NEMA STANDARDS PUBLICATION NO. ICS 5

nema

Industrial Control and Systems Control Circuit and Pilot Devices

NEMA

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

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NEMA Standards Publication No. ICS 5-1993

INDUSTRIAL CONTROL AND SYSTEMS
CONTROL CIRCUIT AND PILOT DEVICES

Published by

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Scope of the Industrial Control and Systems Section S-1

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Foreword

This Standards Publication was prepared by a technical committee of the NEMA Industrial Control and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes the indicated NEMA Standards Publication.

Replacement: The five parts of ICS 5-1993 supersede the following parts of ICS 2-1988:
Part 1 supersedes Part ICS 2-120, 2-125, 2-126 and 2-219
Part 2 supersedes Part ICS 2-212 and 2-218
Part 3 supersedes Part ICS 2-215, 2-221, 2-225, 2-226, 2-227 and 2-228
Part 4 supersedes Part ICS 2-229
Part 5 supersedes Part ICS 2-216

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.

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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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 to:

Vice President, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

Introduction

The standards pertaining to adjustable-speed drives in NEMA Standards Publication ICS 5 are subdivided into the following clauses:

1 General
  Referenced Standards
  Scope
  Normative Standards
2 Definitions
  Terms which supplement the IEEE Standard Dictionary of Electrical and Electronics Terms (Std 100) or assist in clarifying the product standard.
3 Classification
  Product classifications where they have been established.
4 Characteristics and Ratings
  Descriptions of the kinds of ratings applicable to the product and tables of standard ratings for the product where they have been established.
5 Product Marking, Installation and Maintenance Information
  Product information to be provided to assist the user in the installation, use and maintenance of the devices.
6 Service and Storage Conditions
  A description of service and storage conditions for which the devices are intended.
7 Construction
  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.
8 Performance Requirements and Tests
  The performance required to pass each design test specified for the product.
9 Application
  Information and performance considerations of importance to those who specify or use the product.

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The standards for the products included within the scope of the Industrial Control and Systems Section are organized as follows:

NEMA Standards Title
Publication No.

ICS 1-1993 Industrial Control and Systems
General Requirements

ICS 2-1993 Industrial Control and Systems
Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC.

Part 1: *General Standards for Manual and Magnetic Controllers*
Part 2: *AC Noncombination Magnetic Motor Controllers, Rated 600 Volts*
Part 3: *Nonmagnetic Motor Controllers*
Part 4: *Overload Relays*
Part 5: *DC General-Purpose Constant-Voltage Controllers*
Part 6: *AC Combination Motor Controllers*
Part 7: *Magnetic Lighting Contactors*

ICS 3-1993 Industrial Control and Systems
Factory-built Assemblies

Part 1: *Motor Control Centers Rated Not More Than 600 Volts AC*
Part 2: *Medium Voltage Controllers Rated 2001 to 7200 Volts AC*
Part 3: *AC General-Purpose Controllers for Synchronous Motors*

ICS 4-1993 Industrial Control and Systems
Terminal Blocks

ICS 5-1993 Industrial Control and Systems
Control Circuit and Pilot Devices

Part 1: *General Standards for Control Circuit and Pilot Devices*
Part 2: *Industrial Control Relays*
Part 3: *Industrial Control Input Devices Actuated by Force, Temperature and Pressure*
Part 4: *Proximity Switches*
Part 5: *Pushbuttons, Selector Switches, Indicating Lights and Pushbutton Stations*

ICS 6-1993 Industrial Control and Systems
Enclosures

ICS 7-1993 Industrial Control and Systems
Adjustable Speed Drives

Part 1: *General Standards for Drive Converters, Drives, and Drive Systems*
Part 2: *Loop Position and Tension Control Drive Systems*
Part 3: *Wind and Unwind Drive Systems*
Part 4: *Variable-Frequency, Three-Phase Controllers, Rated Not More Than 600 Volts*
Part 5: *Adjustable-Voltage Packaged-Drive Systems (Where DC Armature Power Is Obtained from AC Lines Using Controlled Semiconductor Rectifiers)*
Part 6: *Variable-Frequency Drive Systems Rated Not More Than 600 Volts Using Semiconductor Power Conversion*
Part 7: *Variable-Frequency. Three-Phase Drives, Rated 601 to 7,200 Volts*

ICS 8-1993 Industrial Control and Systems
Crane and Hoist Controllers

Part 1: *General Standards for Crane Controllers Rated 600 Volts or Less AC and DC*
Part 2: *Constant-Voltage DC Magnetic Controllers for Motors on Cranes*
Part 3: *Adjustable-Voltage DC Controllers for Motors on Cranes*
Part 4: *Magnetic Controllers for AC Wound-Rotor Motors on Cranes*
Part 5: *Static Controllers for AC Wound-Rotor Motors on Cranes*

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Part 6: *Crane and Hoist Power-Circuit Limit Switches*
Part 7: *Heavy-Duty DC Magnetic Contactors Rated 600 Volts*

ICS 9-1993 Industrial Control and Systems
Power-Circuit Accessories

Part 1: *Electromagnetic Brakes*
Part 2: *Resistors and Rheostats*
Part 3: *Autotransformers and Reactors*

ICS 10-1993 Industrial Control and Systems
AC Transfer Switch Equipment

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Part 1
GENERAL STANDARDS FOR CONTROL-CIRCUIT AND PILOT DEVICES

1 General

1.1 Referenced Standards

In this NEMA Standards Publication reference is made to the standards listed below. Copies are available from the indicated sources.

National Electrical Manufacturers Association
2101 L Street, NW
Washington, DC 20037

DC 2-1982 (R 1988)	*Quick Connect Terminals*
ICS 1-1993	*Industrial Control and Systems General Standards*
ICS 6-1993	*Industrial Control and Systems Enclosures*

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 353-1974*	*Limit Controls*
UL 508-1984*	*Industrial Control Equipment*
UL 698-1984*	*Industrial Control Equipment for Use in Hazardous (Classified) Locations*
UL 873-1988*	*Temperature-Indicating and Regulating Equipment*

*Also available from ANSI, 1430 Broadway, New York, NY 10018

1.2 Scope

The standards in this part apply to general-purpose mechanical, electromechanical and solid-state devices which are principally used in industrial applications for control-circuit switching and the control of solenoids rated not more than 600 volts.

1.3 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1 and ICS 6 also apply to this part unless otherwise stated.

2 Definitions

For the purposes of this part the following definitions apply.

abnormal conditions of use: Situations where an electromagnet, although energized, has failed to close, or where a transformer core is saturated. A control-circuit switch is required to break the current corresponding to such abnormal condition of use.

conditions of use: The principal load-switching application of a control-circuit switch as indicated for the various utilization categories in Table 1-4-3.

dry reed switch: 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.

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

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

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

form "C" contacts: A contact arrangement 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.

form "Z" contacts: A contact arrangement 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.

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mercury-wetted reed switch: Similar to a dry reed switch except that the contacts are wetted by a film of mercury.

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

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.

rated insulation voltage (U_i): The value of voltage to which dielectric voltage tests and creepage distances are referred. For equipment not having a specified rated insulation voltage, the highest value of any rated voltages is considered to be the rated insulation voltage.

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

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 assigned a number of combinations of rated operational voltage and rated operational current. The rated operational current is stated in relation to the utilization category.

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.

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.

3 Classification

See product parts of this publication for classifications.

4 Characteristics and Ratings

4.1 AC Mechanical Switching Elements

4.1.1 AC Contact Rating Designations

In contact rating designations, the letter (not to be confused with the contact arrangement form letter shown in Clause 1-2) 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.

4.1.2 AC Contact Ratings

The ratings and designations of contacts which make, break or carry AC shall be in accordance with Table 1-4-1 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 test 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 where both the normally open and normally closed contacts are connected to the same polarity.

The ratings given in Table 1-4-1 shall not be exceeded where applied to control-circuit devices.

Caution:

a. In most circumstances, the contacts of control-circuit devices are applied at values less than their make and break ratings. See Clause 9 of this part and other parts of ICS 5 for application guide lines.

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 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 1-4-1.

4.2 DC Mechanical Switching Elements

4.2.1 DC Contact Rating Designations

In contact rating designations, the letters N through R (not to be confused with the contact arrangement form letter defined in Clause 2) 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.

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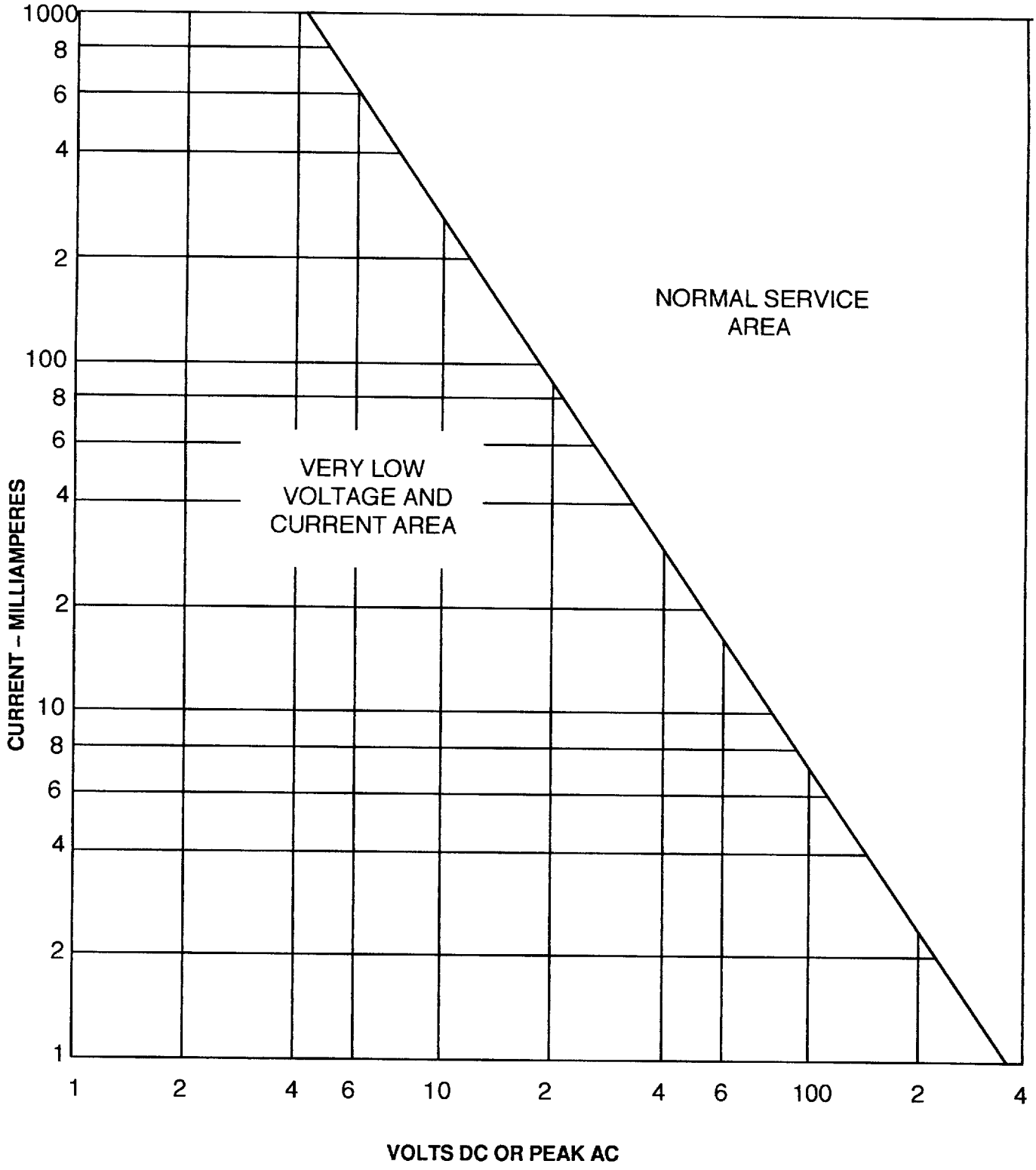


Figure 1-4-1
VERY LOW VOLTAGE AND CURRENT VALUES

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4.2.2 DC Contact Ratings

The ratings and designations of contacts which make, break or carry DC shall be in accordance with Table 1-4-2.

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 test 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 1-4-2 shall not be exceeded where applied to control-circuit devices.

Caution:

a. In most circumstances, the contacts of control-circuit devices are applied at values less than their make and break ratings. See Clause 9 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 aplications.

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 1-8-2.

4.3 AC/DC Solid State Switching Elements Ratings

The rating of a semiconductor switching element shall include:

a. The utilization category

b. The rating designation

c. The rated operational voltage, U_e

Standard utilization categories are given in Table 1-4-3.

Ratings of semiconductor control circuit switching elements shall be in accordance with Table 1-4-4 for AC ratings and Table 1-4-5 for DC ratings.

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

Semiconductor switching elements may have a rated operational current less than shown in Tables 1-4-4 and 1-4-5 for operation in higher ambient temperatures.

4.4 Contact Characteristics of Dry Reed Switches

See Table 1-4-6 for contact characteristics of dry reed switches.

Table 1-4-1
MECHANICAL SWITCHING RATINGS AND TEST VALUES FOR AC CONTROL-CIRCUIT CONTACTS AT 50 OR 60 HERTZ (See 4.1.2)

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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Table 1-4-2
MECHANICAL SWITCHING RATINGS AND TEST VALUES FOR DC CONTROL-CIRCUIT CONTACTS (See 4.2.2)

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

Table 1-4-3
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 1-4-4
RATINGS FOR AC SEMICONDUCTOR CONTROL-CIRCUIT SWITCHING ELEMENTS 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.

