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National Electrical Manufacturers Association
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PROPOSED, NEW AND REVISED STANDARDS

TO ALL REPRESENTATIVES OF MEMBER COMPANIES IN THE
INDUSTRIAL CONTROL AND SYSTEMS SECTION

Subject: Revision No. 2 to NEMA Standards Publication for *General Standards for Industrial Control and Systems*, NEMA Pub. No. **ICS 1-1988.**

Dear Representative:

Revision No. 2, consisting of printed pages dated JANUARY 1990, is enclosed for insertion into your copy of the subject publication. Also enclosed is a title page to indicate that your book now contains Revision 2 and that the publication has been approved as American National Standard.

To bring your copy up-to-date, please insert the attached revised pages in their proper place and delete the pages they replace.

Sincerely,

Beth Anne Gidlund

Beth Anne Gidlund
Assistant Editor
NEMA

Encl: Revision No. 2 to ICS 1-1988.
Copies to: All known holders of ICS 1-1988.

Part 1-111A
SPACINGS

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified.

Part ICS 1-111A is a performance standard covering design requirements and verification tests. For specific design, performance, and application requirements, see appropriate product standards.

The definitions contained in Part ICS 1-100 of this Standards Publication also apply to this part.

For an alternate procedure and tests for determining spacings, see Part ICS 1-111.

If a value for measurement is followed by another value in different units and enclosed in parentheses, the first value is a requirement. The parenthetic value is provided for information, and may be only an approximation because of the precision of the conversion formula and rounding rules.

GENERAL

1-111A.1.1 SCOPE

This document is concerned with spacings (clearance and creepage distances) of industrial control equipment for installation in low-voltage distribution systems which include services, feeders, and branch circuits. The concept of insulation coordination is introduced in this standard. It is a concept under which the insulation characteristics of the components of a system are designed or selected to minimize undesired incidents due to voltage stresses. Voltage stresses are caused by transient overvoltages which can exist in the network system to which the equipment is connected. These overvoltages are caused by external events such as lightning and network switching. Transient overvoltages may also be generated within the equipment itself, mainly from operation of the equipment.

Authorized Engineering Information 11-14-1985.

1-111A.1.2 INTRODUCTION

1-111A.1.2.1 Uncoordinated Insulation System

An uncoordinated insulation system implies the selection of the electrical insulation characteristics of equipment with levels of sparkover voltage of clearances and the breakdown voltage of solid insulation that are unknown. This occurs because most existing product standards, based primarily on experience, specify dimensional requirements for equipment design, but do not specify tests to measure the ability of the equipment to withstand conditions of transient overvoltages. Such standards are considered to be "Design Standards." Furthermore, the various products in an installation may have their design based on different Design Standards, each reflecting different experience. In an uncoordinated system, it is therefore possible for a clearance to have a voltage breakdown level that is higher than the voltage breakdown level of its associated solid insulation, or the solid insulation of another component. Consequently, the sparkover of clearances or the breakdown of solid insulation can occur at random locations and at unknown transient overvoltage levels.

Authorized Engineering Information 11-14-1985.

1-111A.1.2.2 Coordinated Insulation System

1-111A.1.2.2.1 A coordinated insulation system implies the design or selection of the electrical insulation characteristics of equipment with regard to its application and to its micro-environmental conditions. Consideration should be given to the continuity of service desired, to the safety of persons and property, to the overvoltages which can appear within the system, and to the location and characteristics of the transient overvoltage protective devices. An insulation system is considered to be coordinated when it passes the impulse withstand test voltage requirements of Tables 1-111A-7 and 1-111A-8.

Authorized Engineering Information 11-14-1985.

1-111A.1.2.2.2 When an insulation system is coordinated, the solid insulation materials involved should have a voltage breakdown level which is higher than the breakdown voltage level of either the associated overvoltage protective device or the clearance on which the coordination is based (see Table 1-111A-8). Thus the overvoltage protective devices or clearances in air (a renewable insulation) provide a degree of protection for the non-renewable solid insulation. The design basis for a coordinated insulation system is a Performance Standard.

Authorized Engineering Information 11-14-1985.

1-111A.1.3 PERFORMANCE STANDARDS

1-111A.1.3.1 Performance Standards for coordinated insulation systems are uniformly based on fundamental

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mental research data. They permit the designing of insulation systems that significantly minimize the random sparkover of clearances or breakdown of solid insulation. Performance Standards specify requirements for equipment design to withstand specific transient voltages, and they also specify tests that measure the ability of the equipment insulation to withstand the voltage stresses caused by those transient voltages.

Authorized Engineering Information 1-23-1990.

1-111A.1.3.2 In addition to their common data base and performance tests, Performance Standards incorporate new concepts of interrelated influencing factors including insulation material groups, transient overvoltage protective devices, overvoltage categories, macro-environmental conditions, and micro-environmental conditions. Knowledge of and suitable application of these factors also can improve insulation performance. Thus, in order to use insulation to its full advantage, it will be advisable for persons using Performance Standards to acquire in-depth knowledge of principles of insulation coordination and influencing factors. A study of IEC Reports 664 and 664A is recommended for this purpose.

Authorized Engineering Information 1-23-1990.

1-111A.1.4 DEFINITIONS

1-111A.1.4.1 Coordination of Insulation

The coordination of insulating characteristics of electrical equipment on the one hand with the expected overvoltages and with the characteristics of overvoltage protective devices, and on the other hand with the expected micro-environmental conditions and the pollution protective means.

NEMA Standard 11-14-1985.

1-111A.1.4.2 Current, Rated Operational

A rated operational current (I_e) of an equipment is stated by the manufacturer and takes into account the rated operational voltage, the rated frequency, the rated duty, the overvoltage category, and the type of a protective enclosure.

NEMA Standard 11-14-1985.

1-111A.1.4.3 Electric Fields

Homogeneous (Uniform) Field

An electric field which has an essentially constant voltage gradient between electrodes, such as that between two spheres where the radius of each sphere is greater than the distance between them.

NEMA Standard 11-14-1985.

Inhomogeneous (Non-Uniform) Field

An electric field which does not have an essentially constant voltage gradient between electrodes.

NEMA Standard 11-14-1985.

1-111A.1.4.4 Environmental Category

Environmental category is used to classify the macro-environment in which a device or equipment is intended to be installed. The categories are designated by a conventional number.

NEMA Standard 1-23-1990.

1-111A.1.4.5 Insulation Measurement

Clearance

The shortest distance in air between two conductive parts.

NEMA Standard 11-14-1985.

Creepage Distance

The shortest distance along a surface of an insulating material between two conductive parts.

NEMA Standard 11-14-1985.

Creepage distance is sometimes referred to as creepage.

Authorized Engineering Information 11-14-1985.

1-111A.1.4.6 Macro-environment

The macro-environment refers to the ambient physical and electrical environmental conditions in which a product is installed.

NEMA Standard 1-23-1990.

1-111A.1.4.7 Micro-environment

The micro-environment refers to the physical environmental conditions immediately surrounding the clearance or creepage under consideration.

NEMA Standard 1-23-1990.

1-111A.1.4.8 Overvoltage Category

Overvoltage category is used to classify the levels of transient overvoltages which can occur between interfaces within a low-voltage distribution system. The categories are designated by a conventional number.

NEMA Standard 1-23-1990.

1-111A.1.4.9 Pollution

Any addition of a foreign matter; solid, liquid, or gaseous (ionized gases) which can produce a reduction of dielectric strength or surface resistivity.

NEMA Standard 11-14-1985.

1-111A.1.4.10 Pollution Degree

Pollution degree is used to classify pollution in terms of type, severity, combinations of pollutants, and frequency of occurrence. Pollution degrees are designated by a conventional number.

NEMA Standard 1-23-1990.

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1-111A.1.4.11 Tests

Routine Tests

A production test to which each individual device is subjected during or after manufacture to verify that it complies with certain criteria.

NEMA Standard 1-23-1990.

Sampling Tests

A production test of a number of devices taken at random from a batch.

NEMA Standard 11-14-1985.

Type Tests

A design test of one of more devices made to a specific design to verify that the design meets certain specifications or standards.

NEMA Standard 11-14-1985.

1-111A.1.4.12 Voltages

Rated Impulse Withstand Voltage, U_{imp}

The peak value of an impulse voltage, of prescribed form and polarity, that the equipment is capable of withstanding without breakdown under specified conditions of test and to which the value of the clearances is referred.

NEMA Standard 1-23-1990.

Rated Insulation Voltage, U_i

The rated insulation voltage of a component, a device, or an equipment is the voltage to which rated impulse withstand voltage, clearances, and creepage distances are referred.

NEMA Standard 1-23-1990.

Rated Operational Voltage, U_e

A rated operational voltage of an equipment is a value of voltage which, combined with a rated operational current, determines the application of the equipment and to which the various tests and the overvoltage categories are referred. For polyphase circuits, it is stated as the voltage between phases.

NEMA Standard 11-14-1985.

Recurring Peak Voltage

Overvoltages generated within an equipment as a result of its operation or within associated equipment. For example, these peak voltages may be required for the operation of the equipment or they may occur as a consequence of its operation.

These voltages are repetitive as compared to lightning related transient voltages which occur infrequently.

NEMA Standard 1-23-1990.

1-111A.1.5 INTERRELATED INFLUENCING FACTORS

1-111A.1.5.1 Overvoltage Category

1-111A.1.5.1.1 For insulation coordination, locations between interfaces within a low voltage distribution system have been classified into four categories, according to the levels of transient overvoltages which may occur within these locations. The insulation levels required for these categories normally follow each other in descending order of magnitude of the impulse withstand voltage as the categories are located further away from the source of transient voltages.

NEMA Standard 1-23-1990.

1-111A.1.5.1.2 When an equipment is subjected to a transient overvoltage, that overvoltage will impinge on the entire equipment. If the operational voltage is not transformed to a higher level and if the equipment is equipped with an internal interface, that portion of the equipment which is downstream of the interface may be in a lower overvoltage category, and may be subjected to a lower transient overvoltage.

Authorized Engineering Information 1-23-1990.

1-111A.1.5.1.3 Low voltage industrial control equipment shall be assigned one or more of the following overvoltage categories:

Table 1-111A-1
OVERVOLTAGE CATEGORIES

Category No.	Description
IV	*Primary Supply Level.* Overhead lines and cable systems including distribution and its associated overcurrent protective equipment (equipment installed at the service entrance).
III	*Distribution Level.* Fixed wiring and associated equipment (not electrical loads) connected to the primary supply level, Category IV.
II	*Load Level.* Appliances and portable equipment, etc., connected to the distribution level, Category III.
I	*Signal Level.* Special equipment or parts of equipment such as low-voltage electronic logic systems, remote control, signalling, and power-limited (per NEC Article 725) circuits connected to the load level, Category II.

NEMA Standard 11-14-1985.

1-111A.1.5.2 Overvoltage Category Interface Elements

The transition from one overvoltage category to the next lower category (from one impulse withstand voltage level to a lower impulse withstand voltage level) is justified by the effect of transient limiting elements that perform an interface function. Typical elements that perform an interface function are:

1-111A.1.5.2.1 An overvoltage protective device.

1-111A.1.5.2.2 A transformer with isolated windings and secondary load (capable of diverting, dissipating, or absorbing energy of surges).

1-111A.1.5.2.3 A busbar system with a multiplicity of branches (capable of diverting energy of surges).

1-111A.1.5.2.4 A capacitance, for example, a cable or a capacitor (capable of absorbing energy of surges).

While capacitance may be used to absorb the energy of an impulse, the effects or subsequent release of the stored energy back into the circuit should be considered.

1-111A.1.5.2.5 A resistance or similar damping device (capable of dissipating energy of surges).

Authorized Engineering Information 1-23-1990.

1-111A.1.5.3 Material Groups

Material groups for solid insulation are classified according to their Comparative Tracking Index (CTI) values in Table 1-111A-2. The CTI ratings refer to the values obtained, in accordance with ASTM D-3638 and IEC 112 (Method A). The CTI may be obtained using the insulating parts of the device or separate samples of the material used.

Authorized Engineering Information 11-14-1985.

Table 1-111A-2

	Material Group			
CTI Values	I	II	IIIa	IIIb
Equal or Greater than	600	400	175	100
Less Than	—	600	400	175

NEMA Standard 11-14-1985.

1-111A.1.5.4 Macro-environment

1-111A.1.5.4.1 The macro-environment of an installation is typically the ambient condition within an entire room, or office or workshop. It is the source of the type, severity, and frequency of pollution to which the micro-environment of a device or equipment may be subjected. As a practical means of reducing the number of levels of severity which a designer should consider, the climatic environmental conditions are classified into four levels, each of which has a distinct effect upon the performance of solid insulation. These four levels are Climatic Environmental Category I, II, III, and IV as shown in Table 1-111A-3.

Authorized Engineering Information 1-23-1990.

1-111A.1.5.4.2 NEMA standard industrial control equipment shall be suitable for installation in Climatic Environmental Category III.

NEMA Standard 1-23-1990.

1-111A.1.5.5 Micro-environment

1-111A.1.5.5.1 In general, this is the environment inside the enclosure of a product. Within a product, there can be more than one micro-environment.

Table 1-111A-3
CLIMATIC MACRO-ENVIRONMENTAL CONDITIONS

Climatic Environmental Category (EC)	Condition Description	Location Example
I	Air temperature—controlled continuously Humidity—controlled continuously Dust—removal by continuous filtering Condensation—none	Manufacturing process clean room
II	Air temperature—controlled but not continuously Humidity—uncontrolled Dust—uncontrolled, quantity small Condensation—occasional, brief	Office, residential, light commercial building
III	Air temperature—may be controlled but not continuously Humidity—uncontrolled Dust—uncontrolled, quantity moderate Condensation—frequent	Industrial or heavy commercial building
IV	Air temperature—uncontrolled Humidity— uncontrolled Dust—uncontrolled, quantity large Condensation—continuous	Unenclosed or partially enclosed location

NEMA Standard 1-23-1990.

1-111A.1.5.5.2 Pollution (of the micro-environment) is an environmental influencing factor which can cause a hygroscopic material to conduct excessive internal leakage current. It can also cause a material to degrade (track or erode) as a consequence of arcing along a leakage current path on its surface.

1-111A.1.5.5.3 The frequency of condensation is especially important because pollution normally has a long-term effect as a consequence of repetitive events (arcing) which successively degrade the surface of insulation leading to a failure by tracking. Pollution can rarely have a one-time effect on the surface of insulation.

1-111A.1.5.5.4 The effect of a combination of pollutants is significant. Dust, even conductive dust, may not adversely affect creepage. The pressure between dust particles and between dust particles and the surface of the insulating material is extremely low, and the contact resistance is, therefore, extremely high. Conductive moisture is necessary to bridge the particles and cause conduction.

1-111A.1.5.5.5 Degree of pollution has been classified into four levels which correspond to the four environmental categories. These four levels are pollution degree 1, 2, 3, and 4 as shown in Table 1-111A-4.

Authorized Engineering Information 1-23-1990.

1-111A.1.5.6 Relationship of the Macro-environment to the Micro-environment

The design and performance requirements for creepage in 1-111A.2.3 of this standard are based on the suitability of equipment for installation in Climatic Environmental Category III (macro-environment) and consequential Pollution Degree 3 within the micro-environment.

NEMA Standard 1-23-1990.

Table 1-111A-4
MICRO-ENVIRONMENTAL CONDITIONS

Pollution Degree (PD)	Condition Description	Influencing Factors, Modification, Design
1	Moisture – none, always dry Dust – insignificant Effect of pollution – none	PD 1 can occur in EC I. In macro-environments which are more severe than EC I, PD 1 is commonly provided at the micro-environment by the use of coatings, encapsulations, hermetic sealing, and similar treatments which exclude conductive pollution from the micro-environment.
2	Moisture – occurs occasionally Dust – quantity sufficient to become conductive when moist Effect of pollution – tracking or erosion at a slow rate†	PD 2 can occur in EC II. In macro-environments which are more severe than EC II, PD 2 can be provided within suitably enclosed products where means such as ventilation and local heating are provided to control humidity and condensation.
3‡	Moisture – occurs frequently Dust – quantity sufficient to become conductive when moist Effect of pollution – tracking or erosion at a moderate rate†	PD 3 can occur in EC III. In macro-environments which are more severe than EC III, PD 3 can be provided within suitable enclosures which provide protection from exposure to precipitation, dust and water.
4	Moisture – occurs continuously Dust – quantity sufficient to become conductive when moist. Effect of pollution – tracking or erosion at a high rate†	PD 4 can occur within some enclosures installed in unprotected outdoor locations, EC IV. A suitable enclosure can be used to reduce the PD from 4 to 3.

†Rate of tracking or erosion is also dependent on the properties of the insulation material (refer to Table 1-111A-2) and the function of ribs (refer to 1-111A.2.3.4).

‡Pollution degree 3 is the basis for the clearances and creepage requirements in 1-111A.2.2 and 1-111A.2.3 of this standard. Refer to 1-111A.1.5.6.

NEMA Standard 1-23-1990.

Table 1-111A-5
RELATIONSHIP OF CLIMATIC ENVIRONMENTAL CATEGORIES TO POLLUTION DEGREES

Classification of Macro-environment	Classification of Micro-environment			
Climatic Environmental Category	Pollution Degree			
	1	2	3	4
I	(a)			
II	(b)	(a)	(c)	
III		(b)	(a)	(c)
IV			(b)	(a)

a. Conditions at micro-environment may be the same as that of macro-environment, e.g., Environmental Category I and Pollution Degree 1.

b. Conditions at micro-environment can be less severe than the macro-environment. Refer to influencing factors in Table 1-111A-4.

c. Conditions at micro-environment can also be worsened by the presence of production residues and internally generated pollution. Internally generated pollution can be caused by abrasion or arcing caused by operating the device or equipment. This pollution, in the presence of moisture, can become conductive.

Authorized Engineering Information 1-23-1990.

1-111A-1.5.7 Partial Discharge

Another factor influencing solid insulation is its ability to withstand partial discharges at voltage withstand values associated with its application. In the most severe case, this would be the voltage associated with its clearance. In other instances, it may depend on exposure to periodically recurring peak voltages generated within the equipment itself.

Authorized Engineering Information 11-14-1985.

