6 conductors are involved, 70% of these values for 7-24 conductors, 60% of these values for 25-42 conductors, and 50% of these values for 43 or more conductors.

Table 9-8-6
REQUIRED NUMBER OF TEST OPERATIONS

Rating		Number of test operations for each current element selected	
Horsepower	(kW)	1 Phase	3 Phase
0-200	(0-149)	3	2
201-1600	(150-1193)	-	1

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F = FUSE

Z = IMPEDANCE

– – – – – = ENCLOSURE

Figure 9-8-1
TEST CONNECTION DIAGRAMS

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Annex A
NOMINAL FULL-LOAD CURRENTS CORRESPONDING TO THREE-PHASE MOTOR HORSEPOWER RATINGS (Informative)

RATED OPERATIONAL CURRENTS NOMINAL FULL-LOAD CURRENTS IN AMPERES CORRESPONDING TO THREE-PHASE MOTOR HORSEPOWER RATINGS FOR DESIGN B, C, D, AND E SQUIRREL-CAGE AND WOUND-ROTOR MOTORS

Motor Rating HP	200 Volt 60 Hz	230 Volt 60 Hz	400 Volt 50 Hz	460 Volt 60 Hz	575 Volt 60 Hz	800 Volt 60 Hz	1,000 Volt 50 Hz	1,100 Volt 60 Hz	1,500 Volt 60 Hz
½	2.5	2.2	1.2	1.1	0.9	...	...	...	...
¾	3.7	3.2	1.7	1.6	1.3	...	...	...	...
1	4.8	4.2	2.2	2.1	1.7	1.2	1	0.9	0.6
1½	6.9	6.0	3.1	3.0	2.4	1.7	1.4	1.3	0.9
2	7.8	6.8	4.1	3.4	2.7	2.0	1.6	1.4	1.0
3	11.0	9.6	5.8	4.8	3.9	2.8	2.2	2.0	1.5
5	17.5	15.2	9.2	7.6	6.1	4.4	3.5	3.2	2.3
7½	25.3	22	13	11	9	6	5	4.6	3
10	32.2	28	17	14	11	8	6.4	6	4
15	48.3	42	26	21	17	12	10	9	6
20	62.1	54	32	27	22	16	12	11	8
25	78.2	68	42	34	27	20	16	14	10
30	92	80	48	40	32	23	18	17	12
40	120	104	63	52	41	30	24	22	16
50	150	130	79	65	52	37	30	27	20
60	177	154	98	77	62	44	35	32	24
75	221	192	122	96	77	55	44	40	29
100	285	248	157	124	99	71	57	52	38
125	359	312	198	156	125	90	72	65	48
150	414	360	228	180	144	104	83	75	55
175*	483	420	266	210	168	121	98	88	65
200	552	480	304	240	192	138	110	100	74
250	692	602	383	302	242	174	139	126	93
300	...	722	458	361	289	208	166	151	111
350	...	...	532	414	336	238	190	173	127
375	...	...	568	446	359	256	207	186	137
400	...	...	604	477	382	274	219	199	146
450	...	...	676	515	412	296	237	215	158
500	...	...	747	590	472	339	271	247	181
600	...	...	896	704	563	405	324	294	216
650	...	...	971	761	609	438	350	318	234
700	...	...	1045	817	654	470	376	342	251
800	...	...	...	927	742	533	426	388	284
900	...	...	...	1038	830	597	477	434	318
1,000	...	...	...	...	953	660	528	480	352
1,100*	...	...	...	...	1053	720	576	524	384
1,200*	...	...	...	...	...	785	636	572	419
1,250	...	...	...	...	...	811	649	590	433
1,300*	...	...	...	...	...	842	673	612	449
1,500	...	...	...	...	...	963	771	700	514
1,600*	...	...	...	...	...	1024	819	744	546
1,750	...	...	...	...	...	...	891	810	594
2,000	...	...	...	...	...	...	1012	920	674
2,250*	...	...	...	...	...	...	...	1035	759
2,750*			...	...	...	...	...	...	927

* - Non-standard motor rating

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Annex B
INSTALLATION AND MAINTENANCE INSTRUCTIONS FOR 1500 VOLT CONTROLLERS
(Informative)

B.1 INITIAL INSTALLATION

The integrity of the vacuum interrupters should be checked before the contactor is energized for the first time. A dielectric test with a specified AC rms voltage and specified leakage current will determine the dielectric condition and vacuum integrity for each vacuum interrupter.

A vacuum contactor should be protected by a power fuse or a circuit breaker, or both, in accordance with NFPA 70 (NEC).

B.2 PREVENTIVE MAINTENANCE

See ICS 1.3 for general preventive maintenance instructions.

The vacuum interrupter should be tested at regular intervals for the following:

a. vacuum interrupter integrity
b. main contact wear (loss of contact overtravel)
c. physical evidence of stress (distortion, discoloration, or cracks)

The interval between checks will depend on the number of daily operations, but annual checks are recommended as a matter of good preventive maintenance practice.

B.3 MAINTENANCE AFTER A FAULT CONDITION

See Annex A, Maintenance of Motor Controllers After a Fault Condition. Additionally the following inspections should be made on a vacuum controller that has been subjected to a fault:

a. physical evidence of stress (distortion, discoloration, or cracks)
b. contact wear measurement (contact overtravel)
c. vacuum interrupter integrity

B.4 VACUUM INTERRUPTER INTEGRITY TEST

WARNING—Caution should be exercised during this test; high-voltage testing is potentially hazardous.