Table 1-4-5
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.

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5 Product Marking, Installation and Maintenance Information

5.1 Polarity Marking

Where 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.

5.2 Maintenance

See NEMA Standards Publication ICS 1.3 for general maintenance instructions.

6 Service and Storage Conditions

See ICS 1, Clause 6 for standard service and installation conditions.

7 Construction

7.1 Electrical Spacings

See ICS 1, Clause 7 for electrical spacing requiremnts.

7.2 Color Coding of Cord-Connected 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 1-7-1. Where an insulated grounding conductor is supplied, it shall be green or green with one or more yellow stripes.

Table 1-4-6
DRY REED SWITCH 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.

Table 1-7-1
CONDUCTOR COLOR IN MULTICONDUCTOR CABLE

Contact Arrangements (ICS 2-125.01)	When Insulated Grounding Conductor is Provided		When Insulated Grounding Conductor is NOT Provided	
	Conductors	Color	Conductors	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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8 Performance Requirements and Tests

8.1 Control-Circuit Device Connectors for Copper Conductors

8.1.1 General

This subclause establishes performance and test values for noninsulated 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.

The dimensions and performance requirements of quick-connect terminals are given in NEMA Standards Publication DC 2.

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 conductors.

8.1.2 Performance Tests

The connectors shall be evaluated in accordance with UL 486E and shall meet the temperature rise requirements of ICS 1, Clause 8 when torqued to a value of 7 pound-inches (0.77 Nm).

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

8.2 Requirements and Tests for Mechanical Switching Elements

8.2.1 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 Clause 2) 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.

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.

8.2.2 Temperature Rise Testing

Where tested without making or breaking current, a device with a contact rating described in this subclause shall be capable of carrying thermal continuous test current without exceeding the allowable temperature rises given in ICS 1, Clause 8. All poles of the same mode shall be wired in series with 8 feet (2.4 meters) of wire between poles (4 feet or 1.2 meters per terminal).

8.2.3 Overload Testing of AC and DC Contacts

8.2.3.1 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 1-4-1 and 1-4-2 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.

8.2.3.2 Test Criteria

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

8.2.4 Endurance Testing of AC and DC Contacts

8.2.4.1 Test Conditions

The endurance test shall be made on the same contacts which were used for the overload test. The test shall consist of 6,000 operations of making and breaking the make and break amperes, respectively, specified in Tables 1-4-1 or 1-4-2 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 1,000 operations, the on time shall be approximately equal to the off time.

The last 5,000 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.

8.2.4.2 Test Criteria

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

8.2.5 Testing of AC Contacts for Abnormal Conditions of Use

AC contacts shall be capable of interrupting their rated make current or voltamperes under abnormal conditions of use. 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

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100 percent of the make current shown in Table 1-4-1 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.

8.2.6 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 1-4-1 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 1-8-1.

8.2.7 Inductive Test Loads for DC Contacts

8.2.7.1 Construction

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

For the N150 through P600 loads, the magnetic circuit shall be made up of two solid steel cores, 1.75 inches (44 mm) in diameter and 6.25 inches (159 mm) long, which are fastened by screws at each end to solid steel yokes 1 x 2-1/2 x 6 inches (25 x 63 x 152 mm) on 4 inch (102 mm) centers. See Figure 1-8-2.

For the Q150 through Q600 loads, the magnetic circuit shall be made up of two solid steel cores, 1.5 inches (38 mm) in diameter and 4.5 inches (114 mm) long, which are fastened by screws at each end to solid steel yokes 1 x 1.75 x 4.5 inches (25 x 44 x 114 mm) on 3 inch (77 mm) centers. See Figure 1-8-3.

The steel shall have a resistance of between 80 and 120 ohms per circular mil-foot (between 13 and 20 microhm-cm). (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 inch (0.13 mm) and 0.030 inch (0.76 mm) 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 1-8-1 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 increase from the instant of energization to 95 percent of its full value ($T_{0.95}$) within the shaded area shown in Figure 1-8-4. If the current is above the shaded area the cross section of the yokes or cores, or both, shall be increased. Alternatively, if the current is below the shaded area, the cross section of the yokes or cores, or both, shall be reduced.

For the R150 and R300 contact ratings the load is not detailed, but it shall be an iron-cored electromagnet, in series with a resistor (if needed), to obtain the make or break current values shown in Table 1-8-1. The coil current shall increase from the instant of energization to 95 percent of its full value ($T_{0.95}$) within the shaded area shown in Figure 1-8-4.

8.2.7.2 Explanation

The DC 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 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 usually have a charging time ($T_{0.95}$) to 95 percent of their full current value of 6 milliseconds per watt or less.

Where 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 ($T_{0.95}$ milliseconds) equal to six times the watts.

8.3 Requirements and Tests for Semiconductor Switching Elements

8.3.1 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.

8.3.2 Temperature Test

8.3.2.1 Test Conditions

Where 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 14 AWG copper wire, switching elements with prefix SB and SP, with 20 AWG copper wire and the balance with 22 AWG copper wire. The

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length of wire connected at each terminal shall be 4 feet (1.2 meters), which is 8 feet (2.4 meters) from terminal to terminal.

8.3.2.2 Test Criteria

Busses, connecting straps, terminals and insulating systems shall not exceed the allowable temperature rise specified in ICS 1, Clause 8 for these items.

8.3.3 Verification of Make and Break Capability

8.3.3.1 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.

8.3.3.2 Normal Conditions of Use

A switching element shall be tested in accordance with Table 1-8-2.

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 where $U/U_e = 1$. This is the overload segment of the test.

The next 6,000 operations shall be run at $U/U_e = 1$ and shall make and break the test circuit as specified in Table 1-8-2. The test shall be performed in the following sequences:

The first 1,000 operations shall be at the rate of one operation per second except the first ten operations shall be manual operations made as rapidly as possible while making sure of the actual operation of the switching element.

Where the construction of the device is such that rapid manual operation is not possible, the rate of operation shall be six operations per minute or as fast as the device will permit.

The remaining 5,000 operations shall be at the rate of six operations per minute with the switching element conducting for the specified on-time.

8.3.3.3 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 1-8-3.The test shall consist of ten operations at the rate of six per minute with the switching element closed for 0.5 second during each operation.

8.3.3.4 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 two cycle make current and rated operational current shown in Table 1-4-4. If loads in parallel are used, all such parallel loads shall be identical. An example of a test circuit is shown in Figure 1-8-5. The test load power factor shall be as specified in Tables 1-8-2 and 1-8-3.

8.3.3.5 Test Loads for DC Switching Elements

The test load shall have a resistance to yield the final currents described in Table 1-4-4 and the rise times described in Tables 1-8-2 and 1-8-3. If loads in parallel are used, all such parallel loads shall be identical.

8.3.3.6 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 1, Clause 8.

Table 1-8-1
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.

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Table 1-8-2
VERIFICATION OF MAKING AND BREAKING CAPABILITIES OF SEMICONDUCTOR 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

$P = U_eI_e$ = 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 1-8-3
VERIFICATION OF MAKING AND BREAKING CAPABILITIES OF SEMICONDUCTOR 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	—	—		—	—	—		—	10	6	.05
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			
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

$P = U_eI_e$ = 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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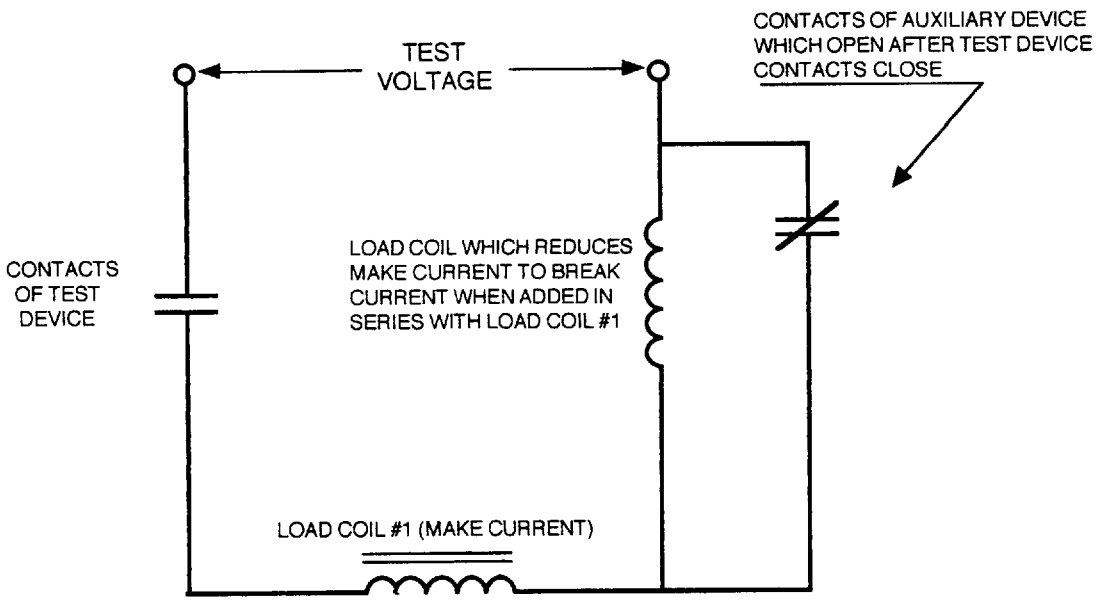