DESIGN

1-111A.2.1 INSULATION REQUIREMENTS

1-111A.2.1.1 Insulation Requirements for Equipment for Use in General Purpose Applications Where Transient Voltages Are Not Controlled by a Transient Limiting Means

1-111A.2.1.1.1 All voltage systems shall be assumed to be either unearthed (ungrounded) or to have one phase earthed (grounded). Refer to Table 1-111A-6, Column 2.

1-111A.2.1.1.2 Clearances between earth and live parts, between poles, and between circuits, shall withstand a value of impulse voltage corresponding to the rated insulation voltage derived from Table 1-111A-6 and the assigned overvoltage category or categories in Table 1-111A-7.

NEMA Standard 1-23-1990.

1-111A.2.1.1.3 Solid insulation of equipment shall withstand the impulse withstand voltage of the associated clearances of requirement 1-111A.2.1.1.2.

NEMA Standard 11-14-1985.

1-111A.2.1.1.4 Creepage distances shall be in accordance with 1-111A.2.3.

NEMA Standard 1-23-1990.

1-111A.2.1.2 Insulation Requirements for Equipment for Use in a System Where Transient Voltages are Controlled by Transient Limiting Means

1-111A.2.1.2.1 Clearances between earth and live parts, between poles, and between circuits, shall withstand a value of impulse withstand voltage corresponding to the rated insulation voltage derived from Table 1-111A-6 and the assigned overvoltage category or categories in Tables 1-111A-8, 1-111A-13, or 1-111A-14. The impulse withstand voltage shall not be less than the maximum voltages of the transient limiting means.

NEMA Standard 1-23-1990.

1-111A.2.1.2.2 Equipment may be assigned several overvoltage categories either at the same rated operational voltage or at different rated operational voltages.

Authorized Engineering Information 1-23-1990.

1-111A.2.1.2.3 Solid insulation of equipment shall withstand the impulse withstand voltage of the associated clearances of requirement 1-111A.2.1.2.1.

NEMA Standard 11-14-1985.

1-111A.2.1.2.4 Equipment shall not generate recurring peak voltages higher than the value corresponding to the lowest impulse withstand voltage rating per requirement 1-111A.2.1.2.1.

NEMA Standard 1-23-1990.

1-111A.2.1.2.5 Because recurring peak voltages are repetitive, they may, in conjunction with the properties of the insulation material and pollution, accelerate the degradation of the insulation material.

Authorized Engineering Information 1-23-1990.

1-111A.2.1.2.6 For any equipment or a device incorporating a transient overvoltage protective device, the impulse sparkover and the discharge voltage shall not

exceed the value of the impulse withstand voltage to earth corresponding to the stated overvoltage category.

NEMA Standard 11-14-1985.

1-111A.2.1.2.7 Equipment shall have creepage distances in accordance with 1-111A.2.3.

NEMA Standard 1-23-1990.

1-111A.2.1.3 Rated Insulation Voltage

1-111A.2.1.3.1 CLEARANCES

1-111A.2.1.3.1.1 For multiphase ac systems, rated insulation voltage is derived from the phase-to-phase voltage in column 1 or 2 of Table 1-111A-6.

NEMA Standard 1-23-1990.

1-111A.2.1.3.1.2 Equipment shall be marked with a straight voltage rating to indicate its suitability for connection to earthed and unearthed systems, e.g. 480 V ac; or it shall be marked with a slash voltage rating to indicate its suitability for connection exclusively to star(wye)-earthed systems, e.g. 480Y/277 V ac (refer to Table 1-111A-6 note 6).

Conversely, equipment marked 480Y/277 is not suitable for use on a 480 V delta system.

1-111A.2.1.3.1.3 For dc systems, the rated insulation voltage is equal to the dc rated operational voltage, U_e, or the dc working voltage within an equipment.

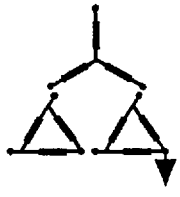
1-111A.2.1.3.2 CREEPAGE

1-111A.2.1.3.2.1 Rated insulation voltage for phase-to-phase distances and phase-to-earth distances are derived from the phase-to-phase voltage in Column 1 or 2 of Table 1-111A-6.

NEMA Standard 1-23-1990.

1-111A.2.1.3.2.2 For equipment marked for connection exclusively to star (wye) -earthed systems, a

Table 1-111A-6
RATED INSULATION VOLTAGE CORRESPONDING TO THE RATED OPERATIONAL VOLTAGE

Rated Operational Voltage, U_e(1)				Rated Insulation Voltage
				
ac rms (2)(6)	ac rms(2)(3)(4)	ac rms	ac rms	U_i ac rms (5)
...	...	12.5, 24, 25, 30, 42, 48	60–30	50
66/115	66	60	...	100
208Y/120, 127/220	115, 120, 127	110, 120	220–110, 240–120	150
220/380, 230/400, 240/415, 260/440, 480Y/277,460Y/265	220, 230, 240, 260, 277	220	440–220	300
347/600, 380/660, 400/690, 415/720, 480/830	347, 380, 400, 415, 440, 480, 500, 577, 600	480, 600	960–480	600
...	660, 690, 720, 830, 1000	1000	...	1000

(1) These values correspond to the nominal voltage of the supply system.

(2) Caution: For rated operational voltage marking requirements, refer to 1-111A.2.1.3.1.2.

Authorized Engineering Information 1-23-1990.

(3) For unearthed (ungrounded) systems or systems with one phase earthed (grounded phase) the phase-to-earth voltage is to be considered equal to the phase-to-phase voltage.

NEMA Standard 1-23-1990.

(4) Phase-to-earth voltage of unearthed or impedanced earthed systems equals the phase-to-phase voltage because the operating voltage to earth of any phase may, under service conditions, approach full-phase voltage. This is because the actual voltage to earth is determined by the insulation resistance and capacitive reactance of each phase-to-earth; thus low (but acceptable) insulation resistance on one phase may in effect earth it and raise the other two to full-phase volts above earth.

(5) These standard levels of rated insulation voltage have been established as a practical means of reducing the number of levels of rated impulse withstand voltages, clearance, and creepage distances. The standard levels of rated insulation voltage represent ranges of voltages from phase-to-earth derived from the rated operational voltage.

(6) In U.S. standards, these voltages are expressed as 480Y/277, etc. In IEC standards, voltages are expressed as 220/380, etc.

Authorized Engineering Information 1-23-1990.

lower level of U_i may be derived from the phase-to-earth voltage in Column 1.

Authorized Engineering Information 1-23-1990.

1-111A.2.1.3.3 For equipment marked for connection exclusively to star(wye)-earthed systems, the phase-to-phase voltage shall be permitted to exceed the rated insulation voltage (refer to Table 1-111A-6, note 2).

NEMA Standard 1-23-1990.

1-111A.2.2 CLEARANCES

1-111A-2.2.1 Within Equipment

1-111A.2.2.1.1 Clearances, except for printed wiring boards, shall be in accordance with Table 1-111A-7 or 1-111A-8.

1-111A.2.2.1.2 Clearances for printed wiring boards shall be in accordance with 1-111A.2.4.

1-111A.2.2.1.3 Clearances which are smaller than those in Tables 1-111A-7 and 1-111A-8 shall be permitted, and they shall be verified only by performance testing in accordance with 1-111A.3.

NEMA Standard 1-23-1990.

1-111A.2.2.1.4 Clearances in Table 1-111A-7 were taken from Table ICS 1-111-1. Table 1-111A-7 is provided to permit these clearances to be verified either by linear measurement or by a performance test in accordance with 1-111A.3.

Authorized Engineering Information 1-23-1990.

1-111A.2.2.2 Clearances to Enclosure Walls

1-111A.2.2.2.1 Clearances to the walls of a metal enclosure shall be in accordance with Tables 1-111A-7, 1-111A-8, and 1-111A-13 except for those portions of the walls which can be deflected and, thereby, reduce a clearance. Attached metal parts shall be considered to be part of a wall.

NEMA Standard 11-14-1985.

Table 1-111A-7
CLEARANCES OF EQUIPMENT FOR GENERAL PURPOSE APPLICATIONS WHERE TEST VOLTAGE VALUES ARE FUNCTIONALLY EQUIVALENT TO MEASURED MINIMUM CLEARANCES SPECIFIED IN TABLE 1-111-1 (2000 Meter Altitude, Pollution Degree 3(1))

Rated (2) Insulation Voltage ac rms or dc	Overvoltage Category					
	II		III		IV (5)	
	Rated Impulse Withstand Voltage (3, 4)	Clearance	Rated Impulse Withstand Voltage (3, 4)	Clearance	Rated Impulse Withstand Voltage (3, 4)	Clearance
	kv	in. (mm)	kv	in. (mm)	kv	in. (mm)
50	2.7	0.063 (1.6)	4.3	0.125 (3.2)	...	... ...
100	2.7	0.063 (1.6)	4.3	0.125 (3.2)	11.0	0.500 (12.7)
150	2.7	0.063 (1.6)	4.3	0.125 (3.2)	...	... ...
300	2.7	0.063 (1.6)	6.8	0.250 (6.4)	16.0	0.750 (19.0)
600	5.6	0.188 (4.8)	8.8	0.375 (9.5)	20.0	1.000(25.4)
1000	...	... ...	12.0	0.550 (14.0)	...	... ...

NEMA Standard 1-23-1990.

(1) Pollution does not basically influence clearances, however, small clearances can be bridged completely by solid particles, dust,. and water. Therefore, minimum clearances such as 1.6 mm and 3.2 mm are specified according to the degree of pollution and impulse voltage which may be present in the micro-environment.

(2) For the relationship of rated insulation voltage to rated operational voltage and voltage phase-to-earth, refer to 1-111A.2.1.3.

Authorized Engineering Information 1-23-1990.

(3) Impulse withstand voltages are given for inhomogeneous field conditions. The values of impulse withstand voltage are from IEC Report 664, Table A1.

(4) See 1-111A.3.4.1.3 for altitude correction factors.

(5) For industrial control equipment used at the service entrance (transition from overvoltage Category IV to III), overvoltage Category IV is required only for the main (line) terminals of service entrance equipment.

NEMA Standard 1-23-1990.

Table 1-111A-8
CLEARANCES OF EQUIPMENT FOR APPLICATIONS WHERE TRANSIENT VOLTAGES ARE CONTROLLED BY TRANSIENT LIMITING MEANS
(2000 Meter Altitude, Pollution Degree 3)

Rated Insulation Voltage (3) ac rms or dc	Overvoltage Categories							
	I		II		III		IV	
	Rated Impulse Withstand Voltage (4)	Clearance (1)	Rated Impulse Withstand Voltage (4)	Clearance (1)	Rated Impulse Withstand Voltage (4)	Clearance (1)	Rated Impulse Withstand Voltage (4,5)	Clearance (1,2)
	kv	mm (in.)	kv	mm (in.)	kv	mm (in.)	kv	mm (in.)
50	0.33	0.8 (0.031)	0.5	0.8 (0.031)	0.8	0.8 (0.031)	1.5	0.8 (0.031)
100	0.5	0.8 (0.031)	0.8	0.8 (0.031)	1.5	0.8 (0.031)	2.5	1.5 (0.059)
150	0.8	0.8 (0.031)	1.5	0.8 (0.031)	2.5	1.5 (0.059)	4.0	3.0 (0.117)
300	1.5	0.8 (0.031)	2.5	1.5 (0.059)	4.0	3.0 (0.117)	6.0	5.5 (0.215)
600	2.5	1.5 (0.059)	4.0	3.0 (0.117)	6.0	5.5 (0.215)	8.0	8.0 (0.312)
1000	4.0	3.0 (0.117)	6.0	5.5 (0.215)	8.0	8.0 (0.312)	12.0	14.0 (0.546)

NEMA Standard 11-14-1985.

(1) Pollution does not basically influence clearances, however, small clearances can be bridged completely by solid particles, dust, and water. Therefore, minimum clearances such as 0.8 mm are specified according to the degree of pollution and the impulse withstand voltage which may be present in the micro-environment.

Authorized Engineering Information 1-23-1990.

(2) Clearances are given for inhomogeneous field conditions from IEC Report 664; however, smaller clearances shall be permitted as stated in 1-111A.2.2.1.

NEMA Standard 1-23-1990.

(3) For the relationship of rated insulation voltage to rated operational voltage and voltage phase-to-earth, refer to 1-111A.2.1.3.

Authorized Engineering Information 1-23-1990.

(4) See 1-111A.3.1.3 for altitude correction factors.

(5) For industrial control equipment used at the service entrance (transition from overvoltage Category IV to III), overvoltage Category IV is required only for the main (line) terminals of service entrance equipment.

NEMA Standard 1-23-1990.

1-111A.2.2.2.2 Clearances to deflectable enclosure walls were taken from Table 1-111-1. They shall be in accordance with the values in Table 1-111A-9.

Table 1-111A-9
CLEARANCES TO DEFLECTABLE ENCLOSURE WALLS

Rated Insulation Voltage ac rms or dc	Overvoltage Category			
	I		II, III, IV	
	in	(mm)	in	(mm)
50	0.5	(12.7)	0.5	(12.7)
100	0.5	(12.7)	0.5	(12.7)
150	0.5	(12.7)	0.5	(12.7)
300	0.5	(12.7)	0.5	(12.7)
600	0.5	(12.7)	0.5	(12.7)
1000	...		0.8	(20.3)

NEMA Standard 1-23-1990.

1-111A.2.3 CREEPAGE

1-111A.2.3.1 Creepage for Insulation Subject to Long-Term Stress

1-111A.2.3.1.1 The minimum values of creepage for Pollution Degree 3 and without the use of ribs are given in Table 1-111A-10. Creepage values shown in this table have been determined for insulation intended to be under stress for a long time (or continuously).

1-111A.2.3.1.2 For inorganic insulating materials (which do not track), for example, glass or ceramics, creepages need not be greater than their associated inhomogeneous field clearance, except for equipment in overvoltage Category IV. Refer to Table 1-111A-8.

NEMA Standard 11-14-1985.

1-111A.2.3.1.3 The minimum creepage distance shall not be less than the associated clearance, regardless of the material group of the solid insulation.

NEMA Standard 1-23-1990.

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Table 1-111A-10
CREEPAGE FOR EQUIPMENT SUBJECT TO LONG TERM STRESS
(Pollution Degree 3)

Rated Insulation Voltage†‡ ac rms or dc	Creepage					
	Overvoltage Categories I, II, III Material Groups			Overvoltage Category IV* Material Groups		
	I	II	IIIa & IIIb	I	II	IIIa & IIIb
	mm (in.)	mm (in.)	mm (in.)	mm (in.)	mm (in.)	mm (in.)
50	1.5 (0.059)	1.7 (0.066)	1.9 (0.074)	1.7 (0.066)	1.9 (0.074)	2.1 (0.082)
100	1.8 (0.070)	2.0 (0.078)	2.2 (0.086)	2.0 (0.078)	2.2 (0.086)	2.5 (0.098)
150	2.0 (0.078)	2.2 (0.086)	2.5 (0.098)	3.2 (0.125)	3.6 (0.140)	4.0 (0.156)
300	4.0 (0.156)	4.5 (0.176)	5.0 (0.195)	6.3 (0.246)	7.1 (0.277)	8.0 (0.312)
600	8.0 (0.312)	9.0 (0.351)	10.0 (0.390)	12.5 (0.488)	14.0 (0.546)	16.0 (0.624)
1000	12.5 (0.488)	14.0 (0.546)	16.0 (0.624)	20.0 (0.780)	22.0 (0.858)	25.4 (1.000)

*For industrial control equipment used at the service entrance (transition from overvoltage Category IV to III) overvoltage Category IV is required only for the main (line) terminals.

NEMA Standard 11-14-1985.

†For the relationship of rated insulation voltage to rated operational voltage and voltage phase-to-earth, refer to 1-111A.2.1.3.

‡For equipment marked for connection exclusively to star-earthed-systems (grounded wye), refer to 1-111A.2.1.3.2.

Authorized Engineering Information 1-23-1990.

1-111A.2.3.2 Function of Grooves and Ribs

Grooves or ribs may be added to the surface of solid insulation to provide the required creepage between conductor parts without increasing the clearance between those parts.

Authorized Engineering Information 1-23-1990.

1-111A.2.3.3 Use of Grooves

1-111A.2.3.3.1 Grooves may function as collectors of dust and moisture; consequently, small grooves can be completely bridged by pollution (refer to example 1-111A.4.1.1). Minimum width of grooves to avoid bridging and to enable the surface of the groove to function as a portion of a creepage distance is given in Table 1-111A-11. The minimum width is based on the degree of pollution which may be present in the micro-environment. For the measurement rules for grooves, refer to 1-111A.2.3.5.

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1-111A.2.3.3.2 Creepage distances, including the surface of grooves, shall not be less than the values in Table 1-111A-10.

NEMA Standard 1-23-1990.

Table 1-111A-11
MINIMUM WIDTH OF GROOVES

Pollution Degree	Minimum Width of Grooves* mm (in.)
1	0.25 (0.010)
2	1.0 (0.039)
3	1.5 (0.059)
4	2.5 (0.100)

*If the associated clearance is less than 3 mm, the minimum groove width shall be permitted to be reduced to 1/3 of the associated clearance.

NEMA Standard 11-14-1985.

1-111A.2.3.4 Use of Ribs

Ribs considerably decrease the formation of leakage current because they diminish the effects of contamination and decrease drying-out time. Creepage distances can therefore be reduced to 80 percent of the values in Table 1-111A-10 provided the minimum height is 2 mm (refer to example 1-111A.4.1.4). However, creepage (including the surface of ribs) cannot be less than the associated clearance (refer to example 1-111A.4.1.8). The minimum width of the base of a rib is determined by mechanical requirements.

NEMA Standard 11-14-1985.

1-111A.2.3.5 Measurement Rules for Creepage and Clearance

These rules do not differentiate between grooves on the surface of solid insulation and gaps between discrete

parts of solid insulation, or between insulation material groups (refer to Table 1-111A-2). Furthermore:

1-111A.2.3.5.1 The bottom of a V shaped groove shall be assumed to be bridged with an insulating link of X mm width moved into the most unfavorable position (refer to example 1-111A.4.1.3).

NEMA Standard 1-23-1990.

1-111A.2.3.5.2 Where the distance across the top of a groove is X mm or more, creepage is measured along the contours of the grooves (refer to example 1-111A.4.1.3).