CAUTION—X-ray emissions may be generated when high-voltage is applied across the open contacts of a vacuum interrupter.

The following test should be performed using a 50 or 60 hertz dielectric (high-pot) tester with output voltage continuously variable up to at least 10 kV rms.

The contactor should be free of dust and other contaminants before conducting this test.
Before performing a dielectric test the line and load power cables are removed. Control wires should be disconnected to avoid any possible feedback to upstream or downstream equipment. Each vacuum interrupter should be tested individually.

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The output leads of the tester are connected across the vacuum interrupter terminals with the contactor in the OPEN position. The voltage is slowly raised from zero to the manufacturer's recommended test voltage and held for 15 seconds while the leakage current is measured.

During voltage ramping any discharge or test equipment tripping should be ignored unless it becomes impossible to reach the recommended test voltage. The leakage current should not exceed 5 milliamps during the test. The user should refer to the manufacturer's instruction manual for detailed testing and checking procedures.

If the unit fails the test, the vacuum interrupter should be replaced.

B.5 MAIN CONTACT WEAR MEASUREMENT

The main contact wear should be measured in accordance with the manufacturer's instructions for loss of contact overtravel. Where the loss of overtravel indicates the end of the contact life, as specified by the manufacturer, the vacuum interrupters should be replaced.

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Annex C
MINIMUM WIRE BENDING SPACE
(Normative)

Wiring space is measured from each line terminal to the enclosure wall toward which the wire will be directed upon leaving the lug or connector.

Size of Wire	Minimum Bending Space, Terminal to Wall, Inches (mm) Wires per Terminal					
	1		2		3	
AWG or kcmil	Inches	(mm)	Inches	(mm)	Inches	(mm)
14-10 AWG	-		-		-	
8-6	1½	(38)	-		-	
4-3	2	(51)	-		-	
2	2½	(64)	-		-	
1	3	(76)	-		-	
1/0	5	(127)	5	(127)	7	(178)
2/0	6	(152)	6	(152)	7½	(191)
3/0	7	(178)	7	(178)	8	(203)
4/0	7	(178)	7	(178)	8½	(216)
250 kcmil	8	(203)	8	(203)	9	(229)
300	10	(254)	10	(254)	11	(279)
350	12	(305)	12	(305)	13	(330)
400	12	(305)	12	(305)	14	(356)
500	12	(305)	12	(305)	15	(381)
600	14	(356)	16	(406)	18	(457)
700	14	(356)	16	(406)	20	(508)
750-800	18	(457)	19	(483)	22	(559)
900	18	(457)	19	(483)	24	(610)

NOTE—Where provision for more than three conductors per terminals is provided, the bending space is in accordance with the appropriate tables for cabinets and boxes in Article 373 of NFPA 70 (NEC).

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Annex D
MAXIMUM COPPER CONDUCTOR SIZE FOR CONTROLLER POWER CIRCUIT TESTING AT NOT MORE THAN 1500 VOLTS [A]
(Normative)

Conductor sizes shown are for use in temperature rise tests, short-time capability tests, making and breaking capacity tests, endurance tests, and fault withstandability tests.

75°C Conductor Size	Controller Rated Operational Current[B] (80% rated conductors) Amperes	Controller Rated Continuous current (100% rated conductors) Amperes
#14 AWG	0 - 12	0 - 15
#12 AWG	13 - 16	16 - 20
#10 AWG	17 - 24	21 - 30
#8 AWG	25 - 40	31 - 50
#6 AWG	41 - 52	51 - 65
#4 AWG	53 - 68	66 - 85
#3 AWG	69 - 80	86 - 100
#2 AWG	81 - 92	101 - 115
#1 AWG	93 - 104	116 - 130
#1/0 AWG	105 - 120	131 - 150
#2/0 AWG	121 - 140	151 - 175
#3/0 AWG	141 - 160	176 - 200
#4/0 AWG	161 - 184	201 - 230
250 kcmil	185 - 204	231 - 255
300 kcmil	205 - 228	256 - 285
350 kcmil	229 - 248	286 - 310
400 kcmil	249 - 268	311 - 335
500 kcmil	269 - 304	336 - 380
600 kcmil	305 - 336	381 - 420
(2) #4 AWG	337 - 368	421 - 460
(2) 250 kcmil	369 - 408	461 - 510
(2) 300 kcmil	409 - 456	511 - 570
(2) 350 kcmil	457 - 496	571 - 620
(2) 400 kcmil	497 - 536	621 - 670
(2) 500 kcmil	537 - 608	671 - 760
(2) 600 kcmil	609 - 672	761 - 840
(3) 350 kcmil	673 - 744	841 - 930
(3) 400 kcmil	745 - 804	931 - 1005
(3) 500 kcmil	805 - 912	1006 - 1140
(3) 600 kcmil	913 - 1008	1141 - 1260

NOTES—
(A) Applies to other than Class A controllers designated by NEMA size and based on not more than three conductors per conduit.
(B) Motor and resistive heating applications where ampacity of conductors must be not less than 125% of nominal motor full-load current.

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