Figure 1-8-1
RECOMMENDED TEST CIRCUIT FOR CONTACTS

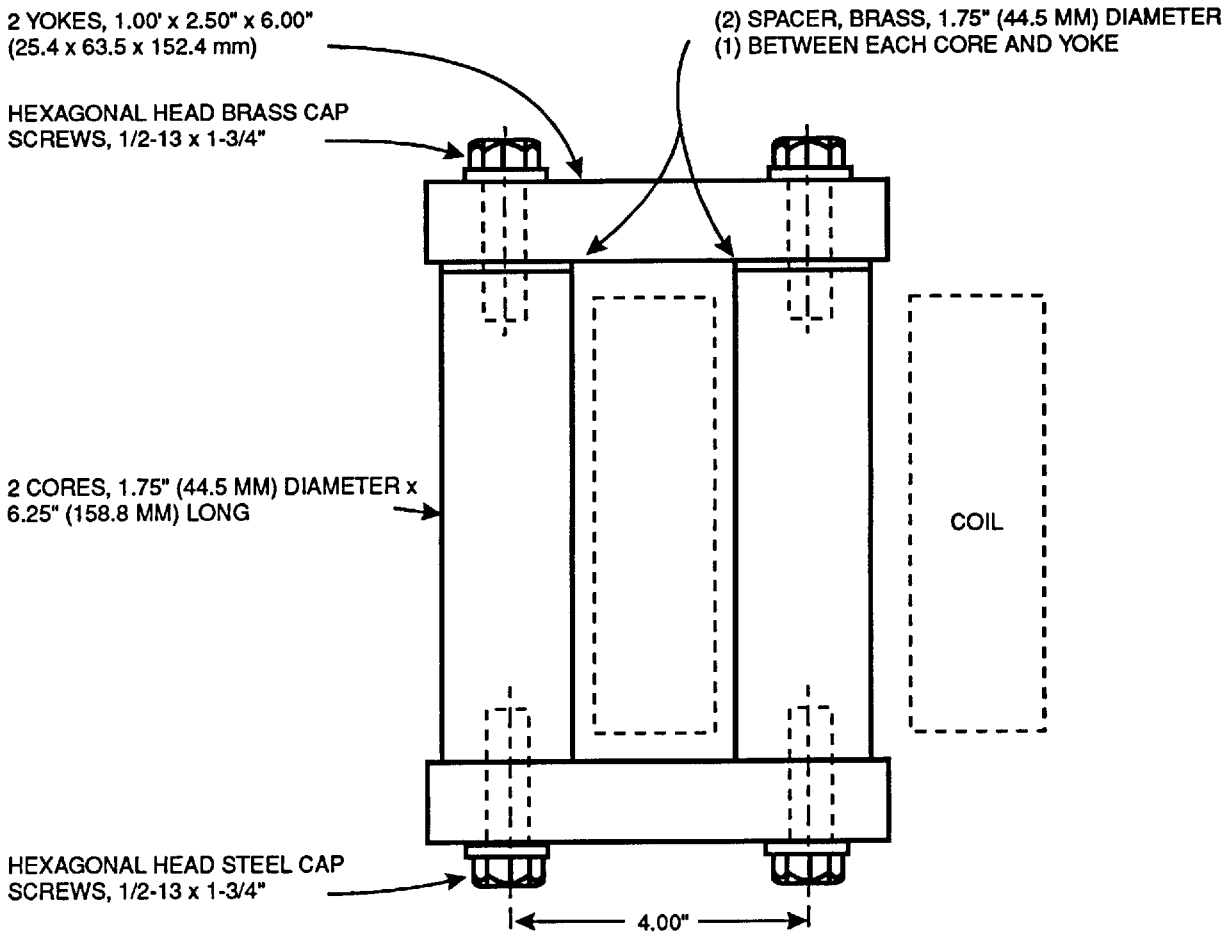


Figure 1-8-2
CONSTRUCTION OF LOAD FOR DC CONTACTS N & P

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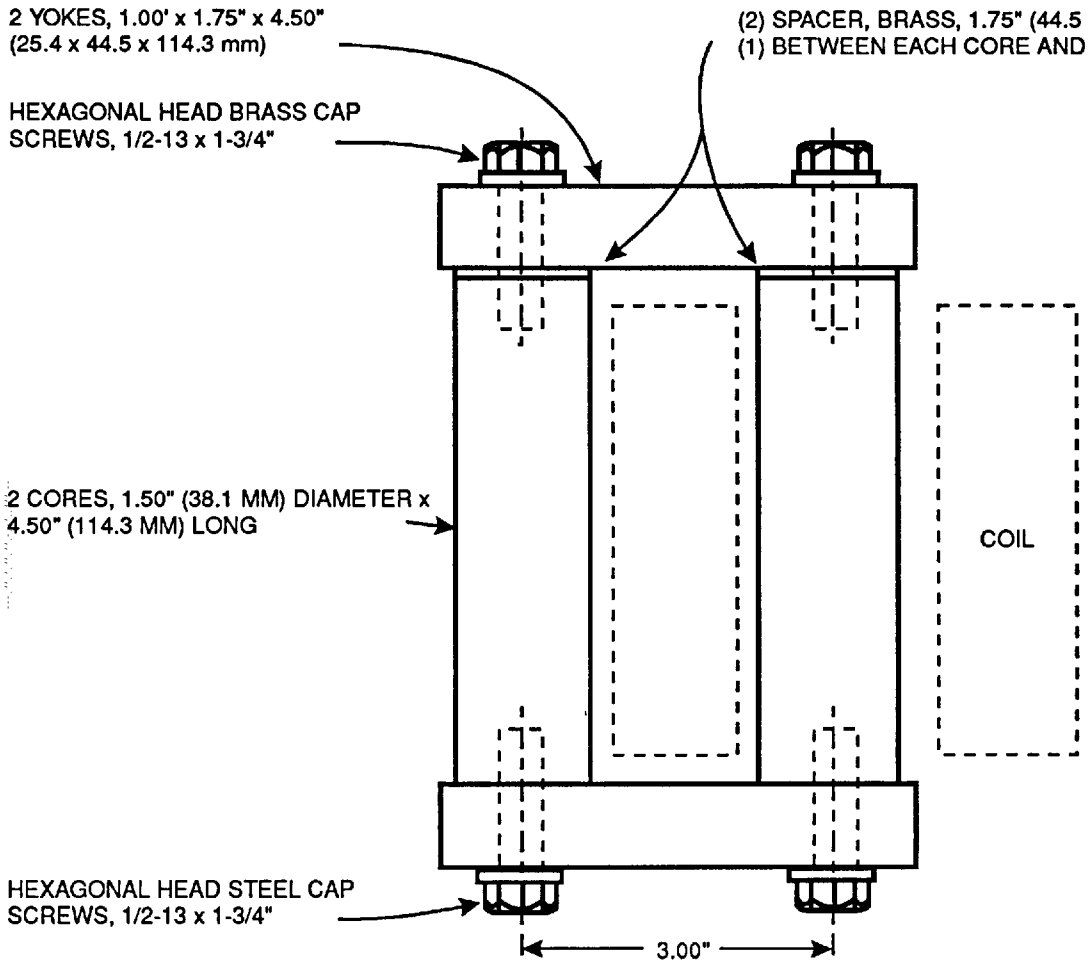


Figure 1-8-3
CONSTRUCTION OF LOAD FOR DC CONTACTS Q

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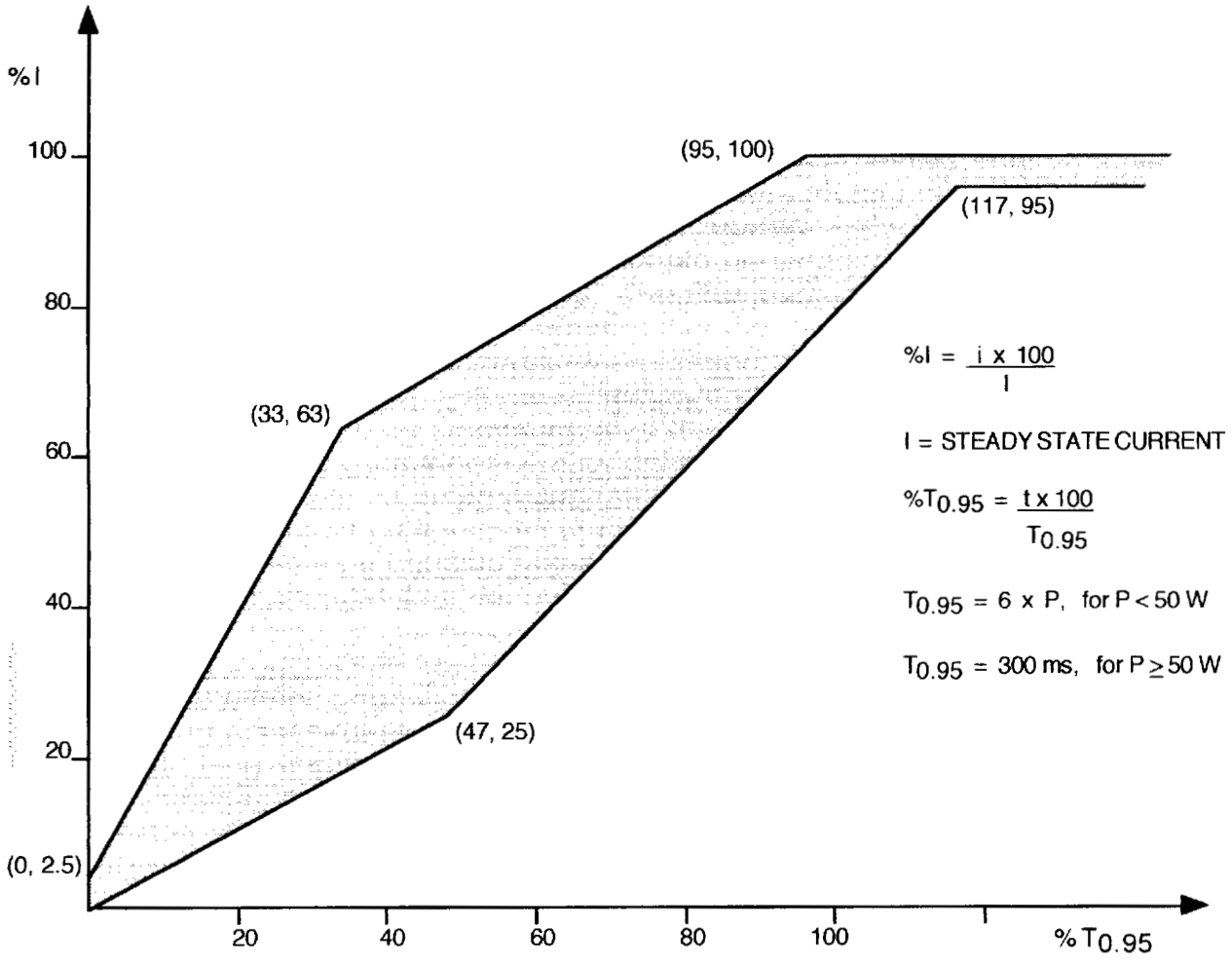


Figure 1-8-4
CURRENT/TIME LIMITS FOR DC CONTACT LOAD

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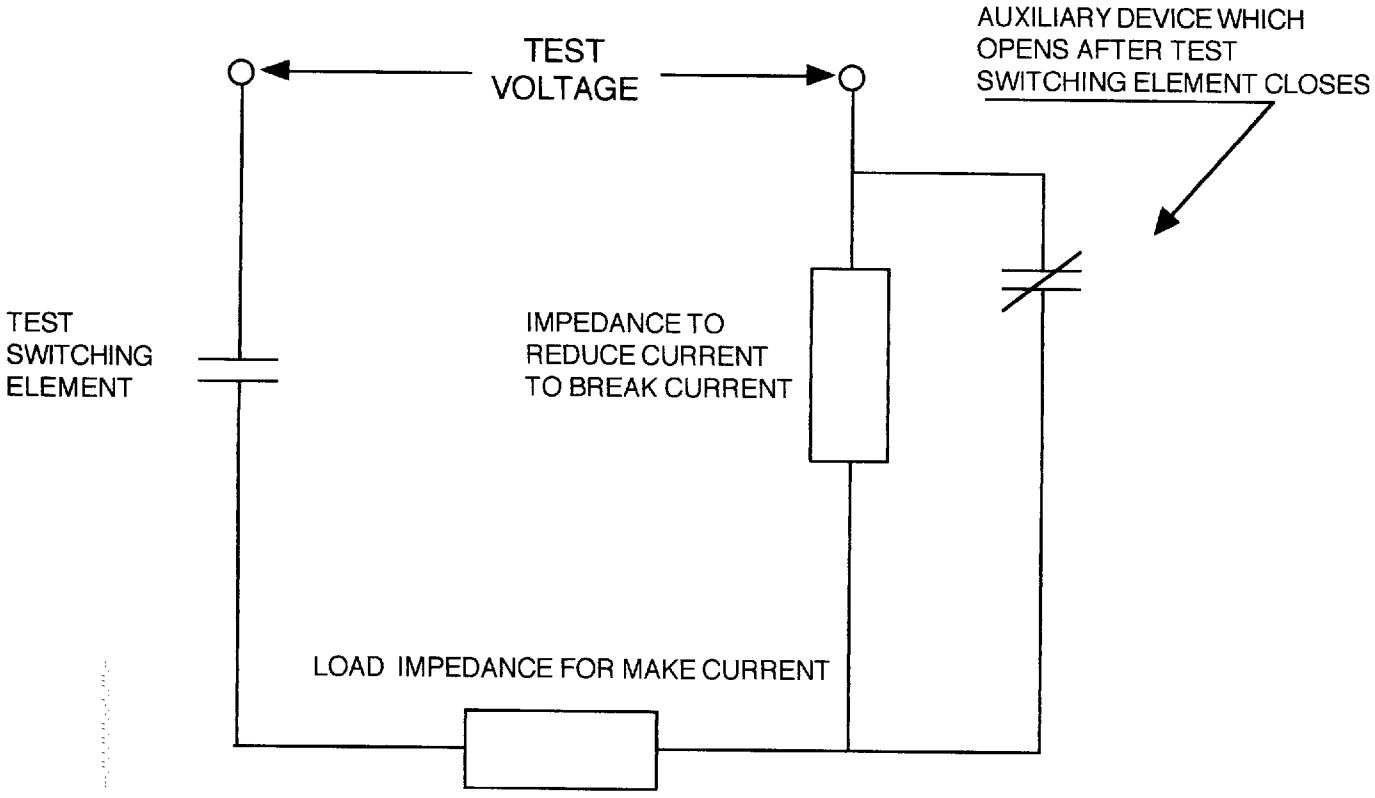


Figure 1-8-5
RECOMMENDED TEST CIRCUIT FOR AC SWITCHING ELEMENTS

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9 Application

9.1 Contact Life

The life of mechanical 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 to the specific control circuit devices.

9.2 Polarity

Polarity, as applied to contacts and terminals (see Figure 1-9-1) 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.

9.3 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.

9.4 Component Applications

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

9.5 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.

9.6 Logic-Type Switches

Logic-type dry reed switches provide contact reliability at low values of voltage and current, and relatively high speed operation, even where exposed to environmental contamination. The contacts of coil-operated dry reed switches having a fanout 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.

9.7 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 transient voltages do not exceed the voltage ratings of the contacts or, alternatively, the relay manufacturer should be consulted for recommendation.

9.8 Voltage Variation Requirement for Static Switching Control Elements

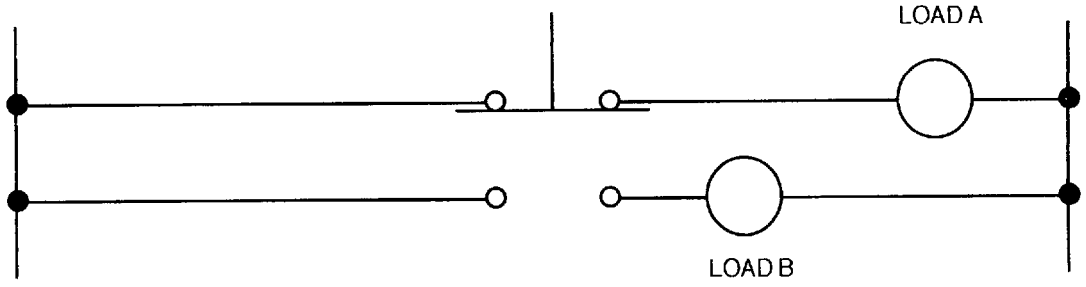
The control system shall operate on a supply voltage from minus 10 percent to plus 10 percent of the rated control system voltage.

9.9 Application Considerations

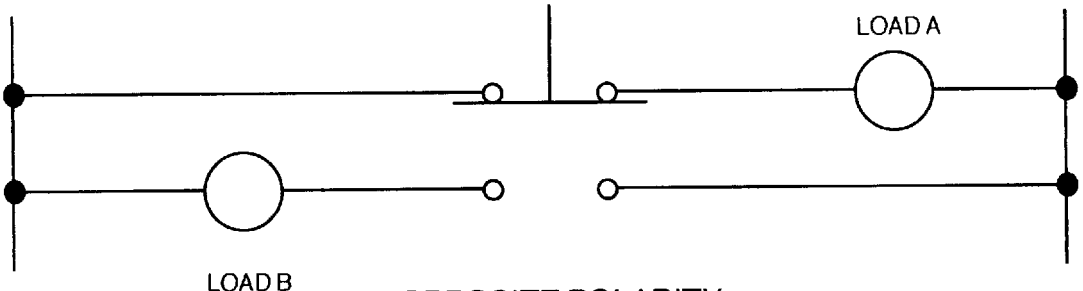
Refer to ICS 1.1, with particular emphasis upon personnel safety for safety requrirements when applying solid state devices.