1-111A.2.3.5.3 Creepage and clearance measured between parts moving in relation to each other are measured when these parts are in their most unfavorable positions.

NEMA Standard 11-14-1985.

1-111A.2.3.5.4 Examples of the measurement for clearances and creepage are provided in 1-111A.4.1.

1-111A.2.4 PRINTED WIRING BOARDS

1-111A.2.4.1 For insulation requirements, refer to 1-111A.2.1.2.

1-111A.2.4.2 In addition, maximum recurring peak voltages shall be limited to the values in Table 1-111A-12 to prevent the degradation of insulation by partial discharges (corona).

1-111A.2.4.3 Electrical spacings for printed wiring boards shall be in accordance with the values in Tables 1-111A-13 and 1-111A-14. For clearances to the walls of metal enclosures, refer to 1-111A.2.2.2.

NEMA Standard 1-23-1990.

1-111A.2.4.4 Uncoated Printed Wiring Boards

1-111A.2.4.4.1 Spacings for Pollution Degree 1, Overvoltage Categories II and III, shall be permitted to be smaller than those in Table 1-111A-13, providing they can withstand their associated impulse withstand voltages; however, they shall not be smaller than the Pollution Degree 1 spacings for Overvoltage Category I.

NEMA Standard 11-14-1985.

1-111A.2.4.4.2 Because of "environmental/chemical" effects which can diminish or bridge small spacings, for Pollution Degree 2, it is not recommended that spacings less than 0.2 mm be used in industrial control equipment.

Authorized Engineering Information 11-14-1985.

1-111A.2.4.4.3 The Comparative Tracking Index (CTI) of the board material shall be:
Pollution Degree 1, CTI ≥ 100
Pollution Degree 2, CTI ≥ 175

NEMA Standard 11-14-1985.

Table 1-111A-12
MAXIMUM RECURRING PEAK VOLTAGE RELATED TO SPACINGS ON UNCOATED PRINTED WIRING BOARDS
(2000 Meter Altitude)

Spacings mm(in.)	Maximum† Recurring Peak, kV	Spacings mm(in.)	Maximum† Recurring Peak, kV
0.025 (0.001)	0.33	1.5 (0.059)	1.14
0.04 (0.002)	0.33	1.6 (0.062)	1.15
0.1 (0.004)	0.33	1.8 (0.070)	1.25
0.2 (0.008)	0.40	3.0 (0.117)	1.65
0.25 (0.010)	0.45	3.2 (0.125)	1.70
0.4 (0.016)	0.60	5.0 (0.195)	2.20
0.5 (0.020)	0.64	5.5 (0.215)	2.30
0.75 (0.029)	0.80	9.0 (0.312)	2.80

†Recurring peak voltage values are based on statistical evaluation of partial discharge data.

NEMA Standard 11-14-1985.

1-111A.2.4.5 Coated Printed Wiring Boards

1-111A.2.4.5.1 Spacings in Table 1-111A-14 are for Overvoltage Category I, Pollution Degree 1. The use of suitable coatings permits the application of the boards in other degrees of pollution and overvoltage categories.

NEMA Standard 11-14-1985.

1-111A.2.4.5.2 Spacings in Table 1-111A-14 apply to the coated portions of the board. Uncoated areas such as solder pads or components shall meet the requirements of 1-111A.2.4.4, according to the pollution degree of the uncoated areas.

1-111A.2.4.5.3 The Comparative Tracking Index (CTI) of the board base material shall be based on the pollution degree for the uncoated areas of the board. Refer to 1-111A.2.4.4.3 for the CTI of the base material.

NEMA Standard 1-23-1990.

1-111A.2.4.5.4 Coating performance requirements are under consideration.

Authorized Engineering Information 1-23-1990.

Table 1-111A-13
UNCOATED PRINTED WIRING BOARDS
SPACINGS (CLEARANCE AND CREEPAGE DISTANCES) FOR EQUIPMENT WHERE TRANSIENT VOLTAGES ARE INTENTIONALLY CONTROLLED BY A TRANSIENT LIMITING MEANS‡
(2000 Meters Altitude)

Rated Insulation Voltage †# ac rms or dc volts	Overvoltage Category								
	I			II			III		
	Impulse Withstand Voltage kV	Spacings for Pollution Degrees*		Impulse Withstand Voltage kV	Spacings for Pollution Degrees*		Impulse Withstand Voltage kV	Spacings for Pollution Degrees*	
		1	2		1	2		1	2
		mm (in.)	mm (in.)		mm (in.)	mm (in.)		mm (in.)	mm (in.)
50	0.33	0.025 (0.001)	0.2 (0.008)	0.5	0.04 (0.002)	0.2 (0.008)	0.8	0.1 (0.004)	0.2 (0.008)
100	0.50	0.1 (0.004)	0.2 (0.008)	0.8	0.1 (0.004)	0.2 (0.008)	1.5	0.5 (0.020)	0.5 (0.020)
150	0.80	0.25 (0.010)	0.4 (0.016)	1.5	0.5 (0.020)	0.5 (0.020)	2.5	1.5 (0.059)	1.5 (0.059)
300	1.50	0.75 (0.029)	1.6 (0.062)	2.5	1.5 (0.059)	1.6 (0.062)	4.0	3.0 (0.117)	3.0 (0.117)
600	2.50	1.8 (0.070)	3.2 (0.125)	4.0	3.0 (0.117)	3.2 (0.125)	6.0	5.5 (0.215)	5.5 (0.215)
1000	4.00	3.2 (0.125)	5.0 (0.195)	6.0	5.5 (0.215)	5.5 (0.215)	8.0	8.0 (0.312)	8.0 (0.312)

NEMA Standard 11-14-1985.

*For Pollution Degree 3, creepage from Table 1-111A-11 shall be used.

NEMA Standard 1-23-1990.

†For insulation coordination within an equipment, creepage distances for printed wiring boards for IEC 664A Table IV, Pollution Degree 1, corresponding to the working voltage within the equipment shall be permitted to be used. In this case, the limiting impulse withstand voltage can be found in IEC Publication 664 Table A1 under Case A impulse values corresponding to the creepage distance (clearance) value under consideration.

NEMA Standard 11-14-1985.

‡The spacings given were derived from IEC Publication 664A Table IV, however, some values of spacings were increased so that no creepage can be smaller than its associated clearance necessary to withstand the required impulse withstand voltage.

Authorized Engineering Information 11-14-1985.

#For the relationship of rated insulation voltage to rated operational voltage and voltage phase-to-earth, refer to 1-111A.2.1.3.

Authorized Engineering Information 1-23-1990.

Table 1-111A-14
COATED PRINTED WIRING BOARDS
SPACINGS (CLEARANCES AND CREEPAGE DISTANCES) FOR EQUIPMENT WHERE TRANSIENT VOLTAGES ARE INTENTIONALLY CONTROLLED BY A TRANSIENT LIMITING MEANS

Rated Insulation Voltage*† ac rms or dc volts	Overvoltage Category					
	I		II		III	
	Impulse Withstand Voltage	Spacings for Pollution Degree 1	Impulse Withstand Voltage	Spacings for Pollution Degree 1	Impulse Withstand Voltage	Spacings for Pollution Degree 1
	Volts	mm (in.)	Volts	mm (in.)	Volts	mm (in.)
50	330	0.025 (0.001)	500	0.025 (0.001)	800	0.025 (0.001)
100	500	0.1 (0.004)	800	0.1 (0.004)	1500	0.1 (0.004)
150	800	0.25 (0.010)	1500	0.25 (0.010)	2500	0.25 (0.010)
300	1500	0.75 (0.029)	2500	0.75 (0.029)	4000	0.75 (0.029)
600	2500	1.8 (0.070)	4000	1.8 (0.070)	6000	1.8 (0.070)
1000	4000	3.2 (0.125)	6000	3.2 (0.125)	8000	3.2 (0.125)

*For insulation coordination within an equipment, creepage distances for printed wiring boards from IEC 664A Table IV, Pollution Degree 1, corresponding to the working voltage values within the equipment shall be permitted to be used. In this case, the limiting impulse withstand voltage can be found in IEC Publication 664 Table A1 under Case A impulse values corresponding to the creepage distance (clearance) value under consideration.

NEMA Standard 11-14-1985.

†For the relationship of rated insulation voltage to rated operational voltage and voltage phase-to-earth, refer to 1-111A.2.1.3.

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TEST

1-111A.3.1 CLEARANCES

1-111A.3.1.1 Design Verification

1-111A.3.1.1.1 Clearances which are designed to be equal to or greater than the values in Tables 1-111A-7, 1-111A-8, or 1-111A-9 require verification of their magnitude. Verification of the values in Tables 1-111A-7 and 1-111A-8 shall be either by linear measurement or by impulse withstand voltage test at a level corresponding to the clearances in the tables. For pre-test conditioning of solid insulation associated with a clearance, refer to 1-111A.3.3.2.

1-111A.3.1.1.2 Verification of the values in Table 1-111A-9 shall be by linear measurement.

NEMA Standard 1-23-1990.

1-111A.3.1.2 Performance Verification

1-111A.3.1.2.1 Clearances which are designed to be less than the values in Tables 1-111A-7, 1-111A-8, 1-111A-13, or 1-111A-14 require type test and sample or routine test verification of their performance. Verification shall be by an impulse withstand voltage test at a level corresponding to the clearance in Table 1-111A-7, 1-111A-8, 1-111A-13, or 1-111A-14.

1-111A.3.1.2.2 Printed Wiring Boards

1-111A.3.1.2.2.1 Clearances from Table 1-111A-13 shall be verified under clean and dry conditions.

1-111A.3.1.2.2.2 Clearances from Table 1-111A-14 shall be verified, prior to coating the board, under clean and dry conditions.

1-111A.3.1.2.2.3 A board, coated but without components installed, shall withstand the impulse voltage corresponding to the rated insulation voltage and the assigned overvoltage category.

1-111A.3.1.2.3 Sample and routine tests are conducted using the same procedures and criteria as for type tests. Refer to 1-111A.3.3.2.

NEMA Standard 1-23-1990.

1-111A.3.2 CREEPAGE DISTANCES

1-111A.3.2.1 Design Verification

1-111A.3.2.1.1 Creepage distances require verification of their magnitude. Verification of the values in Table 1-111A-10 shall be by linear measurement.

1-111A.3.2.1.2 For measurement principles, refer to 1-111A.2.3.4. For measurement examples, refer to 1-111A.4.1.

NEMA Standard 1-23-1990.

1-111A.3.3 SOLID INSULATION

1-111A.3.3.1 Performance Verification

The voltage withstand characteristics of solid insulation shall be verified by a type test. Refer to 1-111A.2.1.1 and 1-111A.2.1.2.

NEMA Standard 1-23-1990.

1-111A.3.3.2 Pre-Test Conditioning

1-111A.3.3.2.1 For type tests, the device or equipment shall be conditioned for 96 hours in an atmosphere of 85±5 percent relative humidity at a temperature of 25±2°C, prior to the application of the test voltage.

NEMA Standard 11-14-1985.

1-111A.3.3.2.2 Routine and sample tests, and dielectric tests conducted after endurance or performance tests, shall be performed without conditioning.

NEMA Standard 1-23-1990.

1-111A.3.3.3 Test Selection Factors

The voltage withstand characteristic of solid insulation is dependent upon many factors which should be considered for the selection of methods and values for testing. One of these factors is the voltage-time characteristic of the insulation. The one-minute dielectric test does not prove its ability to withstand an impulse withstand voltage associated with a clearance. Likewise, a one-minute power frequency test at the rated impulse withstand voltage of the clearance would be too severe. Therefore, the impulse voltage test is used for this purpose at the same level as that required for the clearance.

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1-111A.3.4 DIELECTRIC TESTS

1-111A.3.4.1 Conditions of Test

1-111A.3.4.1.1 ENCLOSURE

If the equipment or the device is to be used in an enclosure, it shall be mounted in the smallest enclosure in which it is likely to be used. If the equipment or the device is to be used without an enclosure, it shall be mounted on a metal plate and all metal parts (frame, etc.) that are earthed (grounded) in normal service shall be connected to the metal plate.

NEMA Standard 11-14-1985.

1-111A.3.4.1.2 ACTUATOR (HANDLE)

An actuator (handle) of insulating material, and the integral non-metallic enclosure of the device that is intended to be used without additional enclosure, shall be covered by a metal foil and connected to the frame or the mounting plate.

NEMA Standard 11-14-1985.

1-111A-3.4.1.3 ALTITUDE

Breakdown voltage of a clearance in air, for a homogeneous field is, according to Paschen's Law, a function of the distance between electrodes and the atmospheric pressure. Therefore, testing at an altitude other than 2000 meters shall require the use of corrected test voltages given in Table 1-111A-15. This table also applies for an inhomogeneous field.

Table 1-111A-15
TEST VOLTAGES FOR VERIFYING CLEARANCES AT ALTITUDES LESS THAN 2000 m

Rated Impulse Withstand Voltage, Kv	Corresponding Test Voltage, Kv			
	Altitude			
2000 m (6562 Ft.)	0 m (0 Ft.)	200 m (650 Ft.)	500 m (1641 Ft.)	1000 m (3281 Ft.)
0.33	0.36	0.35	0.35	0.34
0.5	0.54	0.54	0.53	0.52
0.8	0.93	0.92	0.90	0.86
1.5	1.8	1.7	1.7	1.6
2.5	3.1	3.0	2.9	2.8
2.7	3.3	3.3	3.2	3.0
4.0	4.9	4.8	4.7	4.4
4.3	5.3	5.2	5.0	4.8
5.6	6.9	6.8	6.5	6.2
6.0	7.4	7.2	7.0	6.7
6.8	8.4	8.2	8.0	7.6
8.0	9.8	9.6	9.3	8.9
8.8	10.8	10.6	10.3	9.8
11.0	13.8	13.5	13.0	12.3
12.0	15.0	14.7	14.2	13.4
16.0	20.0	19.6	18.9	17.9
20.0	25.0	24.5	23.7	22.4

NEMA Standard 1-23-1990.

At a given altitude, corrections for normal variations in barometric pressure are disregarded.

NEMA Standard 11-14-1985.

For the principles and formulas used to develop the values in Table 1-111A-15, refer to IEC 664 and 28A(CO)20.

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1-111A.3.4.2 Types of Dielectric Tests

1-111A.3.4.2.1 DIELECTRIC TEST VOLTAGES

The preferred dielectric test voltage is an impulse voltage. Other dielectric tests which provide equivalent voltage levels with greater levels of energy available when the voltage breakdown level of a clearance is reached are shown in Table 1-111A-16. Some of these tests, such as the half sine pulse, can also be used to limit the energy available when a clearance breaks down under test.

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1-111A.3.4.2.2 IMPULSE DIELECTRIC TEST

1-111A.3.4.2.2.1 The purpose of this test is to verify that clearances will withstand specified transient overvoltages.

1-111A.3.4.2.2.2 A test voltage of 1.2/50 microsecond wave shape shall be used to simulate overvoltage due to lightning or switching operations.

NEMA Standard 1-23-1990.

1-111A.3.4.2.3 POWER FREQUENCY DIELECTRIC TEST

1-111A.3.4.2.3.1 The power frequency dielectric tests in this standard are an alternate to the impulse dielectric test.

1-111A.3.4.2.3.2 Since the dielectric test voltage is greater than the rated voltage, care should be taken to not apply the test voltage in a manner which energizes a circuit.

Authorized Engineering Information 1-23-1990.

1-111A.3.4.2.4 DC DIELECTRIC TEST

1-111A.3.4.2.4.1 A dc dielectric test voltage shall be considered to be equivalent to the peak value of the power frequency dielectric test voltage.

NEMA Standard 11-14-1985.

1-111A.3.4.2.4.2 The dc test voltage may be used in place of an ac test voltage in those cases where an ac test voltage would result in undesirable ac current which might be sufficient to damage (overheat or overvoltage, or both) components or which may appear to be a high leakage current. Care should be taken to discharge any stored energy left in the circuit after test.

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Table 1-111A-16
DIELECTRIC TEST VOLTAGES
(2000 Meters Altitude)

Type of Test	Impulse*	Power Frequency			
		ac rms†‡	ac Peak or dc†‡	ac Peak ½ Sine Wave†‡	ac Peak Ramp
Rate of Rise	1.2/50 micro-sec.	—	—	—	6000 V/sec.
Hertz	—	50/60	50/60	50/60	50/60
Duration of Test	3 Pos. & 3 Neg#	3 Pos. & 3 Neg.	ac 3 Pos. & 3 Neg., dc min. 10 ms	3 Pos. & 3 Neg.#	4–5 ma† detection**
	330	230	330	330	330
	500	350	500	500	500
	800	570	800	800	800
	1500	1060	1500	1500	1500
	2500	1770	2500	2500	2500
	4000	2830	4000	4000	4000
	6000	4240	6000	6000	6000
	8000	5660	8000	8000	8000
	12000	8480	12000	12000	12000

NEMA Standard 11-14-1985.

*The test voltage values are given in Table A1 of IEC Publication 664.

†Available current should be limited to 4–5 milliamperes. The test equipment can be power limited or designed to shut off by the detection of 4–5 milliamperes leakage current.

‡ The ½ sine wave pulse and ac voltages are slightly more severe than the impulse voltage values in time duration and have been found to be satisfactory in laboratory tests. These two test methods are relatively easy to achieve with less sophisticated test apparatus than the impulse test method.

Authorized Engineering Information 11-14-1985.

#The minimum interval between pulses is 1 second.

**The voltage is to be increased until the ramp value is exceeded without detection of a leakage current of 4–5 milliamperes.

NEMA Standard 11-14-1985.

1-111A.3.4.3 Points of Application of Test Voltages

The test voltages of 1-111A.3.4.2 shall be applied as follows:

1-111A.3.4.3.1 Between the poles of the main circuit of the equipment and the metal parts that are earthed (grounded) in normal service, including the enclosure, with the contacts in the opened and closed positions.

NEMA Standard 11-14-1985.

1-111A.3.4.3.2 Between each pole of the main circuit and with the other poles connected to the frame, and with the contacts in the opened and closed positions.

NEMA Standard 11-14-1985.

1-111A.3.4.3.3 Between each control and auxiliary circuit that is not normally connected to the main circuit in service and each of the main and other control and auxiliary circuits that have been connected to the frame for the purpose of the test.