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SAME POLARITY



OPPOSITE POLARITY

Figure 1-9-1
POLARITY

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Part 2
INDUSTRIAL CONTROL RELAYS

1 General

1.1 Scope

The standards in this section apply to 50 and 60 hertz, AC and DC magnetic control relays and time-delay (timing) relays principally used in control circuits of industrial control apparatus.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1, ICS 6 and ICS 5, Section 1 apply to this section unless otherwise stated.

2 Definitions

For the purposes of this section the following definitions apply.

alternating-current (AC) relay: A relay which is designed to be actuated from an AC source.

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

convertible contact construction: A contact construction which can be changed from normally open to normally closed and vice versa in the field.

direct-current (DC) relay: A relay which is designed to be actuated from a DC source.

fixed contact construction: A contact construction which cannot be changed from normally open to normally closed or vice versa in the field.

instantaneous switching element (contact or semiconductor): The contact or semiconductor switching elements which operate at the time the relay is energized and deenergized. They are independent of the timed switching elements.

interval timing relay: A type of timing relay which changes the state of its timed contact(s) for predetermined time(s). An interval timer may have more than one predetermined time interval.

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

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

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

repeat accuracy deviation: 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.

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.

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

solid-state time-delay relay: 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 a contact switching element.

time-delay relay; timing relay: A relay which has an assured time interval between energization and the action of the switching element, or between deenergization 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 Deenergization (TDD)" or "Off-Delay" relays.

timed switching elements (contact or semiconductor): Those contact or semiconductor switching elements of a timing relay which operate immediately after the time delay.

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universal contact construction: 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.

3 Classification

3.1 Contact Forms

Fixed and convertible contact constructions may be used for all of the contact forms described in Clause 1-2.

3.2 Control Relay and Time-Delay Relay Class Designations

The classes of relays shall be designated in terms of their contact ratings, by means of the letters and numerals given in Clause 1-4, in the following manner:

a. A letter (not to be confused with the form letter such as "form A Contact") which indicates the maximum continuous thermal test current as shown in Table 2-3-1

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

Example—A relay designated A600 is a relay which has A600 contacts, is suitable for use at all AC voltages through 600 volts, is built to the 600-volt spacing requirements given for Group A controls in ICS 1, Table 7-1, and has a continuous thermal test current rating of 10 amperes and make and break ratings in accordance with Table 1-4-1.

Table 2-3-1
CONTACT CLASS DESIGNATIONS

Letter Designation		Continuous Thermal
Alternation Current	Direct Current	Test Current, Amperes
A	N	10.0
B	P	5.0
C	Q	2.5
D	R	1.0
E		0.5

4 Characteristics and Ratings

4.1 Relay Coils

Control relays and magnetically-operated time-delay relays shall be equipped with coils having the ratings shown in Table 2-4-1. The coil shall have only one rating for any one frequency. See ICS 1.

Table 2-4-1
RATINGS OF COILS FOR CONTROL RELAYS AND TIME-DELAY RELAYS

AC Volts		DC
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.

4.2 Switching Elements

4.2.1 Control and Time-Delay Relay Ratings

The contact ratings of control and time-delay relays shall be in accordance with Clause 1-4. See Clause 2-9 for application guidelines.

4.2.2 Semiconductor Switching Element Ratings

The ratings of time-delay relays having semiconductor switching elements for use in control circuits shall be in accordance with Clause 1-4 for the utilization category specified.

5 Product Marking, Installation and Maintenance Information

See NEMA Standards Publication ICS 1.3 for preventative maintenance instructions.

6 Service and Storage Conditions

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

7 Construction

No construction requirements are included in this section.

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8 Performance Requirements and Tests

8.1 Switching Element Performance Requirements

8.1.1 Mechanical Contact Performance

The contacts of a control relay or time-delay relay shall be capable of passing the overload, endurance and abnormal conditions of use tests described in Clause 1-8.

8.1.2 Semiconductor Switching Element Performance Requirements

Semiconductor switching elements, where used as output for time-delay relays, shall meet the test and performance requirements of Clause 1-8 corresponding to their rating designation for the utilization category specified.

8.1.3 Temperature Rise of Contacts

The contacts of a control relay or time-delay relay, when operating at rated voltage and carrying continuous thermal test current, shall not exceed the temperature rises given in ICS 1, Clause 8. The temperature rise test on contacts shall be made on unused contacts carrying, but not making or breaking, current.

8.2 Coil Performance Requirements

8.2.1 Range of Coil Operating Voltage

AC magnetically-operated control relays and 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. DC magnetically operated control relays and 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 ICS 1, Clause 8 for test procedure.

8.2.2 Coil Temperature Rise

The coil temperature rise of a control relay or time-delay relay, when operating at rated voltage, shall not exceed the limits given in ICS 1, Clause 8.

8.3 Terminal Temperature Rise

The field wiring terminals of control relays and time-delay relays, when operating at rated voltage and carrying continuous thermal test current, shall not exceed the temperature rise given in NEMA Standards Publication No. ICS 1, Clause 8 when wired as shown in Table 2-8-1.

Table 2-8-1
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 (1.2 meters) of wire per terminal (8 feet or 2.4 meters from terminal to terminal).

8.4 Dielectric Test

8.4.1 Control and Time-Delay Relays with Contacts

A control relay or a time-delay relay with contacts shall be capable of withstanding the power frequency dielectric test described in ICS 1, Clause 8 when mounted as it is intended to be used in service.

8.4.2 Time-Delay Relays with Semiconductor Switching Elements

A time-delay relay with a semiconductor switching element shall be capable of withstanding the power frequency dielectric test described in ICS 1, Clause 8 except that the test between the time delay initiating circuit and the output circuit shall be omitted.

9 Application

9.1 Application Guide for Control Relays and Time-Delay Relays with Mechanical Contact Switching Element

The make and break ratings and test values shown in Tables 1-4-1 and 1-4-2 of ICS 2-1 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 NEMA Standards Publication No. ICS 5 Part 1.

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.

When control relays or 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 1-4-1 and 1-4-2 of ICS 2-1.

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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, manufacturer's recommendations should be obtained regarding specific applications.

9.2 Application Guide for Time-Delay Relays Having Semiconductor Switching Elements

The utilization categories given in clause 4 of ICS 2, Part 1 are considered standard.

Applications not covered by standard utilization categories 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.

9.3 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 nonoverlap is essential, the manufacturer should be consulted.

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Part 3
INDUSTRIAL CONTROL INPUT DEVICES ACTUATED BY FORCE, TEMPERATURE OR PRESSURE

1 General

1.1 Scope

The standards in this part apply to limit (position) switches, pressure switches, temperature switches and liquid-level switches that are actuated by force, pressure or temperature and used as inputs to control circuits of industrial control apparatus. This part also applies to auxiliary contacts of controllers and disconnect devices used in the control circuits of industrial control apparatus.

The switches and auxiliary contacts are rated for AC and DC control circuit applications of 600 volts or less.

See Part 5 for standards that apply to push buttons and selector switches.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1, ICS 6 and ICS 5, Part 1 apply to this part unless otherwise stated.

2 Definitions

For the purposes of this part, the following definitions apply.

The definitions in this clause are grouped according to switch category and listed alphabetically in each category.

2.1 Definitions of Switch Types

basic switch: 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.

float switch: A liquid-level switch which is operated by a buoyant constituent part.

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

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

limit switch; position switch: A switch that 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.

liquid-level switch: A switch which is responsive to the level of a liquid.

The design of a liquid-level switch may be based on such principles as buoyancy, liquid weight, optics, capacitance, sound, etc.

maintained contact limit switch; reset switch: A switch that remains in a given condition until actuated to another condition, which is also maintained until further actuation.

See 2.2.3 and Figures 3-2-1 and 3-2-2.

momentary contact limit switch: A limit switch that returns from the operated condition to its normal circuit condition when the actuating force is removed.

See 2.2.2 and Figures 3-2-3 and 3-2-4.

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

power-circuit limit switch: A limit switch the contacts of which are in the power circuit.

precision snap-acting switch: 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 spearation between any butting contacts is 1/8 inch (3.2 millimeters). 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

pressure limit control: A pressure switch set beyond the process operating pressure to limit the operation of the controlled equipment under abnormal conditions.

pressure switch: A switch that is operated by a constituent part and is responsive to fluid (gas or liquid) pressure.

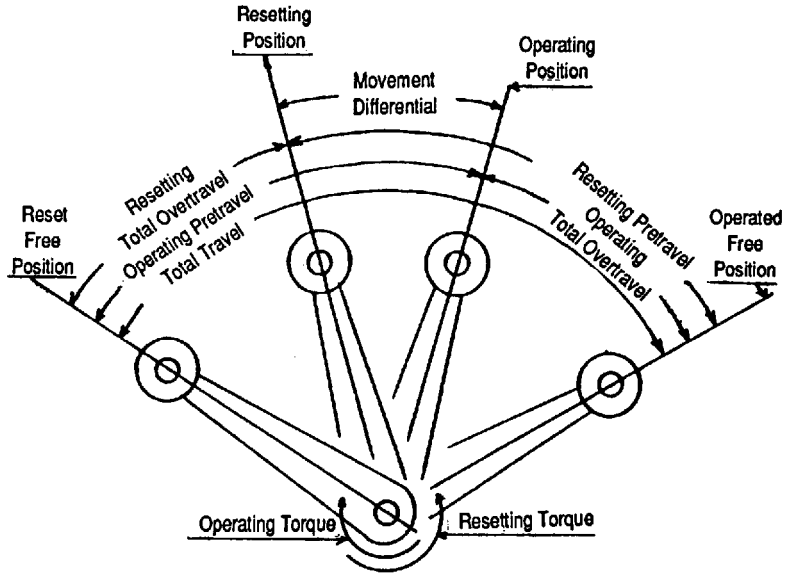
A pressure switch that operates primarily at pressure less than atmospheric is call a vacuum switch.

proportional temperature controller: A controller that is responsive to temperature and which has a continuous proportional relationship between its output and its input within its operating temperature range.

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

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

Figure 3-2-1
MAINTAINED CONTACT LEVER-OPERATED LIMIT SWITCH

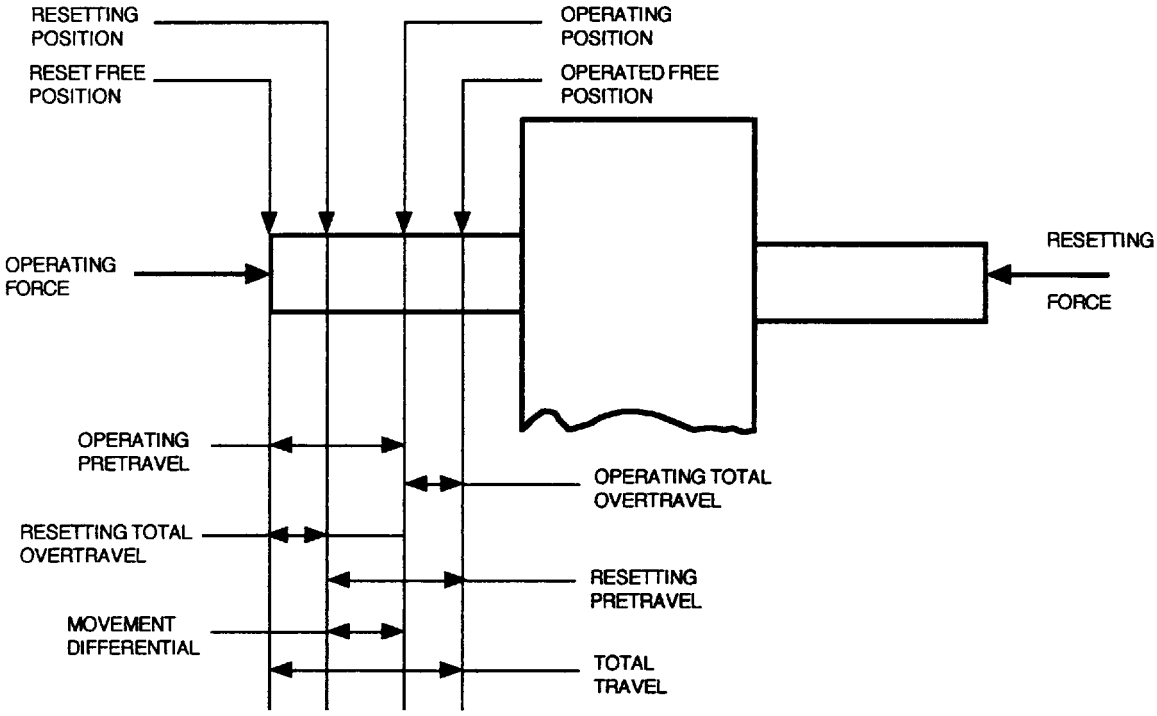
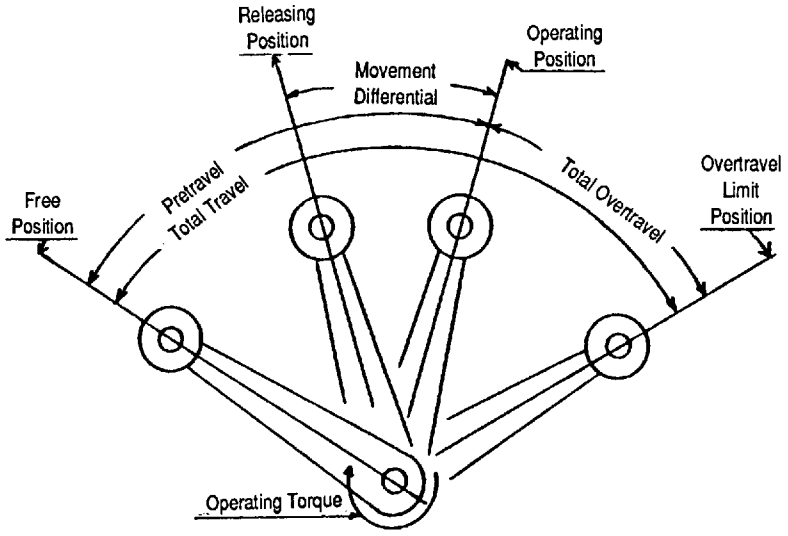


Figure 3-2-2
MAINTAINED CONTACT PLUNGER-LIMIT SWITCH

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

Figure 3-2-3
MOMENTARY CONTACT LEVER-OPERATED LIMIT SWITCH

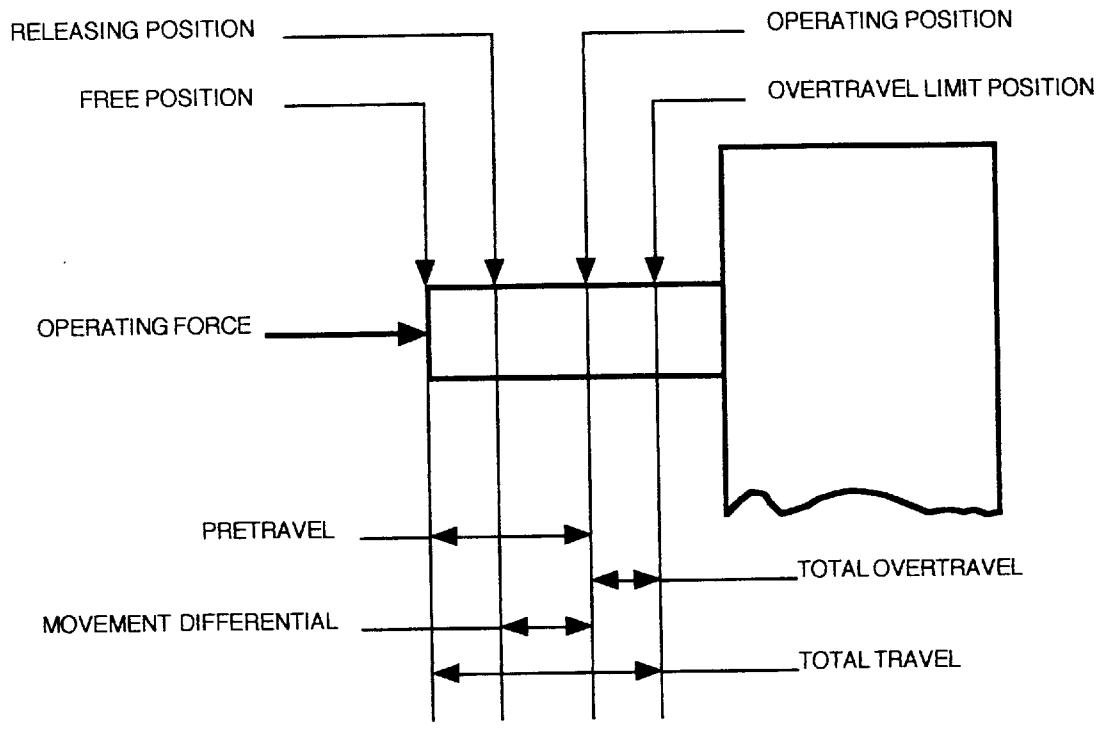


Figure 3-2-4
MOMENTARY CONTACT PLUNGER-OPERATED LIMIT SWITCH

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snap-acting switch: A switch 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.

temperature limit control: A temperature switch set beyond the process operating temperature to limit the operation of the controlled equipment under abnormal conditions.

temperature switch: A two-state (ON-OFF) controller which is responsive to the temperature of a sensed medium.

2.2 Definitions for Limit Switches

2.2.1 General Definitions Applying to Limit Switches

actuating point: The point on an actuator at which operating force is applied.

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

auxiliary actuator: A mechanism which may be attached to a switch to modify its characteristics.

break distance: The effective open-gap distance between the stationary and movable contacts.

contact force: The force exerted by the moving contact on a stationary contact.

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

operated contact position: The position to which the contacts move when the actuator is traveled to or beyond the actuator operating position.

operating force: The straight-line force in the designated direction applied to the actuator to cause the switch contacts to snap to the operated contact position.

operating position: The position of the actuator at which the contacts snap to the operated contact position.

operating torque: The minimum torque applied to the actuator to cause the moving contact to snap to the operated contact position.

overtravel: The movement of the actuator beyond the operating position.

overtravel limit position: That position of the actuator beyond which further overtravel would cause damage to the switch or actuator.

repeat accuracy deviation: 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:

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

Where:

A_R = Percent repeat accuracy deviation

X_1 = Maximum observed travel*

X_2 = Minimum observed travel*

*To be obtained over 100 consecutive operations.

repeatability: The ability to consistently maintain the original operating characteristics.

total travel: The sum of the pretravel and total overtravel.

2.2.2 Definitions Applying to Momentary Contact Limit Switch

(See Figures 3-2-3 and 3-2-4 for illustrations)

force differential: The difference between operating force and the releasing force.

free position: The initial position of the actuator where there is no external force (other than gravity) applied on the actuator and the switch is in the specified position.

movement differential: The distance or angle from the operating position to the releasing position.

normal contact position: That position of the contacts which exists when no operating force is applied.

pretravel: The distance or angle through which the actuator moves from the actuator free position to the actuator operating position.

releasing force: 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.

releasing position: That position of the actuator at which the contacts snap from the operated contact position to the normal contact position.

releasing torque: 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.

torque differential: The difference between the operating torque and the releasing torque.

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total overtravel: The distance or angle through which the actuator moves when traveling from the actuator operating position to the overtravel limit position.

2.2.3 Definitions Applying to Maintained Contact Limit Switches

See Figures 3-2-1 and 3-2-2 for illustrations.

movement differential: The distance or angle from the operating position to the resetting position.

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

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

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

reset contact position: The position to which the contacts snap when the actuator is traveled to or beyond the resetting position.

reset free position: The position of the actuator where there is no external force (other than gravity) applied on the actuator and the switch is in the reset contact position.

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

resetting position: The position of the actuator at which the moving contact snaps from the operated contact position to the reset contact position.

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

resetting torque: The minimum torque that is applied to the resetting mechanism to cause the moving contact to snap from one position to another.

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

2.3 Definitions Applying to Pressure Switches

allowable pressure limits: 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.

Maximum allowable pressure is also referred to as overrange and includes surge pressures.

cut-in pressure: That pressure at which the switch is actuated to energize the load.

The cut-in pressure may be the trip or reset point.

cut-out pressure: That pressure at which the switch is actuated to deenergize the load.

The cut-out pressure may be the trip or reset point.

drift: An inherent change in operating value for a given setting over a specified number of operations and specified environmental conditions.

maximum static pressure: The continuous pressure which the pressure containing envelope of a pressure switch sustains without rupture.

Maximum static pressure is sometimes called rated static pressure.

operating differential pressure: The difference between cut-in pressure and cut-out pressure.

Operating differential pressure is also called dead band or hysteresis.

operating pressure range: 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.

proof pressure: The nondestructive static test pressure, in excess of the maximum allowable pressure, which causes no permanent deformation or malfunction.

pulsation snubber: 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.

2.4 Definitions Applying to Temperature Switches

allowable temperature limits: The maximum and minimum temperatures that a temperature switch may be exposed to without altering its performance characteristics.

cut-in temperature: The temperature of the sensed medium at which a temperature switch is actuated to energize the load.

The cut-in temperature may be the trip or reset point.

cut-out temperature: The temperature of the sensed medium at which a temperature switch is actuated to deenergize the load.

The cut-out temperature may be the trip or reset point.

operating temperature differential: The difference between the cut-in and cut-out temperatures.

Operating temperature differential is also called dead band or hysteresis.

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operating temperature range: The range between the maximum and minimum temperature settings at which a temperature switch will continue to operate within the manufacturer's specifications.

remote temperature sensing: 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.

3 Classification

No classifications are included in this part.

4 Characteristics and Ratings

4.1 Electrical Switching Element or Output Ratings

4.1.1 Contact Ratings

The contact ratings of these switches where used in control circuits shall be in accordance with Clause 1-4. See Clause 1-9 for application guidelines.

4.1.1.1 Standard-Duty Rating

Devices rated standard duty shall have contact rating designations of B150, B300, B600, P150, P300 or P600 as shown in Table 1-4-1 for AC and Table 1-4-2 for DC.

4.1.1.2 Heavy-Duty Rating

Devices rated heavy duty shall have contact rating designations of A150, A300, A600, N150, N300 or N600 as shown in Table 1-4-1 for AC and Table 1-4-2 for DC.

4.1.1.3 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 or voltamperes, or both, or watts for one or more utilization voltages.

4.1.2 Semiconductor Switching Element Ratings

4.1.2.1 The ratings of switches having semiconductor switching elements for use in control circuits shall be in accordance with Clause 1-4 for the utilization category specified.

4.1.2.2 Standard utilization categories are given in Table 1-4-3.

Applications not covered by the utilization categories in Clause 1-4 should be based on agreement between the manufacturer and the user.

4.2 Pressure Ratings

4.2.1 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.

Unless a pressure switch is designed for operation at less than atmospheric pressure, a minimum pressure of zero is not recommended.

4.2.2 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.

4.3 Temperature Ratings

4.3.1 Temperature Switches

A temperature switch shall have a specified operating range, operating differential and allowable temperature limits.

4.3.2 Proportional Temperature Controllers

A proportional temperature controller shall have a specified operating range, a specified relation between input and output, and allowable temperature limits.

4.3.3 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.

4.3.4 Allowable Temperature Limits

The allowable temperature limits of a temperature controller shall exceed the operating temperature range.

4.3.5 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.

5 Product Marking, Installation and Maintenance Information

5.1 Preventative Maintenance

A preventative 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 manufacturer's recommendations.

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See NEMA Standards Publication ICS 1.3 for preventative maintenance instructions.

5.2 Specific Maintenance Instructions for Float Switches

Inspect float mechanism for loss of buoyancy.

6 Service and Installation Conditions

6.1 Pressure Switch Service Conditions

6.1.1 Chemical

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.

6.1.2 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.

6.2 Temperature Switch 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.

6.3 Liquid Level Switch 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.

7 Construction

7.1 Materials for Temperature Switch Actuators

Temperature switches and proportional temperature controllers by their nature may be subjected to ambient temperature operating conditions above or below those given in ICS 1 and, therefore, should incorporate materials suitable to the application.

7.2 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.

8 Performance Requirements and Tests

8.1 Contact Performance

8.1.1 Control Circuit Switches

The contacts of control-circuit switches when new, shall:

a. Not exceed the temperature rise given in 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 NEMA Standards Publication No. ICS 5, Part 1.

8.1.2 Motor Control Switches

The make and break design test for 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 of six operations per minute with a minumum "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.

8.2 Semiconductor Switching Element Performance

Semiconductor switching elements shall meet the test and performance requirements of ICS 5, Part 1 corresponding to their rating designation for the utilization category specified.

8.3 Temperature Rise of Terminals

The field wiring terminals of a control circuit switch carrying continuous thermal test current shall not exceed the temperature rise given in NEMA Standards Publication No. ICS 1, Clause 8.3.3.3 when wired according to Table 3-8-1.

Table 3-8-1
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

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For the purrposes of this test, the field wiring terminals of temperature switches, shall be wired with wire sized appropriately for the switch rating (see Table 3-8-1). The terminals of all poles of the same mode shall be wired in series with 4 feet (1.2 meters) of wire between terminals.

See NEMA Standards Publication No. ICS 5, Part 1 for devices rated for control circuit applications.

For temperature switches and proportional temperature controllers the temperature rise performance requirement is with the sensing element exposed to maximum allowable temperature.

8.4 Dielectric Test

Control-circuit switches shall be capable of withstanding the power frequency design dielectric test described in NEMA Standards Publication No. ICS 1, Clause 8.4 when mounted as they are intended to be used in service.

8.5 Other Requirements

8.5.1 Actuators of Pressure Switches

The parts of a pressure switch shall meet the strength requirements of Underwriters Laboratories Publications UL 353, 508, 698, or 873, as applicable.

8.5.2 Pressure Limit Controls

A pressure limit control shall be evaluated in accordance with Underwriters Laboratories Publication UL 353 or 873, as applicable.

8.5.3 Temperature Limit Control

A temperature limit control shall be evaluated in accordance with Underwriters Laboratories Publication UL 353 or 873, as applicable.

9 Application

Under consideration.