NEMA Standard 11-14-1985.

1-111A.3.4.3.4 For solid-state equipment being tested per 1-111A.3.4.3.1 or 1-111A.3.4.3.2, the test voltage shall be applied between the poles of the main circuit with the solid-state devices in their blocking condition, and also with a shorting wire across the devices simulating the closed condition.

1-111A.3.4.3.5 For equipment intended for use in other than motor branch circuits, the test voltage shall be applied between poles rated for opposite polarity and between all poles and the metal parts that are earthed (grounded) in normal service with contacts in the opened and closed positions.

NEMA Standard 11-14-1985.

1-111A.3.5 TEST RESULTS

There shall be no unintentional flashover or disruptive discharge or puncture (disruptive discharge through solid insulation) during the test. The operation of a specific overvoltage protective function incorporated in the equipment for that purpose shall be permitted.

NEMA Standard 1-23-1990.

1-111A.3.6 OVERVOLTAGES GENERATED BY THE EQUIPMENT OR DEVICE

1-111A.3.6.1 Performance Verification

Equipment intended for use in a system where transient voltages are controlled by transient limiting means shall be type tested to verify compliance with 1-111A.2.1.2.4.

NEMA Standard 1-23-1990.

1-111A.3.6.2 Procedure

All line and load terminals of the component, device, or equipment shall be monitored for overvoltages during operation at rated operational voltage under load and no-load conditions, and while being energized and deenergized.

NEMA Standard 11-14-1985.

1-111A.3.6.3 Test Results

Refer to 1-111A.2.1.2.4.

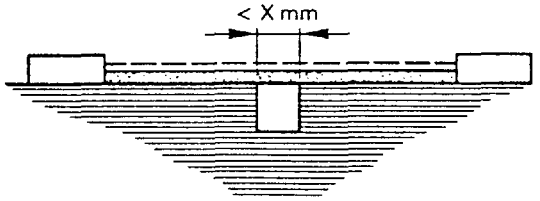
NEMA Standard 1-23-1990.

DETERMINATION OF CLEARANCE AND CREEPAGE MEASUREMENT

1-111A.4.1 EXAMPLES OF CLEARANCE AND CREEPAGE MEASUREMENT

For values of X (minimum width of grooves), refer to Table 1-111A-11.

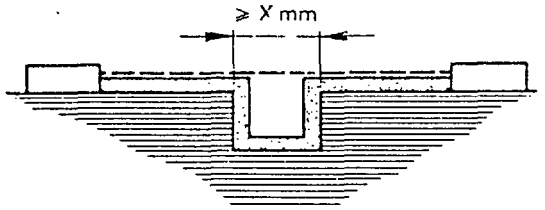
1-111A.4.1.1



Condition: Path under consideration includes a parallel or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are the "line of sight" distance.

1-111A.4.1.2



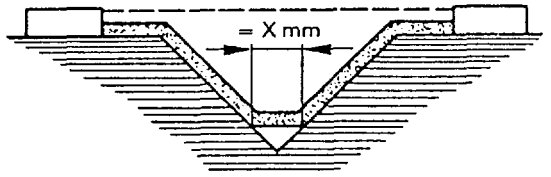
Condition: Path under consideration includes a parallel-sided groove of any depth and equal to or more than X mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove.

— — — —
Clearance

Creepage

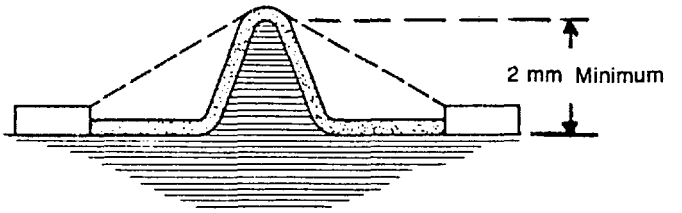
1-111A.4.1.3



Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

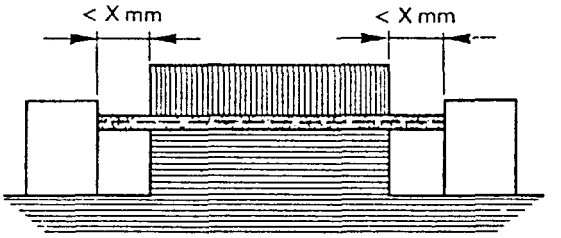
1-111A.4.1.4



Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib.

1-111A.4.1.5



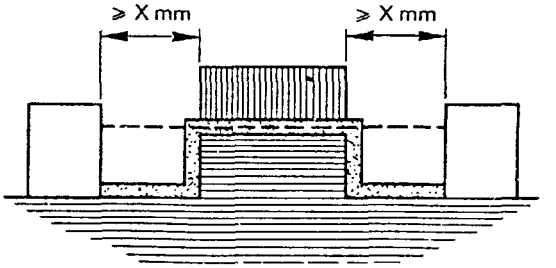
Condition: Path under consideration includes an uncemented joint with grooves less than X mm wide on each side.

Rule: Creepage and clearance path is the "line of sight" distance shown.

— — — —
Clearance

Creepage

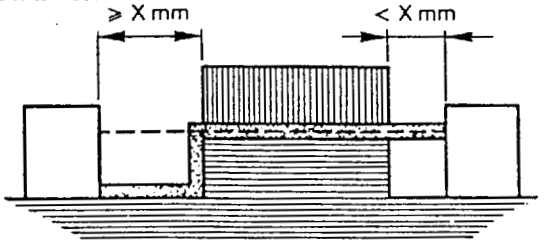
1-111A.4.1.6



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm wide on each side.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the grooves.

1-111A.4.1.7

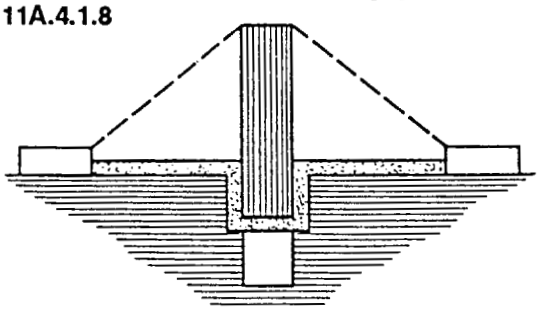


Condition: Path under consideration includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage paths are as shown.

Clearance Creepage

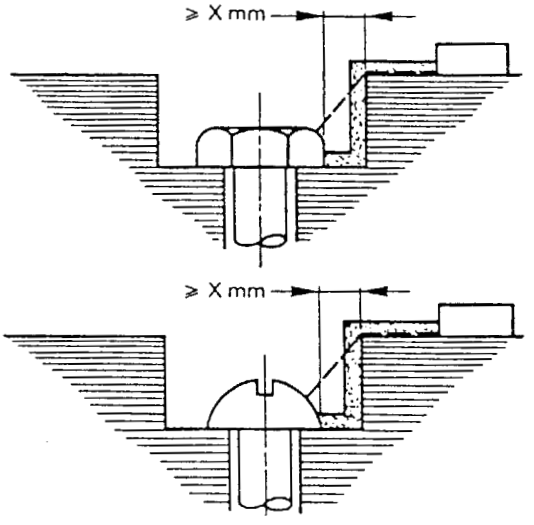
1-111A.4.1.8



Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

Rule: Clearance is the shortest direct air path over the top of the barrier or through the uncemented joint.

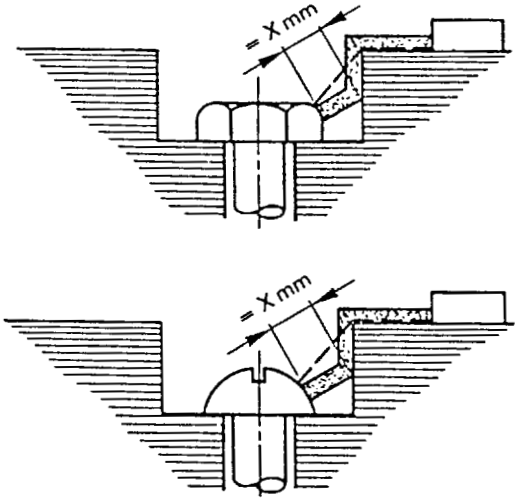
1-111A.4.1.9



Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

Clearance Creepage

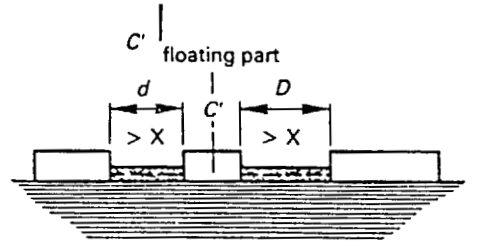
1-111A.4.1.10



Condition: Gap between head of screw and wall of recess too narrow to be taken into account.

Rule: Measurement of creepage distance is from screw to wall when the distance is equal to X mm.

1-111A.4.1.11



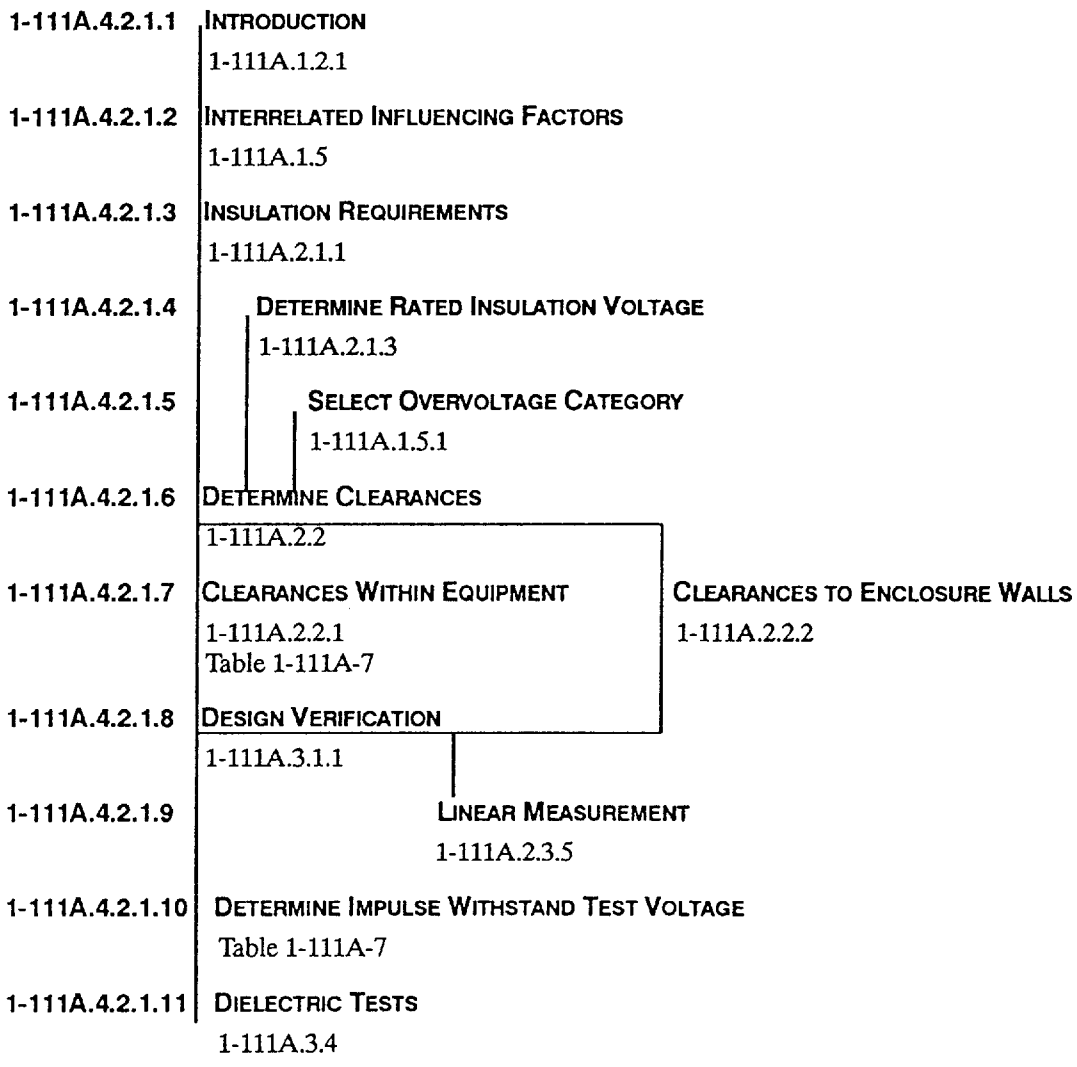
Clearance is the distance of d + D

Creepage distance is also d + D

Clearance Creepage

1-111A.4.2 FLOWCHARTS FOR DETERMINING CLEARANCE AND CREEPAGE DISTANCES

1-111A.4.2.1 Clearances, Transient Voltages Not Controlled



1-111A.4.2.2 Clearances, Transient Voltages Controlled

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and 1-111A-14

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1-111A.2.2.2

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1-111A.4.2.3 Creepage

1-111A.4.2.3.1 INTRODUCTION
1-111A.1.2, 1-111A.1.3

1-111A.4.2.3.2 INTERRELATED INFLUENCING FACTORS
1-111A.1.5

1-111A.4.2.3.3 INSULATION REQUIREMENTS
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1-111A.4.2.3.4 DETERMINE RATED INSULATION VOLTAGE
1-111A.2.1.3

1-111A.4.2.3.5 SELECT OVERVOLTAGE CATEGORY
1-111A.1.5.1

1-111A.4.2.3.6 SELECT MATERIAL GROUP
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1-111A.4.2.3.8 DETERMINE CREEPAGE
1-111A.2.3

1-111A.4.2.3.9 CONSIDER GROOVES AND RIBS ACROSS CREEPAGE PATH
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1-111A.4.2.3.12 PERFORMANCE VERIFICATION
1-111A.3.3

1-111A.4.2.3.13 DIELECTRIC TESTS
1-111A.3.4

Authorized Engineering Information 1-23-1990.

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ICS 1

GENERAL STANDARDS FOR INDUSTRIAL CONTROL AND SYSTEMS

Revision 1—May 1989
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nema

General Standards for Industrial Control and Systems

NEMA

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

9009279 0000249 484

ICS 1

GENERAL STANDARDS FOR INDUSTRIAL CONTROL AND SYSTEMS

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Washington, DC 20037

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Foreword

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

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

Standards Publication No.	Supersedes
ICS 1-1988, *General Standards for Industrial Control and Systems*	ICS 1-1983, formerly Part 1 (white pages) of NEMA Standards Publication No. ICS-1970, *Industrial Controls and Systems*
ICS 2-1983, *Industrial Control Devices, Controllers and Assemblies*	ICS 2-1978, formerly Part 2 (green pages) of NEMA Standards Publication No. ICS-1970, *Industrial Controls and Systems*
ICS 3-1983, *Industrial Systems*	ICS 3-1978, formerly Part 3 (yellow pages) of NEMA Standards Publication No. ICS-1970, *Industrial Controls and Systems*
ICS 4-1983 (R 1988), *Terminal Blocks for Industrial Use*	ICS 4-1977, formerly NEMA Standards Publication No. IS 4-1968, *Terminal Blocks for Industrial Control Equipment and Systems*
ICS 6-1988, *Enclosures for Industrial Controls and Systems*	ICS 6-1983, formerly NEMA Standards Publication No. IS 1.1-1977, *Enclosures for Industrial Controls and Systems*; and Part ICS 1-110 of NEMA Standards Publication No. ICS-1970, *Industrial Controls and Systems*

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

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

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

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

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

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

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

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

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.

NEMA Standards Publications are subject to periodic review. They are revised frequently to reflect user input and 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:

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

Scope

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.

The product scopes of the various Groups of the Industrial Control and Systems Section of NEMA which participated in the development of Standards Publication No. ICS 1 are as follows:

I

Scope of Industrial Controls Group

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

A. To start, stop, protect, accelerate, decelerate, reverse, and/or control the speed of electric motors.

B. To provide some mechanical movement through the action of magnets or solenoids.

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

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

II

Scope of the Industrial Systems Group

A. Systems and devices not falling within the product scope of the Control Group, principally used in industrial applications for regulating power utilization apparatus. These systems are assemblies or groups of components arranged to include one or more feedback loops. These systems may include, when necessary to the operation of the system, data logging, data processing and programming input components, even though they may not be in a feedback loop.

B. AC and DC adjustable-speed drive systems and other systems of similar characteristics whether regulated or unregulated.

This product scope specifically includes, but is not limited to:

1. Adjustable-speed systems of the automatically-regulated type, such as: rolling mill drives, paper mill drives, slasher drives. These include systems for regulating speed, tension, current, etc.

2. Machine tool control incorporating:
   a. Programmed input.
   b. Feedback control of speed, position torque, etc.
   c. Data logging and processing in feedback loops or as readouts.
3. Computer control of machines.
4. Industrial process regulating systems, excluding systems used solely for the control of temperature.
5. Register and synchronizing control.
6. Integrated mill control, including data logging, data processing, and programming.
7. Automatic warehousing, including control of warehouse conveyors, automatic stackers, etc.
8. Adjustable-speed mill systems.
9. Analog-digital converters and transducers.
10. Digital display devices.
11. Semiconductor power converters and inverters for adjustable speed motors.
12. Energy management systems.

Certain classes of equipment are **not** included in the product scope. Examples of these are:

1. Elementary feedback loop combinations of components, such as:
   a. Float switch, motor starter, motor and pump.
   b. Limit switches, reversing controller, motor, machine table.
   c. Pressure switch, motor starter, motor and compressor.
   d. Light dimmers.
2. Relay-type interlock systems not a part of the regulating system, such as relay banks for interlocking related operations of machines. For example: machine tool relay panels, steel mill auxiliary relay and contactor panels.
3. Unregulated constant potential mill auxiliaries.
4. Specific components utilized in these systems and covered by the product scopes of other NEMA Sections.

In this product scope, a component is a functional element of a system, i.e., operational amplifier, computer element, encoder, tape reader, gauging equipment.

III

Scope of the Terminal Block Group

Molded barrier terminal blocks, boards and strips of the type generally used for the connections in electrical and electronic circuits.

IV

Scope of the Resistance Welding Control Group

Control principally used to start, stop and/or control the operations of resistance welding machines.

Excluded from the product scope of this Section are:

1. Automatic electric controls and panels of the types principally used in air-conditioning, refrigeration and comfort heating, which are in the scope of the Residential Controls Section.
2. Motors, generators, and motor-generators which function as control when constituting part of adjustable-speed drives.
3. Controls of the type used specifically for railway and railroad locomotion.
4. Renewal parts.
5. Data logging and processing equipment other than industrial.
6. Temperature and humidity control.

GENERAL STANDARDS FOR INDUSTRIAL CONTROL AND SYSTEMS

Part 1-100

REFERENCED STANDARDS AND DEFINITIONS

1-100.1 REFERENCED STANDARDS

In this publication, reference is made to the standards listed below:

American National Standards Institute
1430 Broadway
New York, NY 10018

C84.1-1982 — *Voltage Ratings for Electric Power Systems and Equipment (60 Hz)*

American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103

D-3638-1985 — *Test Method for Comparative Tracking Index of Electrical Insulating Materials*

Institute of Electrical and Electronics Engineers
345 East 47th Street
New York, NY 10017

91-1984 (ANSI Y32.14) — *Standard Graphic Symbols for Logic Functions**

100-1984 (ANSI C42.100) — *IEEE Standard Dictionary of Electrical and Electronics Terms**

315-1975, 315A-1986 (ANSI Y32.2) — *Graphic Symbols for Electrical and Electronics Diagrams**

C37.2-1987 — *Standard Electrical Power System Device Function Numbers*

International Electrotechnical Commission
1, rue de Varembe
Geneva, Switzerland

112-1979 — *Method for Determining the Comparative and the Tracking Indices of Solid Insulating Materials Under Moist Conditions*

664-1980, 664A-1981 — *Insulation Co-ordination Within Low-Voltage Systems, Including Clearances and Creepage Distances for Equipment*

National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, DC 20037

ICS 1.1-1984 — *Safety Guidelines for the Application, Installation and Maintenance of Solid State Control*

* Also available from the American National Standards Institute.

ICS 2-1983	*Industrial Control Devices, Controllers and Assemblies*
ICS 3-1983	*Industrial Systems**
ICS 4-1988	*Terminal Blocks for Industrial Use**
ICS 6-1988	*Enclosures for Industrial Controls and Systems*
LI 1-1983	*Industrial Laminated Thermosetting Products*
LI 6-1983	*Relative Temperature Indices of Industrial Thermosetting Products*
ST 1-1988	*Specialty Transformers (Except General-purpose Type)*

National Fire Protection Association
Publication Sales Department
Batterymarch Park
Quincy, MA 02269

70-87	*National Electrical Code*
70B-1987	*Electrical Equipment Maintenance*
70E-1988	*Electrical Safety Requirements for Employee Workplaces*

Underwriters Laboratories Inc.
333 Pfingsten Rd.
Northbrook, IL 60062

347-1985	*High Voltage Industrial Control Equipment**
508-1984	*Industrial Control Equipment**

* Also available from the American National Standards Institute.

The standards in this part apply to all NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified. Definitions that are marked with an asterisk (*) are identical to those appearing in ANSI/IEEE Std 100, IEEE Standard Dictionary of Electrical and Electronic Terms.

The terms have been arranged in an alphabetical order that reflects common usage and are selectively cross-referenced through the grouping of commonly used nouns followed by their modifier.

Specialized definitions applying to the contents of their respective parts appear in the other Standards Publications for Industrial Controls and Systems.

1-100.2 DEFINITIONS

accelerating contactor. A contactor, other than the line or directional contactor, used primarily for the purpose of obtaining a change of accelerating torque.

NEMA Standard 9-20-1973.

accuracy, repeat. See **repeat accuracy.**

adaptive control systems. See **control system, adaptive.***

alternating current contactor. A contactor for the specific purpose of establishing and interrupting an alternating current power circuit.

NEMA Standard 3-17-1971.

ambient temperature.* The temperature of the medium such as air, water, or earth into which the heat of the equipment is dissipated.

NEMA Standard 9-20-1973.

NOTES: (A) For self-ventilated equipment, the ambient temperature is the average† temperature of the air in the immediate neighborhood of the equipment. (B) For air- or gas-cooled equipment with forced ventilation or secondary water cooling, the ambient temperature is taken as that of the ingoing air or cooling gas. (C) For self-ventilated enclosed (including oil-immersed) equipment considered as a complete unit, the ambient temperature is the average† temperature of the air outside of the enclosure in the immediate neighborhood of the equipment. (These notes are approved as Authorized Engineering Information.)

†The average of temperature readings at several locations. (This note is not a part of ANSI/IEEE Std 100 definition.)

antihunt. See **damping.**

apparatus. Includes the enclosure, the enclosed equipment, and attached appurtenances.

NEMA Standard 7-16-1969.

application tests. Those tests performed by a manufacturer to determine those operating characteristics that are not necessarily established by standards but that are of interest in the application of devices.

NEMA Standard 9-15-1971.

automatic reset. A function that operates to automatically reestablish specific conditions.

NEMA Standard 1-26-1977.

auxiliary contacts. See **contacts (auxiliary) (switching device).***

barrier.* A partition for the insulation or isolation of electric circuits or electric arcs.

NEMA Standard 5-24-1960.

block diagram. See Part 1-101.

brake, magnet. See **magnet brake.**

breaking, dynamic. See **dynamic braking.**

break rating. The value of current for which a contact assembly is rated for opening a circuit repeatedly at a specified voltage and under specified operating conditions.

NEMA Standard 5-17-1971.

bus. (1) A set of power supply leads or (2) a conductor which provides multiple connections.

NEMA Standard 5-21-1962.

capability, interrupting. See **interrupting capability.**

capability, short-time. See **short-time capability.**

carryover period. The maximum time of power loss during which a system will remain within specified limits of performance.

NEMA Standard 8-20-1966.

clearance. The shortest distance through air between conducting parts, or between a conducting part and the outer surface of the insulating enclosure considered as though metal foil were in contact with the accessible surfaces of the enclosure.

NEMA Standard 1-5-1977.

NOTE: A joint between two parts of an insulating barrier is considered to be part of the surface except where the interstices are completely filled with an insulating material (cement).

Authorized Engineering Information 1-5-1977.

combination controller—600 volts or less.† A full magnetic or semimagnetic controller with additional externally operable disconnecting means contained in a common enclosure. The disconnecting means may be a circuit breaker or a disconnect switch.

NEMA Standard 9-29-1954.

†Combination starters are specific forms of combination controllers.

NOTE: NEMA terms are shown indexed with associated definitions, identical to ANSI, IEEE, and IEC standards, while retaining the advantages of finding definitions through the groupings of commonly used nouns.

*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

compensation, IR-drop. See **IR-drop compensation.**

conducting parts (live parts). Those parts that are designed to carry current or that are conductively connected therewith.

NEMA Standard 4-25-1928.

connection diagram. See Part 1-101.

connection diagram, wireless. See Part 1-101.

construction diagram.* See Part 1-101.

contact, electric. See **electric contact.***

contactor. A two-state (on-off) device for repeatedly establishing and interrupting an electric power circuit. Interruption is obtained by introducing a gap or a very large impedance.

NEMA Standard 9-20-1973.

contactor, accelerating. See **accelerating contactor.**

contactor, alternating current. See **alternating current contactor.**

contactor, direct current. See **direct current contactor.**

contactor, electronic. See **electronic contactor.**

contactor, low-torque. See **low-torque contactor.**

contactor, magnetic. See **magnetic contactor.***

contactor, solid-state. See **solid-state contactor.**

contacts.* Conducting parts that co-act to complete or to interrupt a circuit.

NEMA Standard 5-24-1960.

contacts (auxiliary)(switching device).* Contacts in addition to the main-circuit contacts that function with the movement of the latter.

NEMA Standard 5-24-1960.

contacts (nonoverlapping).* Combinations of two sets of contacts, actuated by a common means, each set closing in one of two positions, and so arranged that the contacts of one set open before the contacts of the other set close.

NEMA Standard 5-24-1960.

contacts (overlapping).* Combinations of two sets of contacts, actuated by a common means, each set closing in one of two positions, and so arranged that the contacts of one set open after the contacts of the other set have been closed.

NEMA Standard 5-24-1960.

continuous periodic rating.* The load that can be carried for the alternate periods of load and rest specified in the rating and repeated continuously without exceeding the specified limitation.

NEMA Standard 12-17-1947.

continuous rating.* The maximum constant load that can be carried continuously without exceeding established temperature-rise limitations under prescribed conditions of test and within the limitations of established standards.

NEMA Standard 1-5-1977.

control.* Broadly the methods and means of governing the performance of any electric apparatus, machine or system.

NEMA Standard 5-21-1962.

control apparatus.* A set of control devices used to accomplish the intended control functions.

NEMA Standard 5-21-1962.

control circuit (industrial control).* The circuit that carries the electric signals directing the performance of the controller but does not carry the main power circuit.

NEMA Standard 5-21-1962.

control-circuit devices, oiltight. See **oiltight control-circuit devices.**

control-circuit transformer.* A voltage transformer utilized to supply a voltage suitable for the operation of control devices.

NEMA Standard 5-24-1960.

control device.* An individual device used to execute a control function.

NEMA Standard 5-21-1962.

control, industrial. See **industrial control.**

control relay. See **relay.***

control relay, magnetic. See **magnetic control relay.**

control, remote. See **remote control.**

control sequence diagram. See Part 1-101.

control sequence table.* A tabulation of the connections that are made for each successive position of the controller.

NEMA Standard 12-18-1932.

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*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

control system. A system in which deliberate guidance or manipulation is used to achieve a prescribed value of a variable.

NEMA Standard 7-7-1965.

control system, adaptive.* A control system within which automatic means are used to change the system parameters in a way intended to improve the performance of the control system.

NEMA Standard 7-7-1965.

control system diagram. See Part 1-101.

control, three-wire. See **three-wire control.***

control, two-wire. See **two-wire control.***

controller, combination—600 volts or less. See **combination controller—600 volts or less.**

controller, definite purpose. See **definite purpose controller.**

controller diagram. See Part 1-101.

controller, drum. See **drum controller.***

controller, electric. See **electric controller.***

controller, electric motor. See **electric motor controller.***

controller, electropneumatic. See **electropneumatic controller.***

controller, full-magnetic. See **full-magnetic controller.***

controller, general-purpose. See **general-purpose controller.***

controller, manual. See **manual controller.***

controller, semimagnetic. See **semimagnetic controller.***

controllers for steel-mill accessory machines. See 3-441.05 of NEMA Standards Publication No. ICS 3.

controllers for steel-mill auxiliaries. See 3-441.05 of NEMA Standards Publication No. ICS 3.

converter. A network or device for changing the form of information or energy.

NEMA Standard 5-21-1962.

corrosion-resistant. So constructed, protected or treated that corrosion will not exceed specified limits under specified test conditions.

NEMA Standard 10-21-1987.

counter. A network or device for storing integers and permitting these integers to be changed by unity or by an arbitrary integer as successive input signals are received.

NEMA Standard 5-21-1962.

counter, reversible. See **reversible counter.**

creepage distance. The shortest distance along the surface of an insulating material between two conducting parts, or between a conducting part and the outer surface of the insulating enclosure considered as though metal foil were in contact with the accessible surfaces of the enclosure.

A joint between two parts of an insulating barrier is considered to be part of the surface except where the interstices are completely filled with an insulating material (cement).

NEMA Standard 1-5-1977.

critically damped. Damping that is sufficient to prevent any overshoot of the output following an abrupt stimulus.

NEMA Standard 9-29-1960.

current relay.* A relay that functions at a predetermined value of current.

NEMA Standard 5-24-1960.

NOTE: It may be an overcurrent, undercurrent, or reverse-current relay. (This note is approved as Authorized Engineering Information.)

damped, critically. See **critically damped.**

damping. The reduction or suppression of the oscillation of a system. See critically damped.

NEMA Standard 1-25-1961.

deactivating means, interlocking (defeater). See **interlocking deactivating means (defeater).**

dead time. The time interval between the initiation of an input and the start of the resulting response. Dead time shall be expressed in seconds.

NEMA Standard 8-19-1964.

defeater. See **interlocking deactivating means (defeater).**

definite-purpose controller.* Any controller having ratings, operating characteristics, or mechanical construction for use under service conditions other than usual or for use on a definite type of application.

NEMA Standard 9-29-1960.

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*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

delay, off. See **off delay.**

delay, on. See **on delay.**

delay, time. See **time delay.***

design test. A test that demonstrates compliance of a product design with applicable standards; it is not intended to be a production test.

NEMA Standard 7-16-1969.

diagram, block. See Part 1-101.

diagram, connection or wiring. See Part 1-101.

diagram, construction. See Part 1-101.

diagram, control sequence, or table. See Part 1-101.

diagram, control system. See Part 1-101.

diagram, illustrative. See Part 1-101.

diagram, interconnection. See Part 1-101.

diagram, logic. See Part 1-101.

diagram, one-line (single-line). See Part 1-101.

diagram, process or flow. See Part 1-101.

diagram, schematic or elementary. See Part 1-101.

diagram, wireless connection. See Part 1-101.

dielectric withstand-voltage tests.* Tests made to determine the ability of insulating materials and spacings to withstand specified overvoltages for a specified time without flashover or puncture.

NEMA Standard 1-5-1977.

NOTE: The purpose of the tests is to determine the adequacy against breakdown of insulating materials and spacings under normal or transient conditions.(This note is approved as Authorized Engineering Information.)

direct current contactor. A contactor for the specific purpose of establishing and interrupting a direct current power circuit.

NEMA Standard 3-17-1971.

disruptive discharge. The phenomena associated with the failure of insulation under electric stress; these include a collapse of voltage and the passage of current; the term applies to electrical breakdown in solid, liquid, and gaseous dielectrics, and combinations of these dielectrics.

NEMA Standard 1-5-1977.

disturbance.* An undesired input variable that may occur at any point within a feedback control system.

NEMA Standard 9-29-1960.

drawing, dimension or outline. See Part 1-101.

drift (as applied to devices). As applied to devices such as pressure switches, temperature switches, and so forth is a change in operating characteristics over a specified number of operations or time and specified environmental conditions.

NEMA Standard 1-5-1977.

drift (as applied to systems). An undesired but relatively slow change in output over a specified time with a fixed reference input and fixed load, with specified environmental conditions. The specified time is normally after the warm-up period.

Drift shall be expressed in percent of the maximum rated value of the variable being measured.

NEMA Standard 9-8-1976.

drum controller.* An electric controller that utilizes a drum switch as the main switching element.

NEMA Standard 5-24-1960.

NOTE: A drum controller usually consists of a drum switch and a resistor. (This note is approved as Authorized Engineering Information.)

drum switch.* A switch in which the electric contacts are made on segments or surfaces on the periphery of a rotating cylinder or sector, or by the operation of a rotating cam.

NEMA Standard 8-20-1966.

dynamic braking. A control function that brakes the drive by dissipating its stored energy in a resistor.

NEMA Standard 8-19-1964.

effective actuation time. The time that elapses between initial energization of the control circuit and the time the contacts of a normally open device close and remain closed or the contacts of a normally closed device open and remain open. Effective actuation time includes any contact bounce time or chatter time which occurs due to the operation of the device being tested.

NEMA Standard 1-5-1977.

electric contact.* The junction of conducting parts permitting current to flow.

NEMA Standard 5-24-1960.

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*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

electric controller.* A device or group of devices that serves to govern in some predetermined manner the electric power delivered to the apparatus to which it is connected.

NEMA Standard 5-2-1916.

electric motor controller.* A device or group of devices that serves to govern in some predetermined manner the electric power delivered to the motor.

NEMA Standard 6-3-1956.

NOTE: An electric motor controller is distinct functionally from a simple disconnecting means whose principal purpose in a motor circuit is to disconnect the circuit, together with the motor and its controller from the source of power. See **combination controller** for an example where the two devices are combined in one piece of apparatus. (The preceding sentence is not a part of the ANSI/IEEE Std 100 definition and is approved as Authorized Engineering Information.)

electronic contactor. A contactor whose function is performed by electron tube(s) or semiconductor device(s).

NEMA Standard 9-20-1973.

electronic direct current motor controller. For the purposes of this standard, a phase-controlled rectifying system using semiconductors or tubes of the vapor- or gas-filled variety for power conversion to supply the armature circuit or the armature and shunt-field circuits of a direct current motor, to provide adjustable-speed, adjustable- and compensated-speed, or adjustable- and regulated-speed characteristics.

NEMA Standard 5-17-1971.

electropneumatic controller.* An electrically supervised controller having some or all of its basic functions performed by air pressure.

NEMA Standard 5-24-1960.

enclosure, ventilated. See **ventilated enclosure.***

failure of a control component or system. A state or condition in which a control component or system does not perform its essential function(s) when its ratings are not exceeded.

NEMA Standard 8-20-1966.

fault current. A current that results from the loss of insulation between conductors or between a conductor and ground.

NEMA Standard 3-22-1972.

fault current, low-level (as applied to a motor branch circuit). A fault current that is equal to or less than the maximum operating overload.

NEMA Standard 3-22-1972.

fault withstandability. The ability of electrical apparatus to withstand the effects of specified electrical fault current conditions without exceeding specified damage criteria.

NEMA Standard 3-17-1971.

feedback, negative. See **negative feedback.***

feedback, positive. See **positive feedback.**

full-magnetic controller.* An electric controller having all of its basic functions‡ performed by devices that are operated by electromagnets.

NEMA Standard 5-24-1960.

‡"Basic functions" usually refers to acceleration, retardation, line closing, reversing, and so forth. (This note is not a part of the ANSI/IEEE Std 100 definition and is approved as Authorized Engineering Information.)

general-purpose controller. Any controller having ratings, characteristics, and mechanical construction for use under usual service conditions in accordance with the NEMA Standards Publications for Industrial Controls and Systems.

NEMA Standard 9-29-1960.

general-use switch. A switch that is intended for use in general distribution and branch circuits. It is rated in amperes and is capable of interrupting the rated current at the rated voltage.

NEMA Standard 8-20-1966.

graphic symbol. See Part 1-101.

ground (earth).* A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth or to some conducting body of relatively large extent that serves in place of the earth.

NEMA Standard 10-29-1979.

inch (jog). See **jog (inch).***

industrial control. Broadly the methods and means of governing the performance of an electric device, apparatus, equipment, or system used in industry.