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Part 4
PROXIMITY SWITCHES

1 General

1.1 Scope

The standards in this part apply to 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. The response is a change in the bistate output.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1, ICS 6 and ICS 5, Part 1 apply to this part unless otherwise stated.

2 Definitions

For purposes of this part the following definitions apply.

2.1 Basic Definitions

Type 1 (nonbreak beam) proximity switches: Switches that operate on the principle that the designated object reflects, absorbs, or alters energy radiated from the sensor.

Type 2 (break beam) proximity switches: Switches that operate on the principle that the designated object interrupts a beam directed between a transmitter (emitter) and a receiver.

2.2 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 nonmetallic 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 (target): 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: The ratio of the signal received by a photoelectric switch, 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.

free zone: 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 (as it pertains to 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 8.11.)

response time: The time required for the device output to respond when the target enters or exits the sensing zone. (See turn-on, turn-off time.)

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.

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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 Clause 8.)

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 Clause 4.)

turn-off time: The time required for the output to respond after the target reaches the release point.

turn-on time: The time required for the output to respond after the target reaches the operate point.

unshielded (inductive, capacitive, or magnetic) proximity switch: Proximity switch requiring a free zone around its sensing face to maintain its characteristics.

2.3 Definitions Pertaining to Type 1 Switches

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 4-2-1.)

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 8.4. (See Figure 4-2-1.)

lateral approach: The approach of a designated object in a plane perpendicular to and toward 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 value used to designate the nominal operating distance. It does not take

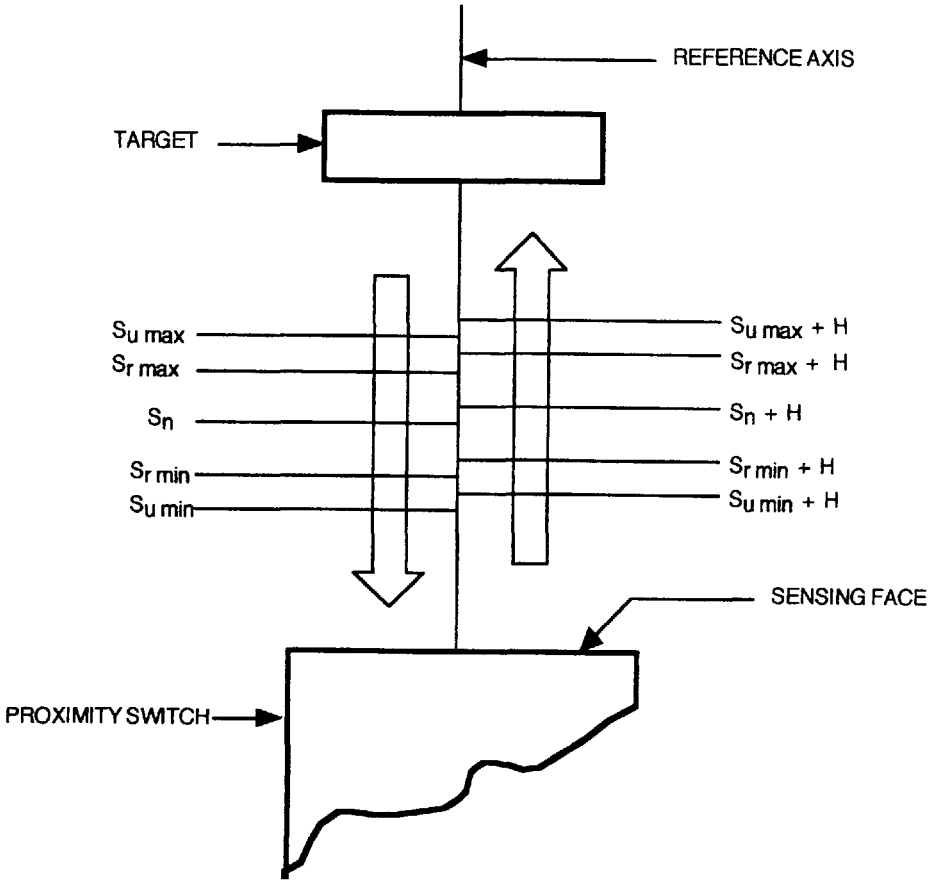


Figure 4-2-1
DISTANCE MEASUREMENTS FOR TYPE 1 PROXIMITY SWITCHES

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into account either manufacturing tolerances or variations due to external conditions such as voltage, temperature and so forth. (See Figure 4-2-1.)

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.

2.4 Definitions Pertaining to Type 2 Switches

rated range, R_n : A value assigned by the manufacturer to designate the maximum recommended distance between the transmitter and receiver elements (Mode T); or sensor and reflector (Mode R) under specified conditions. (See Figure 4-2-2.)

reference axis: An axis perpendicular to, and through the center of, the transmitter and receiver elements (Mode T) sensing faces, when they are aligned (sensor and reflector, Mode R). (See Figures 4-2-2 and 4-2-3.)

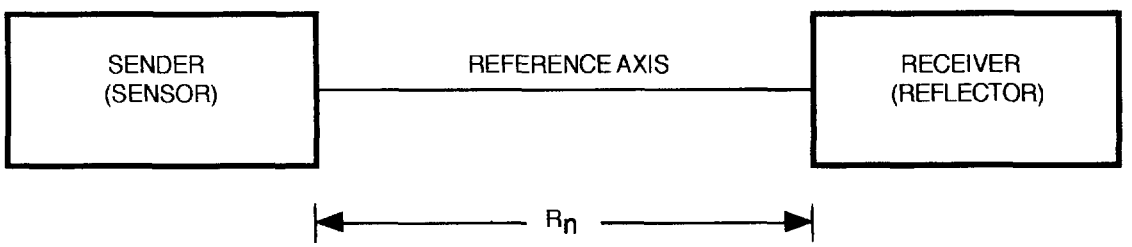


Figure 4-2-2
DISTANCE MEASUREMENTS FOR TYPE 2 PROXIMITY SWITCHES

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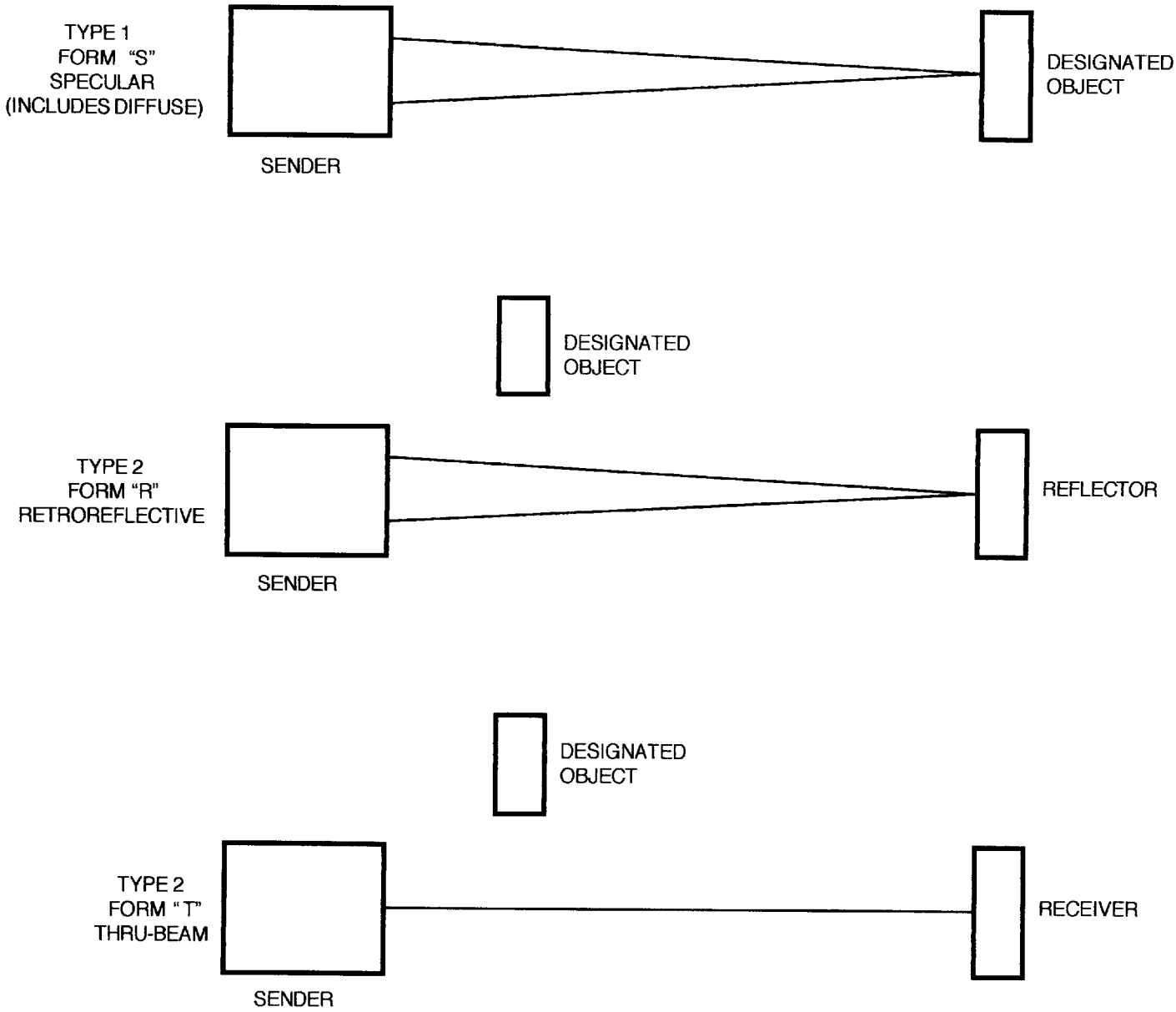


Figure 4-2-3
FORMS OF PHOTOELECTRIC SWITCHES

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3 Classification

3.1 Classification of Proximity Switches by Sensing Means

(See Table 4-3-1.)

3.1.1 Inductive

Inductive proximity switches are Type 1 devices used to sense metallic objects. An induced current in the target 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 for use with magnetic metals are designated by the letter "F" in the fourth position. The letter "N" is used for nonmagnetic metals and the letter "M" is used for universal detection. In the NEMA classification system, inductive proximity switches are designated by the letter "I" in the second position.

3.1.2 Capacitive

Capacitive proximity switches are Type 1 devices used to sense metallic or 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 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. In the NEMA classification system, capacitive proximity switches are designated by the letter "C" in the second position.

3.1.3 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 the letter "G" in the second position.

3.1.4 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 4-2-3. In the NEMA classification system, optical proximity switches are designated by the letter "O" in the first position.

3.1.5 Ultrasonic

Ultrasonic (sometimes called sonic) proximity switches are used to sense objects that reflect (Type 1) or interrupt (Type 2) sound 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.

3.2 Classification of Proximity Switches by Output

The output of a proximity switch may be through contacts rated in accordance with Clause 1-4 or a semiconductor rated in accordance with Clause 1-4. Output ratings may be AC or DC, or both. Output forms may be Normally Open (NO) or Normally Closed (NC), or both.

3.3 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.

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.

3.4 Dimensional Classifications of Self-Contained Proximity Switches

Two types of self-contained proximity switches are classified by dimension.

3.4.1 Standard Dimensions of Cylindrical Switches

Self-contained proximity switches that are cylindrical in shape and have the dimensions and thread sizes shown in Table 4-3-2 may be designated NEMA Style C8, C12, C18, or C30 proximity switches. (See Figure 4-3-1.)

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Table 4-3-1
DIMENSIONS OF CYLINDRICAL PROXIMITY SWITCHES

Style	Nominal Diameter d_1 (mm)	Thread Size (metric)	Nut Dimensions: Thickness m (mm)	Nut Dimensions: Across Corners d_3 (mm)	Nut Dimensions: Across Flats Sw (mm)	Length: Minimum L_1 (mm)	Length: Maximum L_2 (mm)	Length: 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.

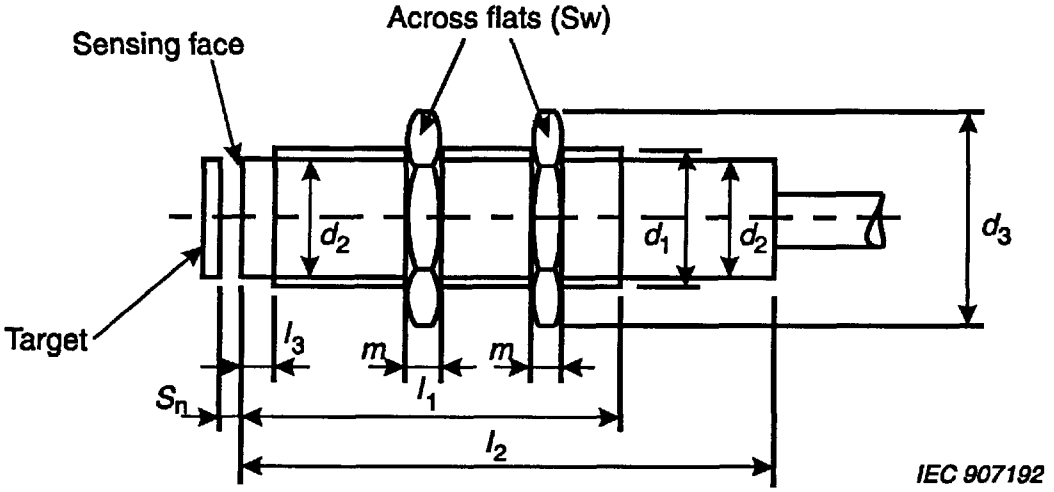


Figure 4-3-1
PROXIMITY SWITCH, CYLINDRICAL

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3.4.2 Standard Dimensions of Rectangular Switches

Self-contained proximity switches that are rectangular in shape and have a square cross section of approximately 35mm 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.