NEMA Standard 5-21-1962.

interconnection diagram. See Part 1-101.

interlock. A device actuated by the operation of some other device with which it is directly associated, to govern succeeding operations of the same or allied devices.

Interlocks shall be permitted to be either electrical or mechanical.

NEMA Standard 5-24-1960.

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*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

interlocking deactivating means (defeater). A manually actuated provision for temporarily rendering an interlocking device ineffective, thus permitting an operation that would otherwise be prevented.

NEMA Standard 8-20-1962.

For example, when applied to apparatus such as combination controllers (Part 2-321 of NEMA Standards Publication No. ICS 2) or control centers (Part 2-322 of NEMA Standards Publication No. ICS 2, it refers to voiding of the mechanical interlocking mechanism between the externally operable disconnect device and the enclosure doors to permit entry into the enclosure while the disconnect device is closed.

Authorized Engineering Information 8-20-1962.

intermittent periodic duty or intermittent duty. A duty in which the main contacts of an equipment remain closed for periods bearing a definite relation to the no-load periods, both periods being too short to allow the equipment to reach thermal equilibrium. See also **periodic rating.**

NEMA Standard 5-25-1988.

interrupting capability. The maximum value of current that a contact assembly is required to successfully interrupt at a specified voltage for a limited number of operations under specified conditions. The term is usually applied to abnormal or emergency conditions.

NEMA Standard 5-17-1971.

inverse time. A qualifying term applied to a relay indicating that its time of operation decreases as the magnitude of the operating quantity increases.

NEMA Standard 9-29-1960.

IR-drop compensation. A control function that compensates for voltage drop due to current.

The amount of IR-drop compensation shall be expressed in percent of rated voltage, i.e.,

$$\text{IR-drop compensation percent} = \frac{\text{Volts compensation at full-load current}}{\text{Rated full-load voltage}} \times 100$$

NEMA Standard 8-19-1964.

isolating switch.* A switch intended for isolating an electric circuit from the source of power.

NEMA Standard 8-20-1966.

NOTE: It has no interrupting rating, and it is intended to be operated only after the circuit has been opened by some other means. (This note is approved as Authorized Engineering Information.)

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

NEMA Standard 7-12-1961.

jogging speed.* The steady-state speed that would be attained if the jogging pilot device contacts were maintained closed.

NEMA Standard 8-19-1964.

NOTE: It may be expressed either as an absolute magnitude of speed or a percentage of maximum rated speed. (This note is approved as Authorized Engineering Information.)

limit switch. See Part 2-225 of NEMA Standards Publication No. ICS 2 for definition of limit switch and associated terms.

live parts. See **conducting parts.**

loop-position control systems. See Part 3-106C of NEMA Standards Publication No. ICS 3.

low-torque contactor. A contactor used in a motor circuit in addition to a line, directional, plugging, or accelerating contactor, for the purpose of limiting stalled torque of the motor to less than 100 percent of the full load torque by inserting resistance in the circuit.

NEMA Standard 7-14-1982.

magnet brake. A friction brake that is controlled by electromagnetic means.

NEMA Standard 5-23-1919.

magnetic contactor.* A contactor actuated by electromagnetic means.

NEMA Standard 5-24-1960.

magnetic control relay. A relay that is actuated by electromagnetic means. When not otherwise qualified, the term refers to a relay intended to be operated by the opening and closing of its coil circuit, and having contacts designated for energizing or deenergizing, or both, the coils of magnetic contactors or other magnetically operated device.

NEMA Standard 7-27-1955.

make rating. The value of current for which a contact assembly is rated for closing a circuit repeatedly under specified operating conditions.

NEMA Standard 5-17-1971.

manual controller.* An electric controller having all of its basic functions performed by devices that are operated by hand.

NEMA Standard 4-25-1960.

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*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

manual reset. A function that requires a manual operation to reestablish specific conditions.

NEMA Standard 1-26-1977.

motor-circuit switch.* A switch intended for use in a motor branch circuit.

NEMA Standard 8-20-1966.

NOTE: It is rated in horsepower, and it is capable of interrupting the maximum operating overload current of a motor of the same rating at the rated voltage. See **operating overload.** (This note is approved as Authorized Engineering Information.)

negative feedback.* A feedback signal in a direction to reduce the variable that the feedback represents.

NEMA Standard 5-16-1963.

nonoverlapping contacts. See **contacts (nonoverlapping).***

off delay. The timing period of a pneumatic time delay relay is initiated upon deenergization of its coil.

NEMA Standard 6-1-1959.

oiltight control-circuit devices. Devices such as pushbutton switches, pilot lights, and selector switches that are so designed that, when properly installed, they will prevent oil and coolant from entering around the operating or mounting means.

NEMA Standard 9-26-1952.

on delay. The timing period of a pneumatic time delay relay is initiated upon energization of its coil.

NEMA Standard 6-1-1959.

operate time. The elapsed time between the initial energization of the control circuit and the time the contacts of normally open device first touch or the time the contacts of a normally closed device first open.

NEMA Standard 1-5-1977.

operating overload. The overcurrent to which electric apparatus is subjected in the course of the normal operating conditions that it may encounter.

NEMA Standard 5-24-1960.

For example, those currents in excess of running current that occur for a short time as a motor is started or jogged are considered normal operating overloads for control apparatus. See 1-112.40.

Authorized Engineering Information 5-24-1960.

overcurrent relay. A relay that operates when the current through the relay during its operating period is equal to or greater than its setting.

overlapping contacts. See **contacts (overlapping).***

overload protection.* The effect of a device operative on excessive current, but not necessarily on short circuit, to cause and maintain the interruption of current flow to the device governed.

NEMA Standard 5-24-1960.

part-winding starter. A starter that applies to voltage successively to the partial sections of the primary winding of an ac motor.

NEMA Standard 8-7-1952.

period, carryover. See **carryover period.**

periodic rating.* The load that can be carried for the alternate periods of load and rest specified in the rating, the apparatus starting at approximately room temperature, and for the total time specified in the rating, without causing any of the specified limitations to be exceeded. See also **intermittent periodic duty** or **intermittent duty.**

NEMA Standard 5-25-1988.

periodic rating, continuous. See **continuous periodic rating.***

pick-up and seal voltage (magnetically operated device). The minimum voltage, suddenly applied, at which the device moves from its deenergized into its fully energized position.

NEMA Standard 9-15-1971.

pick-up voltage or current (magnetically operated device). The voltage or current, suddenly applied, at which the device starts to operate.

NEMA Standard 9-15-1971.

pilot duty rating. A generic term formerly used to indicate the ability of a control device to control other devices (See Part 2-125 of NEMA Standards Publication No. ICS 2.)

NEMA Standard 9-15-1971.

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

NEMA Standard 7-12-1961.

pole (electrical switching device). A combination of mating contacts that are normally open, or normally closed, or both.

NEMA Standard 3-12-1975.

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*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

pole, multi (electrical switching device). The term "multipole" is applied to a contact arrangement that includes two or more separate mating contact combinations; that is, two or more single-pole contact assemblies, having a common operating means.

NEMA Standard 3-12-1975.

pole, single (electrical switching device). The term "single pole" is applied to a contact arrangement in which all contacts connect in one position or another to a common contact.

NEMA Standard 3-12-1975.

positive feedback. A feedback signal in a direction to increase the variable that the feedback represents.

NEMA Standard 5-16-1963.

pressure operated switches. See Part 2-226 of NEMA Standards Publication No. ICS 2 for definitions of pressure operated switches and associated terms.

production tests. Those tests that are made at the discretion of the manufacturer on some or all production units for the purpose of maintaining quality and performance.

NEMA Standard 9-15-1971.

protection, overload. See **overload protection.***

protection, undervoltage. See **undervoltage protection.**

pulse.* A signal of relatively short duration.

NEMA Standard 1-25-1961.

pushbutton station.* A unit assembly of one or more externally operable pushbutton switches, sometimes including other pilot devices such as indicating lights or selector switches, in a suitable enclosure.

NEMA Standard 8-20-1966.

rating, break. See **break rating.**

rating, continuous. See **continuous rating.***

rating, continuous periodic. See **continuous periodic rating.***

rating (controller).* An arbitrary designation of an operating limit. It is based on power governed, the duty and service required.

NEMA Standard 1-5-1977.

NOTE: A rating is arbitrary in the sense that it must necessarily be established by definite field standards and cannot, therefore, indicate the safe operating limit under all conditions that may occur. (This note is approved as Authorized Engineering Information.)

rating (device).* The designated limit(s) of the rated operating characteristic(s).

NEMA Standard 1-5-1977.

NOTE: Such operating characteristics as current, voltage, frequency, and so forth, may be given in the rating. (This note is approved as Authorized Engineering Information.)

rating, make. See **make rating.**

rating, periodic. See **periodic rating.***

rating, pilot duty. See **pilot duty rating.**

rating, short-time. See **short-time rating.***

regeneration. The transfer of rotational energy through a motor and its control equipment back to its electrical source.

NEMA Standard 5-17-1971.

relay.* An electric device that is designed to interpret input conditions in a prescribed manner and after specified conditions are met to respond to cause contact operation or similar abrupt change in associated electric control circuits.

NEMA Standard 1-5-1977.

NOTES: (A) Inputs are usually electric, but may be mechanical, thermal, or other quantities. Limit switches and similar simple devices are not relays. (B) A relay may consist of several units, each responsive to specified inputs, the combination providing the desired performance characteristics. (These notes are approved as Authorized Engineering Information.)

relay, current. See **current relay.***

relay, magnetic control. See **magnetic control relay.**

relay, overcurrent. See **overcurrent relay.***

relay, voltage. See **voltage relay.***

release time. The time between initial deenergization of the control circuit and the initial opening of a normally open contact or the initial closing of a normally closed contact.

NEMA Standard 1-5-1977.

release, undervoltage. See **undervoltage release.**

remote control. A control function that provides for initiation or change of a control function from a remote point.

NEMA Standard 9-29-1960.

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*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

repeat accuracy. A term used to express the degree of consistency of repeat operations under specified conditions.

NEMA Standard 3-17-1971.

reset. To restore a mechanism, storage, or device to a prescribed state.

NEMA Standard 5-21-1962.

reset, automatic. See **automatic reset.**

reset, manual. See **manual reset.**

reversible counter. A counter that will count either up or down.

NEMA Standard 5-21-1962.

schematic or elementary diagram. See Part 1-101.

sealing voltage or current. The voltage or current that is necessary to seat the armature of a magnetic circuit closing device from the position at which the contacts first touch each other.

NEMA Standard 10-27-1964.

semimagnetic controller.* An electric controller having only part of its basic functions performed by devices that are operated by electromagnets.

NEMA Standard 5-24-1960.

sequence diagram, control. See Part 1-101.

service of a controller. The specific application in which the controller is to be used, for example:

(1) General purpose.
(2) Definite purpose.
  (a) Crane and hoist.
  (b) Elevator.
  (c) Machine tool, and so forth.

NEMA Standard 9-26-1970.

short-time capability. The ability of electrical apparatus to operate within specified performance criteria when carrying electrical overloads of a specified current and time duration under specified conditions.

NEMA Standard 3-17-1971.

short-time rating.* Defines the load that can be carried for a short and definitely specified time, the machine, apparatus, or device being at approximately room temperature at the time the load is applied.

NEMA Standard 10-27-1944.

single-line diagram. See Part 1-101.

snap action. A rapid motion of the contacts from one position to another position, or their return. This action is relatively independent of the rate of travel of the actuator.

NEMA Standard 6-24-1957.

solid-state contactor. A contactor whose function is performed by semiconductor device(s).

NEMA Standard 7-16-1969.

starter, part-winding. See **part-winding starter.**

surface-mounted (type). Designed to be secured to and to project from a flat surface.

NEMA Standard 7-16-1969.

switch.* A device for opening and closing or for changing the connection of a circuit.

NEMA Standard 1-5-1977.

NOTE: A switch is understood to be manually operated, unless otherwise stated. (This note is approved as Authorized Engineering Information.)

switch, drum. See **drum switch.***

switch, general-use. See **general-use switch.**

switch, isolating. See **isolating switch.***

switch, motor-circuit. See motor-circuit switch.*

symbol, graphic. See Part 1-101.

system diagram, control. See Part 1-101.

temperature, ambient. See **ambient temperature.***

temperature operated controllers. See Part 2-227 of NEMA Standards Publication No. ICS 2 for definitions of temperature operated controllers and associated terms.

tests, design. See **design tests.**

tests, application. See **application tests.**

tests, production. See **production tests.**

three-wire control.* A control function that utilizes a momentary-contact pilot device and a holding-circuit contact to provide undervoltage protection.

NEMA Standard 1-15-1963.

time, dead. See **dead time.**

time, effective actuation. See **effective actuation time.**

NOTE: NEMA terms are shown indexed with associated definitions, identical to ANSI, IEEE, and IEC standards, while retaining the advantages of finding definitions through the groupings of commonly used nouns.

*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

time, inverse. See **inverse time.**

time, operate. See **operate time.**

time, release. See **release time.**

time delay.* A time interval is purposely introduced in the performance of a function.

NEMA Standard 8-13-1959.

transformer, control-circuit. See **control-circuit transformer.**

transient. That part of the variation in a variable that ultimately disappears during transition from one steady-state operating condition to another.

NEMA Standard 5-16-1963.

two-wire control.* A control function that utilizes a maintained-contact type of pilot device to provide undervoltage release.

NEMA Standard 1-15-1963.

undervoltage protection (low-voltage protection). The effect of a device, operative on the reduction or failure of voltage, to cause and maintain the interruption of power to the main circuit.

NEMA Standard 1-5-1977.

NOTE: The principal objective of this device is to prevent automatic restarting of the equipment. Undervoltage or low-voltage protection devices are usually not designed to become effective at any specific degree of voltage reduction.

Authorized Engineering Information 1-5-1977.

undervoltage release (low-voltage release). The effect of a device, operative on the reduction or failure of voltage, to cause the interruption of power to the main circuit but not to prevent the re-establishment of the main circuit on return of voltage.

NEMA Standard 1-11-1984.

NOTE: Undervoltage or low-voltage releases are generally not designed to become effective at any specific degree of voltage reduction.

Authorized Engineering Information 1-11-1984.

variable operating. See Part 3-106A of NEMA Standards Publication No. ICS 3.

ventilated enclosure.* An enclosure provided with means to permit circulation of sufficient air to remove an excess of heat, fumes, or vapors.

NEMA Standard 1-5-1977.

NOTE: For outdoor applications, ventilating openings or louvers are usually filtered, screened, or restricted to limit the entrance of dust, dirt, or other foreign objects. (This note is approved as Authorized Engineering Information.)

voltage, pick-up. See **pick-up voltage or current.**

voltage, pick-up and seal. See **pick-up and seal voltage.**

voltage, sealing. See **sealing voltage or current.**

voltage relay.* A relay that functions at a predetermined value of voltage.

NEMA Standard 5-29-1960.

NOTE: It may be an overvoltage relay, an undervoltage relay, or a combination of both. (This note is approved as Authorized Engineering Information.)

wireless connection diagram. See Part 1-101.

withstandability, fault. See **fault withstandability.**

NOTE: NEMA terms are shown indexed with associated definitions, identical to ANSI, IEEE, and IEC standards, while retaining the advantages of finding definitions through the groupings of commonly used nouns.

*Identical to ANSI/IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms.*

Part 1-101

DIAGRAMS, DEVICE DESIGNATIONS, AND SYMBOLS

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified. The definitions contained in Part 1-100 of this Standards Publication also apply to this part. Parts 1-101 and 1-101A are alternative standards for specifying diagrams, device designations, and symbols. Part 1-101A is intended to encourage harmonization with other national and international standards. ▲

1-101.1 IDENTIFICATION

Diagrams and drawings should be identified by one of the titles shown in 1-101.2 or by a combination of titles from 1-101.2 and 1-101.3, where applicable, but not solely by the titles given in 1-101.3.

NEMA Standard 5-17-1965.

1-101.2 TYPES OF DIAGRAMS AND DRAWINGS

1-101.2.1 Process Diagram or Flow Diagram

A process or flow diagram is a conceptual diagram of the functional interrelationship of subsystems in block or pictorial form. Process equipment such as machinery is shown for proper understanding.

1-101.2.2 Control System Diagram

A control system diagram is a conceptual diagram of the functional interrelationship of subsystems, usually in block form. It does not include the process equipment or details of circuits and device elements.

1-101.2.3 Schematic Diagram or Elementary Diagram

A schematic or elementary diagram is one which shows all circuits and device elements of an equipment and its associated apparatus or any clearly defined functional portion thereof. Such a diagram emphasizes the device elements of a circuit and their functions as distinguished from the physical arrangement of the conductors, devices or elements of a circuit system.

Circuits which function in a definite sequence should be arranged to indicate that sequence.

1-101.2.4 Control Sequence Diagram and Table

A control sequence diagram or table is a portrayal of the contact positions or connections which are made for each successive step of the control action.

1-101.2.5 Wiring Diagram or Connection Diagram

A wiring or connection diagram is one which locates and identifies electrical devices, terminals, and interconnecting wiring in an assembly. This diagram shall be (1) in a form showing interconnecting wiring by lines or indicating interconnecting wiring only by terminal designations (wireless diagram), or (2) a panel layout diagram showing the physical location of devices plus:

(a) The elementary diagram, or
(b) A wiring table, or
(c) A computer wiring chart, or
(d) A machine command tape or cards.

The term does not include mechanical drawings, commonly referred to as wiring templates, wiring assemblies, cable assemblies, etc.

1-101.2.6 Interconnecting Diagram

An interconnection diagram is one which shows only the external connections between controllers and associated machinery and equipment.

1-101.2.7 Dimension or Outline Drawing

A dimension or outline drawing (base plan, floor plan, and so forth) is one which shows the physical space and mounting requirements of a piece of equipment. It shall be permitted to also indicate ventilation requirements and space provided for connections or the location to which connections are to be made.

1-101.2.8 Construction Diagram*

A diagram that shows the physical arrangement of parts, such as wiring, buses, resistor units, and so forth. Example: A diagram showing the arrangement of grids and terminals in a grid-type resistor.

1-101.2.9 Controller Diagram*

A diagram that shows the electrical connections between the parts comprising the controller and that shows the external connections.

1-101.2.10 Illustrative Diagram*

A diagram whose principal purpose is to show the operating principle of a device or group of devices without necessarily showing actual connections or circuits. Illustrative diagrams may use pictures or symbols to illustrate or represent devices or their elements. Illustrative diagrams may be made of electric, hydraulic, pneumatic, and combination systems. They are applicable chiefly to instruction books, descriptive folders, or other media whose purpose is to explain or instruct.

* Definition from ANSI/IEEE Std 100.
▲Revised 7-11-1984.

1-101.2.11 Wireless Connection Diagram*

The general physical arrangement of devices in a control equipment and connections between these devices, terminals, and terminal boards for outgoing connections to external apparatus. Connections are shown in tabular form and not by lines. An elementary (or schematic) diagram may be included in the connection diagram.

NEMA Standard 9-15-1971.

1-101.2.12 Other Drawings

There may be additional drawings, such as conduit layout drawings, foundation drawings, and so forth.

Authorized Engineering Information 9-15-1971.

1-101.3 FORMS OF DIAGRAMS

Diagrams shall be permitted to take one or a combination of the following forms.

1-101.3.1 Block Diagram

A block diagram is made up of a group of interconnected blocks, each of which represents a device or subsystem.

1-101.3.2 One-Line Diagram (Single-Line)

A one-line or single-line diagram is one which shows, by means of single lines and graphic symbols, the course of an electrical circuit or circuits and the component devices or parts used therein. Physical relationships are usually disregarded.

1-101.3.3 Logic Diagram

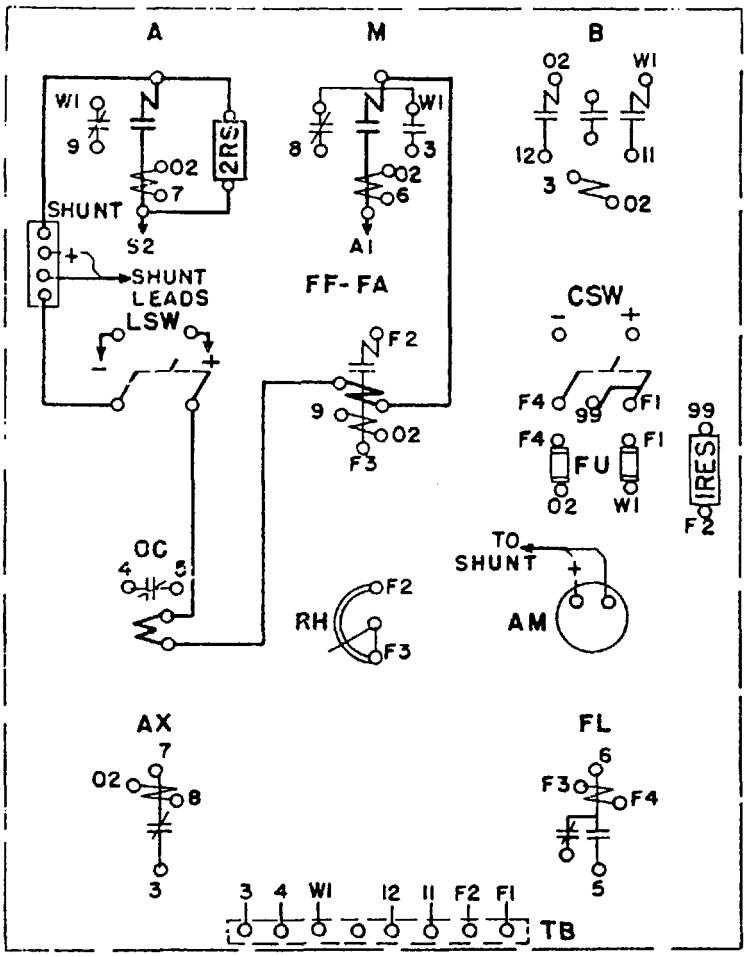
A logic diagram is a particular form of one-line or single-line diagram of a logic circuit using logic symbols.

NEMA Standard 9-21-1966.

1-101.4 WIRELESS CONNECTION DIAGRAMS

1-101.4.1 Symbols

Symbols for the devices shown in connection diagrams shall be in accordance with 1-101.8. Detailed device symbols shall be made up to represent the physical arrangement of the main component parts and of the terminals to which connections are made.



WIRE TABLE		
WIRE	CONNECT TO	
+		LSW, CSW
−		LSW, CSW
F1	TB	CSW, FU
F2	TB	IRES, RH, FF-FA
F3		FF-FA, RH, FL
F4		FL, CSW, FU
02		FU, M, A, AX, FF-FA, B
WI	TB	FU, M, A, B
3	TB	M, AX, B
4	TB	OC
5		OC, FL
6		FL, M
7		A, AX
8		M, AX
9		A, FF-FA
11	TB	B
12	TB	B
99		IRES, CSW

Figure 1-101-1
WIRELESS CONNECTION DIAGRAMS

*Definition from ANSI/IEEE Std 100.

1-101.4.2 Physical Arrangement

The physical arrangement of devices in the connection diagram shall correspond to the physical arrangement of the equipment. Physical groupings comprising control panel sections, auxiliary panels, subpanels, overhead racks, resistor compartments and the like shall be so indicated and marked. See Figure 1-101-1 for wireless connection diagram.

1-101.4.3 Device Designations

Each device in an equipment to which a connection is made shall be assigned a device designation which shall be in accordance with 1-101.5. These designations shall be distinct and there shall be no duplication of designations for the devices in any connection diagram. All designations shall correspond to those used in the elementary diagram.

1-101.4.4 Terminal Markings

Each terminal of a device to which a connection is to be made shall be assigned a distinct terminal marking. This marking shall correspond to the one used in the elementary diagram for designating the same circuit.

1-101.4.5 Control Circuit Connections

Control circuit connections shall be listed in the form of a panel wire table which shall consist of a single continuous column. This table shall list the circuit (terminal) numbers in numerical or alphabetical order, or both. Opposite each circuit (terminal) number shall be listed the designations of the devices to which the circuit will be connected. Short connections between terminals of the same device or between points on a terminal board are sometimes drawn as lines.

1-101.4.6 Power Circuit Connections

Power circuit connections shall be drawn completely by lines or shall be included in the panel wire table.

NEMA Standard 11-12-1953.

1-101.5 DEVICE DESIGNATIONS

Device designations are intended for use on diagrams in connection with graphic symbols to indicate the function of the particular device. Device designations are based on the assignment of a letter or letters to each of the fundamental functions performed by the component devices of a complete control equipment. Suitable prefix numbers or letters, or both, and suffix letters shall be permitted to be added to the basic device designations to discriminate between devices performing similar functions. When two or more basic device designations are combined, the function designation is normally given first. For example, the first control relay initiating a jog function is designated "1JCR."

Table 1-101-1
DEVICE DESIGNATIONS

Device or Function	Designation
Accelerating	A
Ammeter	AM
Braking	B
Capacitor, capacitance	C or CAP
Circuit breaker	CB
Control relay	CR
Current transformer	CT
Demand meter	DM
Diode	D
Disconnect switch	DS or DISC
Dynamic braking	DB
Field accelerating	FA
Field contactor	FC
Field decelerating	FD
Field-loss	FL
Forward	F or FWD
Frequency meter	FM
Fuse	FU
Ground protective	GP
Hoist	H
Jog	J
Limit switch	LS
Lower	L
Main contactor	M
Master control relay	MCR
Master switch	MS
Overcurrent	OC
Overload	OL
Overvoltage	OV
Plugging or potentiometer	P
Power factor meter	PFM
Pressure switch	PS
Pushbutton	PB
Reactor, reactance	X
Rectifier	REC
Resistor, resistance	R or RES
Reverse	REV
Rheostat	RH
Selector switch	SS
Silicon controlled rectifier	SCR
Solenoid valve	SV
Squirrel cage	SC
Starting contactor	S
Suppressor	SU
Tachometer generator	TACH
Terminal block or board	TB
Time-delay relay	TR
Transformer	T
Transistor	Q
Undervoltage	UV
Voltmeter	VM
Watthour meter	WHM
Wattmeter	WM

NEMA Standard 9-4-1969.

Device designations are given in alphabetical order in Table 1-101-1.

Where alternate designations are shown, care shall be taken not to use the same designation for different kinds of devices on the same drawing.

NEMA Standard 9-21-1966.

1-101.6 COIL AND CONTACT DESIGNATIONS

Table 1-101-2 shows the designations used to identify the functions of coils and contacts on complex devices. They are not a part of the device designation. If used in connection with a device designation, the two designations shall be separated by a hyphen, parenthesis, or other suitable means.

NEMA Standard 9-21-1966.

Table 1-101-2
COIL AND CONTACT DESIGNATIONS

Function	Designation
Closing coil	CC
Holding coil	HC
Latch coil	LC
Time-delay closing contacts	TC or TDC
Time-delay opening contacts	TO or TDO
Trip coil	TC
Unlatch coil	ULC

1-101.7 PREFIX NUMBERS

Prefix numbers are used with device designations to distinguish two or more devices having the same function. These numbers are assigned in an orderly fashion in agreement with the order of the relaying or switching or functional sequence, if possible.

NEMA Standard 9-21-1966.

1-101.8 GRAPHIC SYMBOLS

1-101.8.1 Definition

Graphic symbols are a shorthand means of showing graphically the function or interconnections of a circuit. They are used on schematic, one-line, or wiring diagrams. Graphic symbols are correlated with parts lists, descriptions, or instructions by means of device designations. See Table 1-101-3.

1-101.8.2 Symbol Principles

(a) The graphic symbols given in Table 1-101-3 are in general use on industrial control diagrams. Symbols not readily recognizable have been excluded. Other symbols shall be permitted to be used on industrial control diagrams provided a suitable explanation is given as to their meaning.

(b) The orientation of a symbol on a drawing, including a mirror image presentation, does not alter the meaning of the symbol.

(c) The width of a line does not affect the meaning of the symbol. A wider line shall be permitted to be used for emphasis or for power wiring in contrast to control wiring.

(d) The symbols shown in Table 1-101-3 are in their correct relative size; they were prepared on a 1/10-inch grid basis. A symbol shall be permitted to be drawn to any proportional size that suits a particular drawing, depending on the reduction or enlargement anticipated.

(e) When polarity marks are used, the sign + is positive and the − sign is negative.

(f) The arrowhead or triangle of a symbol shall be permitted to be closed, $\rightarrow$, or open, $\rightarrow$, unless noted.

(g) The symbol for a terminal (o) shall be permitted to be added to each point of attachment of conductors to any one of the symbols, but such added terminal symbols shall not be considered to be a part of the individual graphic symbol itself. The use of terminal symbols on all diagrams is optional. DO NOT SHOW TERMINALS ON ELEMENTARY DIAGRAMS UNLESS THOSE TERMINALS ARE ACCESSIBLE TO THE CUSTOMER!

(h) On a schematic diagram, parts of a symbol for a device, such as a relay or contactor, electron tube or transformer, shall be permitted to be separated. Each of the parts of the device then must carry the same designation.

(i) In general, the angle at which a connecting line is brought to a symbol has no particular significance unless otherwise noted.

(j) Associated or future paths and equipment shall be shown by lines composed of short dashes, - - - - - - - -

(k) An enclosure of a device or panel outline shall be permitted to be shown on a wiring or interconnection diagram as a solid line or a series of long dashes.

(m) A pictorial representation shall be permitted to be used as an alternate for any of the wiring and interconnection diagram symbols shown in this standard.

NEMA Standard 9-20-1972.

1-101.8.3 Uniformly Shaped Symbols

Rather than create new distinctively shaped symbols for new devices, a uniformly shaped symbol shall be used. The uniformly shaped symbol shall also be permitted to be used as an alternate for any distinctively shaped symbol shown in this standard. The uniformly shalped symbol is a rectangle, properly labled at the top to designate the type of device it represents and at the bottom to identify the device in a particular circuit. Terminal identification shall be immediately outside the rectangle.

NEMA Standard 5-25-1988.

Examples to illustrate the use of uniformly shaped symbols are shown in Figure 1-101-2.

Authorized Engineering Information 9-20-1972.

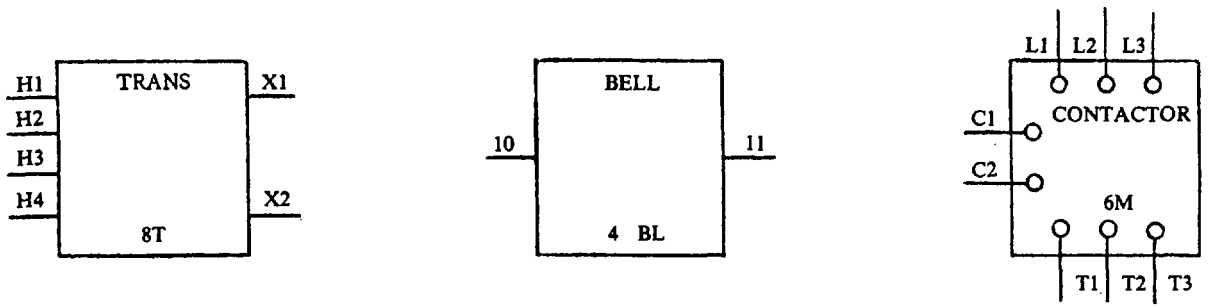


Figure 1-101-2
UNIFORMLY SHAPED SYMBOLS

1-101.8.4 Organization of Symbols

The symbols shown in Table 1-101-3 are given in alphabetical order and are in general agreement with ANSI Y32.2.

Examples identified with an asterisk have been approved as Authorized Engineering Information and not as NEMA Standards. The wiring diagram symbol for each such device will consist of the basic NEMA Standard symbols arranged to represent the particular device and will vary with the manufacturer.

NEMA Standard 9-20-1972.

When more than one symbol is shown, the first one shown is preferred. The symbols, arranged in two columns from left to right, are:

(a) For use on schematic or elementary diagrams.
(b) For use on wiring or interconnection diagrams.

Authorized Engineering Information 9-20-1972.

1-101.9 TERMINAL MARKINGS

Terminal markings used on connection diagrams for designating connections shall conform to those shown in the applicable standards of NEMA Standards Publication No. ICS 2.

NEMA Standard 11-15-1979.

1-101.10 STATIC ELEMENTS OR DEVICES

A diamond surrounding a symbol indicates a semiconductor device which has the same function as the electromechanical device represented by the symbol without the diamond.

NEMA Standard 9-20-1973.

These symbols are intended primarily for use on control circuit diagrams along with electromechanical devices.

It is recommended that, when the diamond is used for this purpose, an explanation of its meaning be stated on the diagram.

A uniformly shaped symbol with a description or a complete circuit of the device may be used if preferred.

Authorized Engineering Information 9-20-1973.

Table 1-101-3
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
AC MACHINE See "Induction Machine" and "Wound Rotor Induction Motor."	
ADJUSTABILITY General	
	none
AIR CIRCUIT BREAKER See "Circuit Breaker."	
AIR CORE If it is necessary to identify an air core, add a note adjacent to the symbol of the inductor or transformer.	
AMPLIFIER	
†	†
AMPLIFIER, ROTATING See "Armature with Commutator and Brushes," "Armature, Rotary Amplifier with Shorted Brushes," and "Machine, Rotating."	
ANODE OR PLATE	
	none

† Use uniformly shaped symbol. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

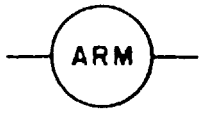
Elementary or Schematic Diagram	Connection or Interconnection Diagram

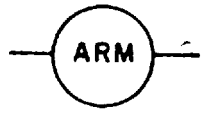
ANNUNCIATOR



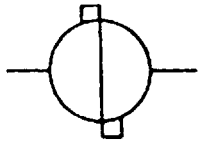
†

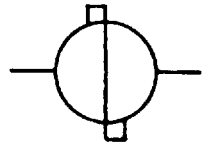
ARMATURE WITH COMMUTATOR AND BRUSHES





ARMATURE, ROTARY AMPLIFIER WITH SHORTED BRUSHES



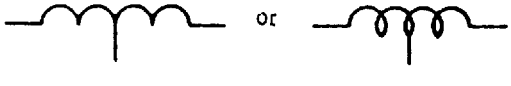


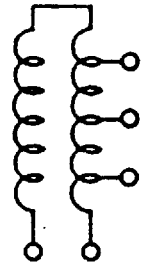
ARRESTER, LIGHTNING
See also "Gap, Protective."





AUTOTRANSFORMER





Example *

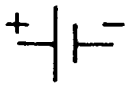
* Example only; approved as Authorized Engineering Information. See 1-101.8.
† Use uniformly shaped symbol. See 1-101.8.

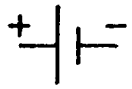
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Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

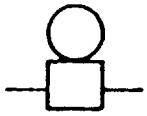
Elementary or Schematic Diagram	Connection or Interconnection Diagram

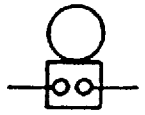
BATTERY
The long line is always positive, but polarity may be indicated in addition.





BELL





BLOWOUT COIL





BRAKE COIL





BREAKER
See "Circuit Breaker."

BRIDGE RECTIFIER
See "Rectifier."

BUZZER





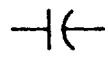
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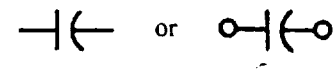
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

CABLE
See "Conductor."

CAPACITOR
If it is necessary to identify capacitor electrodes, have the curved element represent the outside electrode in fixed paper and ceramic capacitors, the moving element in adjustable and variable capacitors, and the low-potential element in feed-through capacitors.





CAPACITOR, POLARIZED
Show polarity of leads, + and/or −.
+ on straight side, − on curved side.

CATHODE

CATHODE—COLD, INCLUDING IONICALLY HEATED CATHODE



none

CATHODE, DIRECTLY HEATED (FILAMENTARY)



none

CATHODE, INDIRECTLY HEATED



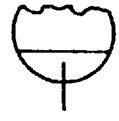
none

CATHODE, PHOTOCATHODE



none

CATHODE, POOL



none

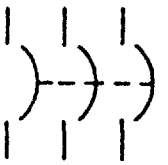
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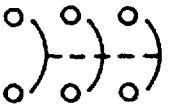
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

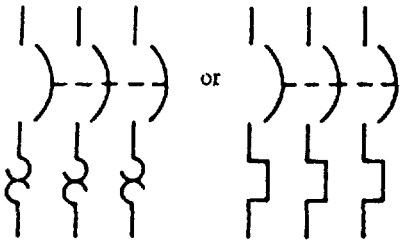
CELL
See "Battery."