4 Characteristics and Ratings

4.1 Nominal Input Voltage Ratings

The nominal input voltage ratings of a proximity switch may be one, or a combination of those shown in Table 4-4-1.

4.2 Output Ratings

The output ratings of proximity switches with contacts shall be in accordance with Clause 1-4.

4.3 Rated Operating Distance, S_n

The rated operating distance characteristics shall be as shown in Table 4-4-2.

4.4 Rate of Operation

Every proximity device shall have a specified nominal rate of operation that is used for calibration and evaluation purposes. (See clause 4-8.)

4.5 Maximum Start-Up Time

The start-up time for a proximity switch shall not exceed 300 milliseconds.

Table 4-4-1
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 4-4-2
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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5 Product Marking, Installation and Maintenance Information

5.1 Marking

Each proximity switch shall be marked with its input ratings expressed in volts, amperes, or voltamperes and its output designation in accordance with Clause 4.

Proximity switches may be marked by a NEMA code number incorporating the type, class, style, material and form number from the Table 4-5-1.

5.2 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 startup times.

5.3 Preventive Maintenance Guide

See NEMA Standards Publication ICS 1.3 for general maintenance instructions.

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Table 4-5-1
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			Ferrous			
				35mm Rectangular	R35	(Magnetic) Metal	F	Normally Open	A
				40mm Rectangular	R40				
				80mm Rectangular	R80	Any Metal	M	Normally Closed	B
				8mm Cylindrical	C8				
				12mm Cylindrical	C12	Non-Ferrous			
				18mm Cylindrical	C18	(Non-Magnetic)	N		
				30mm Cylindrical	C30	Metal			
		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			Ferrous			
				35mm Rectangular	R35	(Magnetic) Metal	F	Normally Open	A
				40mm Rectangular	R40				
				8mm Cylindrical	C8	Permanent Magnet			
				12mm Cylindrical	C12		P	Normally Closed	B
				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	
				12mm Cylindrical	C12				B
				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.)

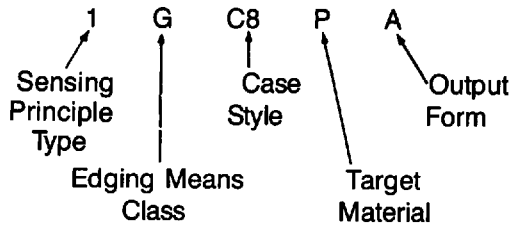
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Table 4-5-1 Continued

NEMA Classification Explanation

Example:



6 Service and Storage Conditions

6.1 Tolerance to Environmental Conditions

Proximity switches are designed for standard conditions of service per ICS 1, Clause 6, except for ambient temperature limits, which are -20°C to +70°C. For applications pertaining to the following environmental conditions, consult the manufacturer.

6.1.1 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.

6.1.2 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.

6.1.3 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.

6.1.4 Surrounding Metal

Proximity switches are identified by the manufacturer as suitable or not suitable for embedding in metal. See Clause 4-2 for definitions of shielded and unshielded proximity switches.

6.1.5 Magnetic Fields

The performance of proximity switches may be affected by magnetic fields.

6.1.6 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.

6.1.7 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.

6.1.8 Shock and Vibration

Shock and vibration may affect the accuracy and repeatability of proximity switches and eventually may reduce their life.

6.1.9 Nuclear Radiation

The performance of proximity switches may be affected by nuclear radiation.

6.2 Circuit Considerations

6.2.1 Connections

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 NEMA Standards Publication ICS 1.1.

6.2.2 Grounding

A change in potential of the designated object with respect to ground (earth) may affect the operation of a capacitive proximity switch.

7 Construction

7.1 Enclosures

Proximity switches in their enclosures shall be designated by type numbers in accordance with NEMA Standards Publication No. 250.

7.2 Indicators

Proximity devices may incorporate status indicators to designate POWER ON or other operating conditions.

8 Performance Requirements and Tests

8.1 Electrical Noise Withstandability

AC proximity switches shall be capable of withstanding the noise test described in ICS 1, Annex E without malfunctioning when the generated noise is injected onto the power supply circuit and onto the output circuit. The

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tests shall be performed with the device in both the energized and deenergized states. For Type 1 switches, the energized condition is defined with the standard target at S_u minimum and the deenergized condition with the target at S_u maximum plus H.

8.2 Thermal Cycling and Humidity Test Procedure

8.3.1 Test Temperature Limits

8.3.1.1 The low limit shall be the minimum rated ambient temperature.

8.3.1.2 The high limit shall be the maximum rated ambient temperature.

8.3.2 Apparatus

The accuracy of the test temperature shall be within ±2°C.

8.3.3 Test Sequence

a. Check operating characteristics and examine for physical faults such as cracks and separation of permanently sealed areas.

b. Place in chamber, with chamber at low limit temperature for 3 hours minimum.

c. Remove from chamber and expose to room temperature for 3 hours minimum.

d. Place in chamber, with chamber at high limit temperature for 3 hours minimum.

e. Repeat c.

f. Repeat b though e for a total of five times.

g. Place in humidity chamber at 95 percent relative humidity at 40°C for 24 hours minimum.

h. Remove from chamber and repeat a within 30 minutes.

8.3.4 Performance

Operating characteristics and physical parameters measured preceding and following thermal cycling and humidity tests shall meet the manufacturer's specification.

8.3.5 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.

8.4 Operating Distance Verification for Type 1 Proximity Switches

8.4.1 Construction of the Target

Standard targets for Type 1 proximity switches shall be as shown in Table 4-8-1.

8.4.2 Measurement

As shown in Figure 4-8-1, the standard target is moved slowly (not faster than 1 mm per second) toward the

Table 4-8-1
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.

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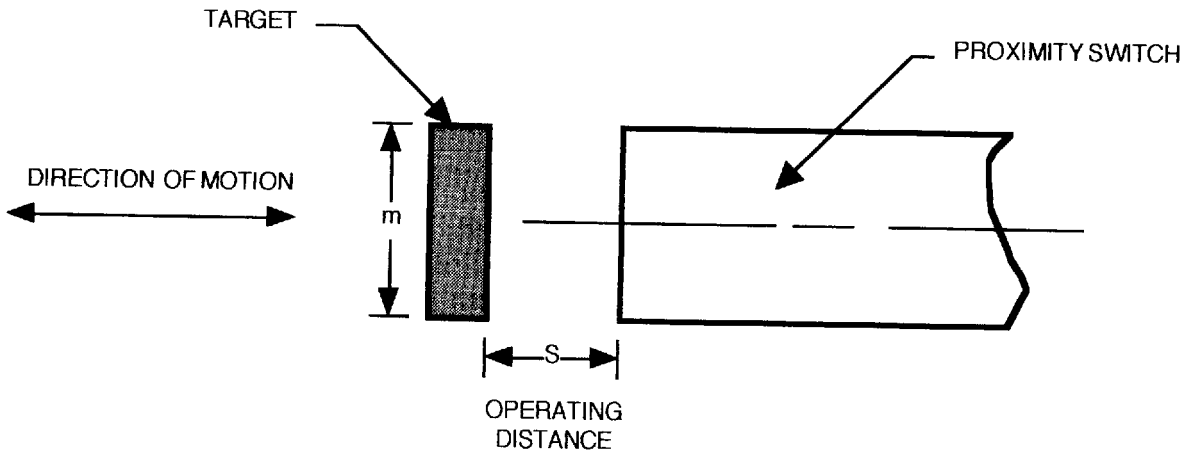


Figure 4-8-1
METHOD FOR MEASURING THE OPERATING DISTANCE

proximity switch in an axial approach and the operating distance is measured.

8.4.3 Operating Conditions

Effective operating range (S_r) shall be verified by the manufacturer using the method shown in Figure 4-2-1 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 temperatures specified by the manufacturer. Verification at each temperature is made:

a. For single input voltage rated devices, tests shall be conducted at 85 percent and 110 percent of 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.

8.5 Operating Distance Verification of Type 2 Proximity Switches

8.5.1 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.

8.5.2 Measurement of Rated Range, R_n

As shown in Figure 4-8-2, the transmitter 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).

8.5.3 Operating Conditions for Measurement of the Rated Range

Rated range (R_n) shall be verified by the manufacturer using the method shown in Figure 4-8-2 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 percent and 110 percent of 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.

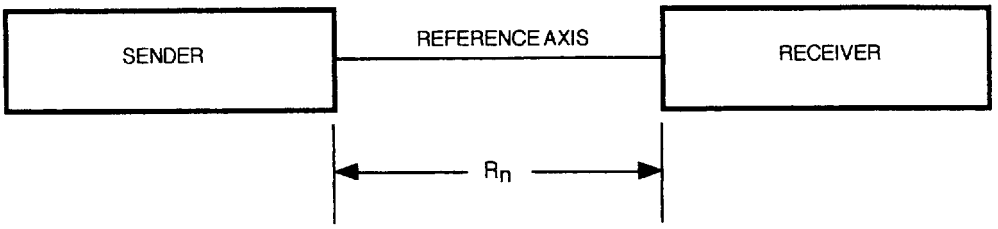
8.6 Rate of Operation Verification for Proximity Switches

The following test procedure using Figure 4-8-3 is applicable for frequencies up to 300 hertz. For higher frequencies other equivalent methods shall be used.

8.6.1 Construction of the Target

a. The standard target for Type 1 switches shall be as specified in Table 4-8-1.

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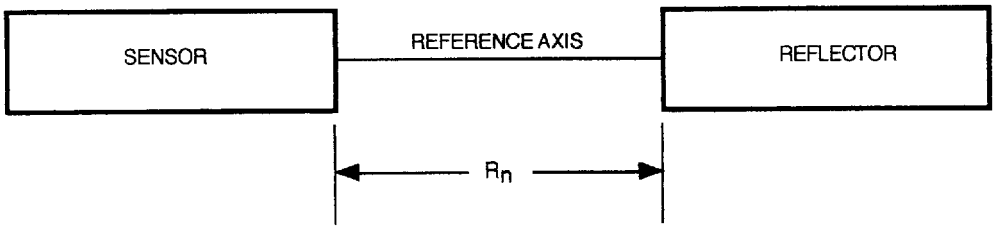
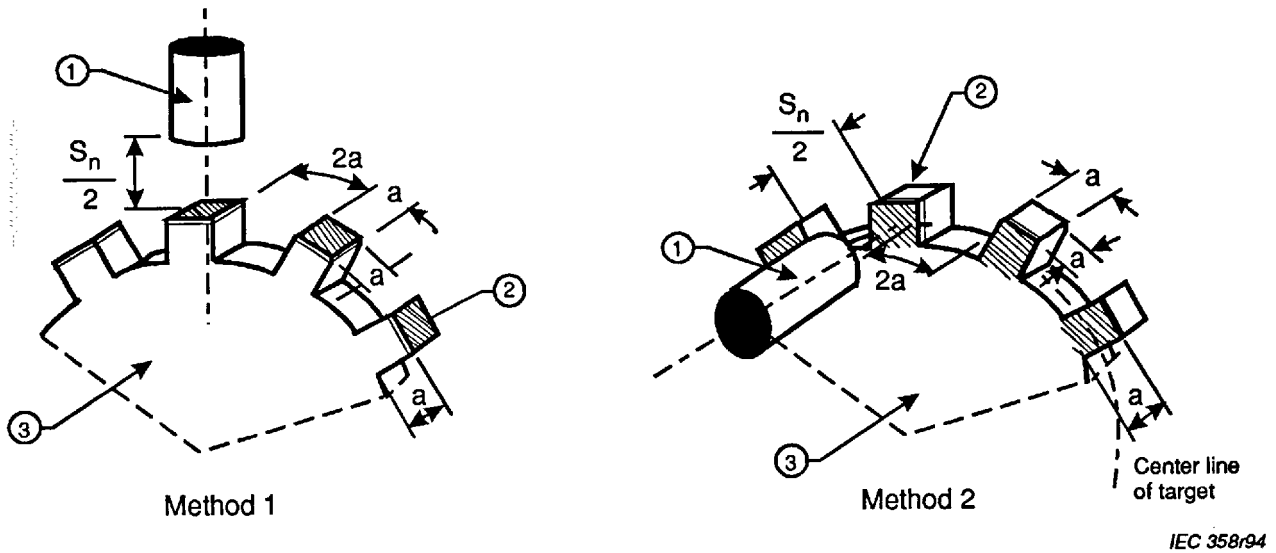


Figure 4-8-2
MEASUREMENT OF RATED RANGE R_n



1 = proximity switch
2 = target
3 = disc in non-magnetic and non-conducting material

NOTE—To avoid angular influence from one target to another, the disc shall be constructed to include at least 10 targets, if the rated operating distance (S_n) is less than 10 mm, or 6 targets for higher operating distances.

Figure 4-8-3
METHOD FOR MEASURING THE NOMINAL RATE OF OPERATION

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b. The standard 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 standard target shall be permitted to simplify the test fixture.

8.6.2 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 an oscilloscope.(See Figure 4-8-4.)

An illustration of the output signal is shown in Figure 4-8-4. 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 1/2 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 hertz.

8.6.3 Measurement, Type 2 Switches

Measurements are identical to 4-8.6.2 for Type 1 switches with the physical arrangement of Figure 4-8-3, 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.

8.7 Temperature Rise of Current-Carrying Parts

The output means and field wiring terminals of proximity switches, where carrying rated continuous (load) current, shall not exceed the temperature rises given in ICS 1, Clause 8. Where the proximity switch has output contacts, 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 proximity switches shall be wired with wire sized appropriately for the switch current rating. See Clause 1-8 for devices rated for control circuit application.

8.8 Output Performance

The output means of proximity switches that are rated for control circuit applications shall be capable of passing the tests described in ICS 5, Section 1.

8.9 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 4-2-1. The test load shall be resistive and require a current equal to minimum 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 shall consist of at least 10 applications of power with at least 5 seconds off time between each reapplication.

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.

8.10 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.

8.11 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 8.4 shall not exceed 5% of the average of the largest and the smallest value.

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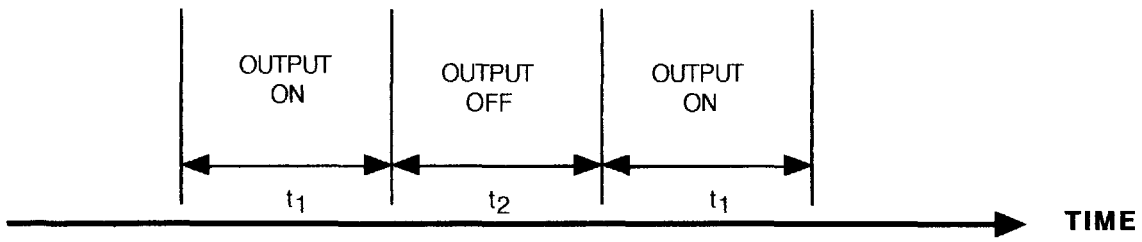


Figure 4-8-4
OUTPUT SIGNAL OF TYPE 1 PROXIMITY SWITCHES DURING THE VERIFICATION OF RATE OF OPERATION

9 Application

9.1 Service Conditions

Proximity switches shall be applied under the usual service and installation conditions described in ICS 1, Clause 6 unless the device is specifically marked with the exceptions.

9.2 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 NEMA Standards Publication ICS 1.1 should be followed.

9.3 Special Applications

Where using proximity switches with programmable controllers, the following items require special consideration to assure compatibility.

a. Maximum steady state leakage current
b. Transient leakage current during power up
c. Maximum on-state voltage
d. Minimum operating voltage
e. Maximum load impedance
f. Minimum load current

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Part 5
PUSHBUTTONS, SELECTOR SWITCHES, INDICATING LIGHTS AND PUSHBUTTON STATIONS

1 General

1.1 Scope

The standards in this part apply to indicating lights, pushbuttons, selector switches and related manually operated devices, as well as enclosed pushbutton stations used in control circuits of industrial control apparatus.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1, ICS 6 and ICS 5 Part 1 apply to this part unless otherwise stated.

2 Definitions

For the purposes of this part the following definitions apply.

2.1 General Definitions

master switch: A switch which dominates the operation of contacts, relays, or other remotely operated devices.

2.2 Pushbutton Definitions

guarded pushbutton: 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 where the actuating surface is below the surrounding surface in its initial and operated positions

b. Shrouded pushbutton—A pushbutton where the relationship between the guard and the actuating surface is 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 positionspushbutton: A switch having a manually operable plunger, rocker or button for actuating the switch.

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

3 Classification

3.1 Standard-Duty Pushbutton Stations

Standard-duty pushbutton stations shall consist of pushbuttons or selector switches, or both, rated in accordance with 4.1.2 or indicating lights in accordance with 4.2 or both, mounted in a suitable enclosure.

3.2 Heavy-Duty Pushbutton Stations

Heavy-duty pushbutton stations shall consist of pushbuttons or selector switches, or both, rated in accordance with 4.1.3 or indicating lights in accordance with 4.2, or both, mounted in a suitable enclosure.

4 Characteristics and Ratings

4.1 Contact Ratings

4.1.1 Contact Ratings

The contact ratings of manually-operated pushbuttons and selector switches used in control circuits shall be in accordance with Part 1.5.

4.1.2 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 5-4-1 for AC and Table 5-4-2 for DC.

4.1.3 Heavy-Duty Pushbuttons and Selector Switches

Heavy-duty pushbuttons and selector switches shall have contact rating designations of A600, A300, A150,

Table 5-4-1
INDICATING LIGHT VOLTAGE RATINGS

Standard Duty 60 Hertz		Heavy Duty 60 Hertz	
AC	DC	AC	DC
120	120	6	6
240	240	12	12
		24	24
		120	120
		240	240
		480	
		600	

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

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N600, N300 or N150 as shown in Table 1-4-1 for AC and Table 1-4-2 for DC.5.

4.2 Indicating Light Ratings

Indicating lights in pushbutton stations shall have any single voltage rating shown in Table 5-4-1.

4.3 Selector Switch Characteristics

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

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

5 Product Marking, Installation and Maintenance Information

See NEMA Standards Publication ICS 1.3 for preventative maintenance instructions.

6 Service and Storage Conditions

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

7 Construction

7.1 Color Coding of Pushbuttons

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

7.2 Direction of Operation of Selector Switches

7.2.1 Rotary Selector Switches

Where a rotary selector switch is mounted in a pushbutton station or in the cover of an AC 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 Figure 5-7-1.

7.2.2 Straight-Line Motion Selector Switches

Where a selector switch having a lever with straight-line motion is mounted in a pushbutton station or in the cover of an AC 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 Figure 5-7-2.

7.3 Legends for Pushbutton Stations

Tables 5-7-1 and 5-7-2 show legends for standard-duty and heavy-duty pushbutton stations.

Table 5-7-1
STANDARD-DUTY PUSHBUTTON STATION LEGENDS

One-Button	Two-Button	Three-Button
Start	Start-stop	Forward-reverse-Stop
Stop	Forward-reverse	Open-close-stop
	Open-close	Up-down-stop
	Up-down	Fast-slow-stop

Table 5-7-2
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-stop
	Open-close	Fast-slow-stop
	Up-down	Up-down-stop

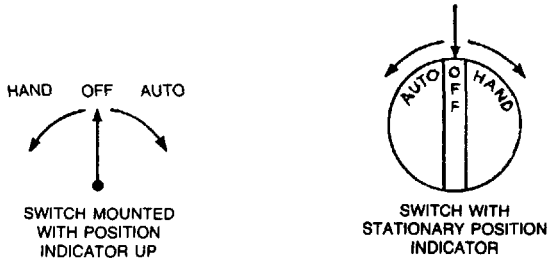


Figure 5-7-1
ROTARY SELECTOR SWITCH OPERATION

7.4 Arrangement of Elements in Pushbutton Stations

7.4.1 Stop Button Location

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.

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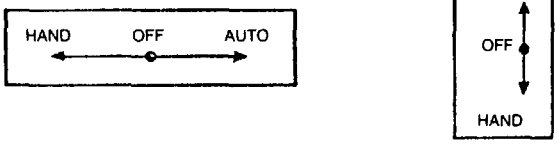


Figure 5-7-2
LEVER SELECTOR SWITCH OPERATION

7.4.2 Arrangement of Pushbutton Stations for Multispeed Motor Controllers

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

a. Where 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. Where 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.

8 Performance Requirements and Tests

8.1 Contact Performance

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

a. Not exceed the temperature rise given in Standards Publication ICS 1, Clause 8.3.3.1 when carrying continuous thermal test current.

b. Be capable of passing the overload, endurance and emergency condition tests described in ICS 5, Part 1.

9 Application

9.1 Contact Life

9.1.1 General

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, manufacturer's recommendations should be obtained regarding specific applications.

9.1.2 Long Cycle Life

The make and break ratings and test values shown in ICS 5, Part 1, Table 1-4-1 for alternating current and ICS 5, Part 1, Table 1-4-2 for direct current 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 ICS 5, Part 1.

9.1.3 Solenoid Control Circuits

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 below include provision for this situation.

9.2 Magnetic Controller 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 deenergized.

9.3 Overlapping Contacts

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

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SUPPLEMENT 1
SCOPE OF THE INDUSTRIAL CONTROL AND SYSTEMS SECTION

The NEMA Standards Publications for Industrial Control and Systems cover the requirements for all industrial control apparatus except as modified below. These standards cover all devices, whether electric, magnetic, mechanical, or electronic (except those devices intended specifically for marine auxiliaries and propulsion control apparatus, mine locomotive control apparatus, and railway and railroad locomotion) which, individually or grouped, serve to govern in some predetermined manner the electric power delivered to the apparatus to which they are connected, and which are intended to function on commercial voltages of 750 volts or less, direct current and 7200 volts or less, alternating current.

Industrial Control and Systems Section equipment comprises, but is not limited to, mechanical, electromechanical and solid state devices, components, and controls.

The equipment is principally used in industrial applications for the control, or regulation, or both, of power utilization apparatus, including motors. Such equipment is rated not more than 750 volts DC or 7,200 volts AC.

These devices, components, and controls may be arranged to include one or more feedback loops. Functional elements in such arrangements include, sensors, programmable controllers, operational amplifiers, encoders, tape readers, gauging equipment and computer elements. Computer elements for the readout, logging, processing, and programming input and monitoring output of data may or may not be in the feedback loop. Devices, components and controls so arranged are used in functions such as:

a. Computer control of machines
b. Industrial process regulation
c. Integrated mill control
d. Energy management
e. Emergency and standby power control
f. Control of the cogeneration of electric power

The Industrial Control and Systems Section scope specifically includes, but is not limited to, products principally used:

a. To start, stop, protect, accelerate, decelerate, reverse, or control the speed of electric motors.
b. To automatically disconnect, connect, or transfer all classes of loads fed by primary or alternate power sources.
c. To provide some mechanical movement through the action of magnets or solenoids.
d. To start, stop and control AC or DC adjustable speed drives, whether unregulated, regulated, or automatically regulated, including semiconductor power converters and inverters for adjustable speed drives, and providing such functions as: regulating speed, tension, current, frequency and voltage.
e. To start, stop and control the function and operation of machine tools, including feedback control and speed, position and torque.
f. To start, stop and control the operation of automatic warehouses, including control of conveyors, stackers, and the like.
g. To start, stop and control the operation of cranes and hoists.
h. To start, stop and control the operation of AC motors applied to fans, pumps, and blowers, including provision for feedback control of speed by sensors such as for temperature, flow, and pressure.
i. To control the management of energy under normal and emergency conditions including peak load shaving.
j. To control generator equipment used in dispersed power generation systems for cogeneration, emergency, or stand-by electric power.

Also included, but not limited to, are:

a. Motor controllers
b. Motor control centers
c. Medium-voltage controllers
d. Programs and related documentation making up the software that is furnished with programmable devices for industrial control and systems equipment
e. Register and synchronizing controls
f. Digital display devices
g. Analog-digital convertors and transducers
h. Programmable controllers
i. Functional elements of systems, such as:
   Operational amplifiers
   Computer elements
   Encoders
   Tape readers
   Sensors

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Man-machine interface devices

Gaging equipment

j. Renewal parts for Industrial Control and System products.

Examples of Industrial Control and System products are:

a. Manual, magnetic and solid-state (static) starters and controllers

b. Relays and contactors

c. Automatic transfer switches and controllers, and associated by-pass isolation switches

d. Drum switches

e. Overload devices intended primarily for the starting and running protection of electric motors, including inherent overload protective devices

f. Rheostats and resistors

g. Autotransformers and reactors of the type principally used in reduced-voltage starters

h. Control-circuit and pilot devices including, but not limited to, timers, pushbuttons, indicating (pilot) lights, solenoids, photoelectric switches, and plugging switches, speed switches, domestic water pump pressure switches

i. limit, pressure, vacuum, temperature and liquid-level switches.

j. AC and DC brakes, clutches, and electrical operators

k. Resistance dimmers, autotransformer dimmers, reactor dimmers, and solid-state (static) dimmer systems

l. Solid-state logic devices

m. Control panels for machine tool and similar machines

n. Terminal blocks of the molded barrier or sectional type and terminal strips used for the connection of conductors, electrical and electronic circuits and equipment. These include, but are not limited to, terminal blocks using, wire binding screws, pressure wire connectors, stud and nut, quick connect, solder lug, and solderless wrapped terminations, and terminal blocks which incorporate fuse holders, test/disconnect features, indicator lamps, diodes, etc.

o. Automatically regulated adjustable speed drive systems such as: rolling mill drives, paper mill drives, slasher drives

p. Programmable controllers and their accessories devices used for the supervision, or control or command of industrial machines and processes Exclusions:

Excluded from the product scope are:

a. Specific components and systems covered by the product scopes of other NEMA sections

b. Automatic and manual temperature and humidity controls and panels that are in the scope of the Residential Controls Section of the types principally used in air conditioning, refrigeration, and comfort heating of nonindustrial areas

c. Motors, generators and motor-generators, which function as control when constituting part of adjustable speed drives.

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NEMA STANDARDIZATION BACKGROUND

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 the purchaser 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.

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, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 1)

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. 6)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes, which have received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.
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.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 5)

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 received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 5)

Identification of Status

Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword or throughout the text.

The material identified as "Authorized Engineering Information" is designated similarly. Statements incorporating other auxiliary verbs such as "should," "may," etc. refer to the authorized engineering information and not to procedures required for compliance with the standard.

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