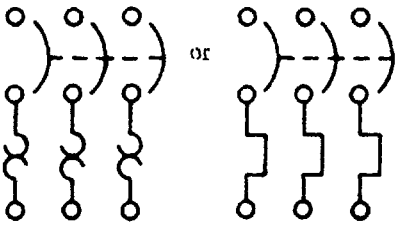
CIRCUIT BREAKER, 3 POLE NONAUTOMATIC
(Without trip units.)



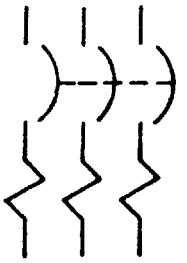


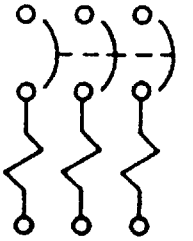
CIRCUIT BREAKER, 3 POLE WITH THERMAL OR THERMOMAGNETIC TRIP UNITS





CIRCUIT BREAKER, 3 POLE WITH ONLY MAGNETIC TRIP UNITS





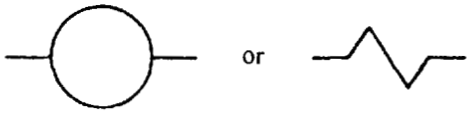
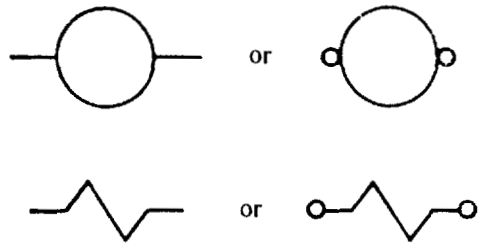
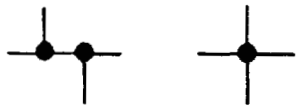
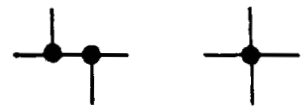
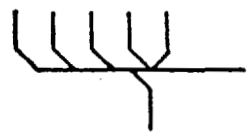
CLOCKWISE ROTATION
See "Motion, Mechanical—Rotation One Direction."

CLUTCH
See "Coil, Operating."

COIL, BLOWOUT
See "Blowout Coil."

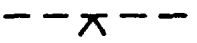
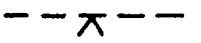
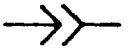
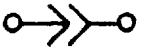
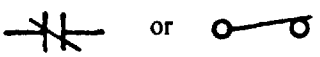
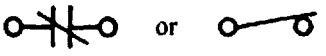
(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
COIL, OPERATING	
	
CONDUCTOR, OR CONDUCTIVE PATH	
CONDUCTOR, CROSSING OF PATHS OR CONDUCTORS NOT CONNECTED	
	
CONDUCTOR, JUNCTION OF CONNECTED PATHS, CONDUCTORS OR WIRES	
	
CONDUCTOR, MULTICONDUCTOR CABLE The bend of the line indicates the direction the conductor continues within the cable.	
none	
CONDUCTOR, SHIELDED SINGLE OR MULTICONDUCTOR Shield may be grounded.	
	
CONDUCTOR, ASSOCIATED OR FUTURE	

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
CONNECTION, MECHANICAL	
CONNECTION, MECHANICAL WITH INTERLOCK	
	
CONNECTOR, DISCONNECTING DEVICE The connector symbol is not an arrowhead. It is larger and the lines are drawn at a 90° angle.	
CONNECTOR, FEMALE	
	
CONNECTOR, MALE	
	
CONNECTOR, SEPARABLE OR JACKS ENGAGED	
	
CONTACT, BASIC ASSEMBLIES Show a contact by a symbol indicating the circuit condition it produces when the actuating device is in the deenergized or nonoperated position. The actuating device may be of any nature, and a note may be necessary with the symbol to explain the proper point at which the contact functions, for example, the point where a contact closes or opens as a function of changing pressure, level, flow, voltage, current, etc. Where it is desirable to show contacts in the energized condition or where confusion may result, add a note.	
CONTACT, NORMALLY CLOSED—BREAK	
	

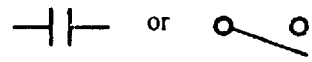
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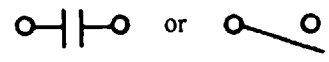
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

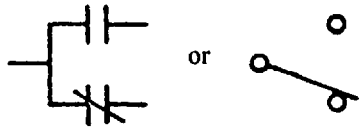
CONTACT, BASIC ASSEMBLIES (Continued)

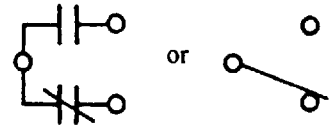
CONTACT, NORMALLY OPEN—MAKE





CONTACT, TRANSFER

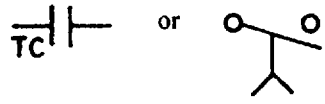


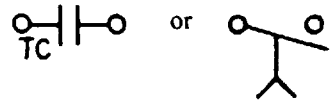


CONTACT, TIME DELAY

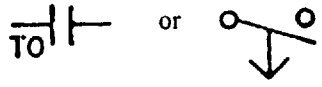
The point of the arrow indicates the direction of switch operation in which contact action is delayed. See also 1-101.6 Time-delay closing contacts and Time-delay opening contacts.

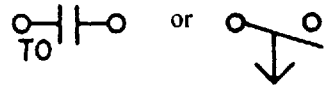
NORMALLY OPEN WITH TIME DELAY CLOSING (TC)



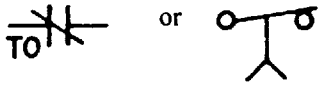


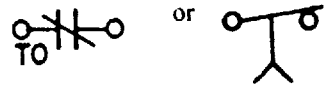
NORMALLY OPEN WITH TIME DELAY OPENING (TO)



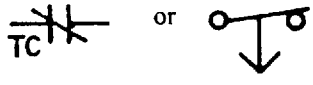


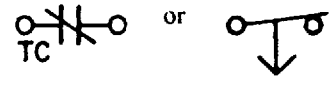
NORMALLY CLOSED WITH TIME DELAY OPENING (TO)



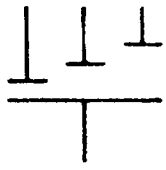


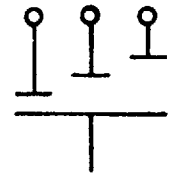
NORMALLY CLOSED WITH TIME DELAY CLOSING (TDC) OR (TC)





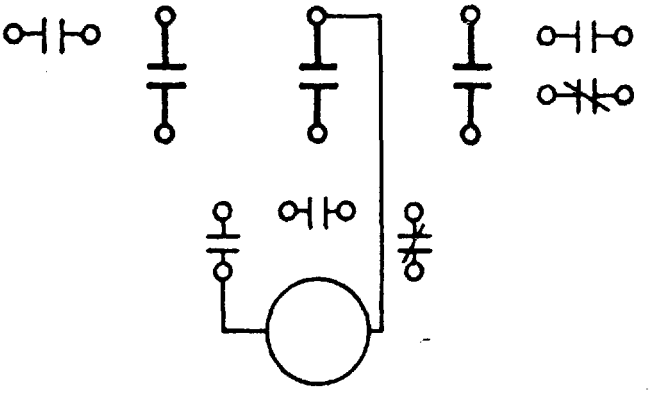
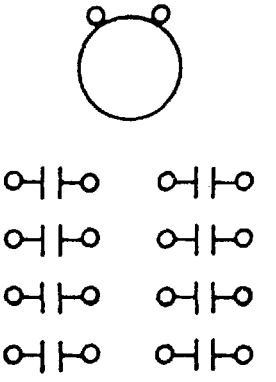
CONTACT, TIME SEQUENTIAL CLOSING





(Continued)

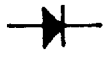
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
CONTACTOR, WITH INTERLOCKS See 1-101.8.2(h).	 Example*
CONTROL RELAY See 1-101.8.2(h).	 Example*
CONTROL TRANSFORMER See "Transformer, General."	
CONTROL TRANSMITTER See "Synchro."	
CORE, MAGNETIC See "Transformer, With Magnetic Core."	

*Example only; approved as Authorized Engineering Information. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
CURRENT TRANSFORMER See "Transformer, Current."	
DC MACHINES See "Armature," "Field," and "Machine, Rotating."	
DC SOURCE See "Battery."	
DIFFERENTIAL RECEIVER TRANSMITTER See "Synchro."	
DIODE, SEMICONDUCTOR 	‡
DIODE, TUNNEL 	‡
DIODE, UNIDIRECTIONAL BREAKDOWN (ZENER) 	‡
DIODE, BIDIRECTIONAL BREAKDOWN 	‡
DISCONNECT SWITCH See "Switch, Single Throw."	

‡ Use pictorial representation. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

DRUM SWITCH

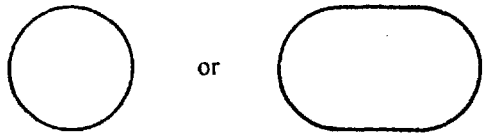
See "Switch, Drum Switch, Sliding Contact Type."

ELECTRON TUBE COMPONENTS

See "Anode or Plate," "Cathode," "Envelope," "Grid, Including Beam-confining or Beam-forming Electrodes," "Semiconductor Device," "Triode", "Pentrode, Equipotential Cathode," and "Rectifier, General."

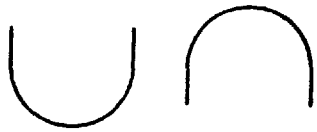
ENVELOPE

The envelope symbol indicates a vacuum enclosure, unless otherwise specified. A gas filled device is indicated by a dot within the envelope.



none

ENVELOPE, SPLIT



none

FIELD

See also "Winding."

FIELD, COMPENSATING OR COMMUTATING





FIELD, SERIES





FIELD, SHUNT OR SEPARATELY EXCITED





(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

FLOW-ACTUATED SWITCH
See "Switch, Flow Actuated."

FLUORESCENT LAMP
See "Light, Illuminating, Fluorescent."

FOOT-OPERATED SWITCH
See "Switch, Foot Operated."

FUSE

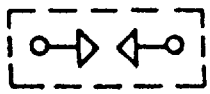






GAP, PROTECTIVE
See also "Arrester, Lightning." These triangles shall not be filled.





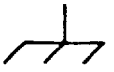
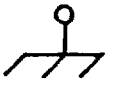
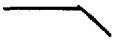
GENERATOR
See "Armature with Commutator and Brushes," and "Field."

GENERATOR FIELD
See "Field."

GRID, INCLUDING BEAM-CONFINING OR BEAM-FORMING ELECTRODES

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
GROUND, CHASSIS OR FRAME	
A CHASSIS, BUS, OR FRAME CONNECTION WHICH IS INTENDED TO BE AT EARTH POTENTIAL	
	
A CHASSIS, BUS, OR FRAME CONNECTION WHICH MAY BE AT A SUBSTANTIAL POTENTIAL WITH RESPECT TO THE EARTH OR STRUCTURE IN WHICH IT IS MOUNTED.	
	
HEATER, ELECTRON TUBE	
	none
HORN	
	‡
IGNITOR, POOL TUBE Should extend into pool.	
	none
INDICATING LAMP See "Light, Indicating" and "Light, Indicating, Push-to-test."	

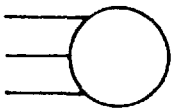
‡ Use pictorial representation. See 1-101.8.

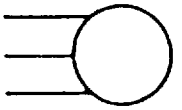
(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

INDUCTION MACHINE, SQUIRREL-CAGE INDUCTION MOTOR OR GENERATOR





INDUCTOR
See "Winding."

INSTRUMENT (METER)
See "Meter (Instrument)."

INSTRUMENT SHUNT
See "Shunt, Instrument or Relay."

INTERLOCK, MECHANICAL
See "Connection, Mechanical With Interlock."

KNIFE, SWITCH
See "Switch, Knife."

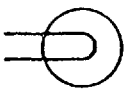
LIGHT OR LAMP

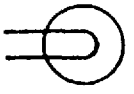
LIGHT, ILLUMINATING, FLUORESCENT





LIGHT, ILLUMINATING, INCANDESCENT





(Continued)

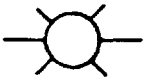
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

LIGHT OR LAMP (Continued)

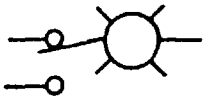
LIGHT, INDICATING
(Pilot, Signalling, or Switchboard.) To indicate characteristic, insert the specified letter or letters inside the symbol.

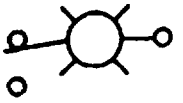
A —Amber	O —Orange
B —Blue	OP—Opalescent
C —Clear	P —Purple
G —Green	R —Red
NE—Neon	W —White
	Y —Yellow





LIGHT, INDICATING, PUSH-TO-TEST





LIGHTNING ARRESTER
See "Arrester, Lightning."

LIMIT SWITCH
See "Switch, Limit."

LIQUID LEVEL SWITCH
See "Switch, Liquid Level Actuated (Float)."

MACHINE, ROTATING
See "Induction Machine, Squirrel-cage Induction Motor or Generator," "Wound-rotor Induction Motor or Induction Frequency Converter," "Armature with Commutator and Brushes" and "Field."

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

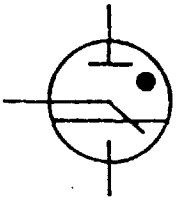
MAGNETIC CORE OF INDUCTOR OR TRANSFORMER
See "Transformer, With Magnetic Core."

MAGNET, PERMANENT
See "Permanent Magnet."

MASTER, SWITCH
See "Switch, Master or Control."

MECHANICAL INTERLOCK
See "Connection, Mechanical With Interlock."

MERCURY-POOL TUBE
Single Anode Vapor Rectifier with Ignitor. See also "Rectifier, Pool-type Cathode."

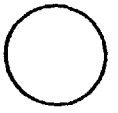


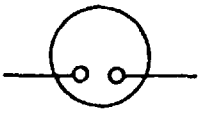
‡

METER (INSTRUMENT)
To indicate the function of the meter or instrument, place the specified letter or letters within the symbol.

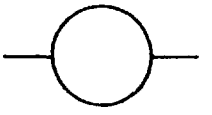
AM—Ammeter	V —Voltmeter
AH—Ampere-Hour	VA —Volt-Ammeter
μA —Microammeter	VAR —Varmeter
mA —Millammeter	VARH—Varhour Meter
PF —Power Factor	W —Wattmeter
	WH —Watthour Meter

For other functions, use adequate description.





or



‡ Use pictorial representation. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

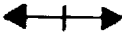
MOTION, MECHANICAL

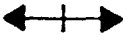
TRANSLATION, ONE DIRECTION





TRANSLATION, BOTH DIRECTIONS





ROTATION, ONE DIRECTION





ROTATION, BOTH DIRECTIONS



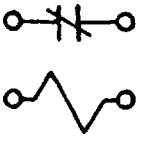


MOTOR
See "Induction Machine, Squirrel-cage Induction Motor or Generator," "Wound-rotor Induction Motor or Induction Frequency Converter," "Armature with Commutator and Brushes," and "Field."

MOTOR FIELD
See "Field."

OVERLOAD RELAY

OVERLOAD RELAY, MAGNETIC
See "Coil, Operating" and "Contact, Normally Closed—Break."

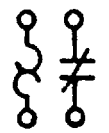
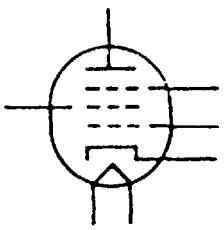
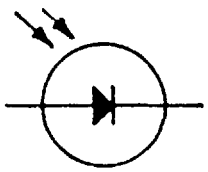
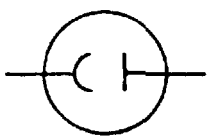


Example*

* Example only; approved as Authorized Engineering Information. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
OVERLOAD RELAY (Continued)	
OVERLOAD RELAY, THERMAL See "Thermal Element Actuating Device" and "Contact, Normally Closed—Break."	 Example*
PENTODE, EQUIPOTENTIAL CATHODE	
	Use appropriate tube socket symbol and tube type number; see "Tube Socket."
PERMANENT MAGNET	PM or PM —
PHOTOSENSITIVE CELL, SEMICONDUCTOR	
	
PHOTOTUBE, SINGLE UNIT, VACUUM TYPE	
	Use appropriate tube socket symbol and tube type number; see "Tube Socket."

* Example only; approved as Authorized Engineering Information. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

PILOT LIGHT
See "Light, Indicating" and "Light, Indicating, Push-to-test."

PLATE
See "Anode or Plate."

PLUG
See "Connector, Disconnecting Device."

POLARIZED CAPACITOR
See "Capacitor, Polarized."

POLARIZING MARKS
See "Transformer, Current," "Transformer, Potential" and item 2(e) of 1-101.8.

POTENTIOMETER
See "Resistor, Adjustable" and "Resistor, Adjustable With a Section Having Negligible Resistance."

PRESSURE OPERATED SWITCH
See "Switch, Pressure or Vacuum Operated."

PUSHBUTTON
See "Switch, Pushbutton."

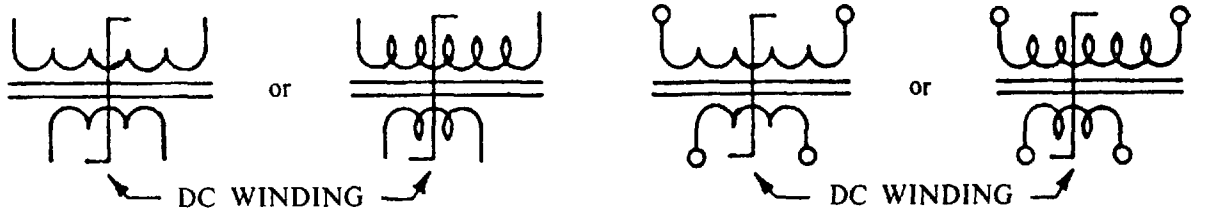
(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

REACTOR
See "Winding."

REACTOR, SATURABLE CORE
Polarity may be added to direct current winding.



RECEIVER, SYNCHRO
See "Synchro."

RECEPTACLE
See "Connector, Disconnecting Device."

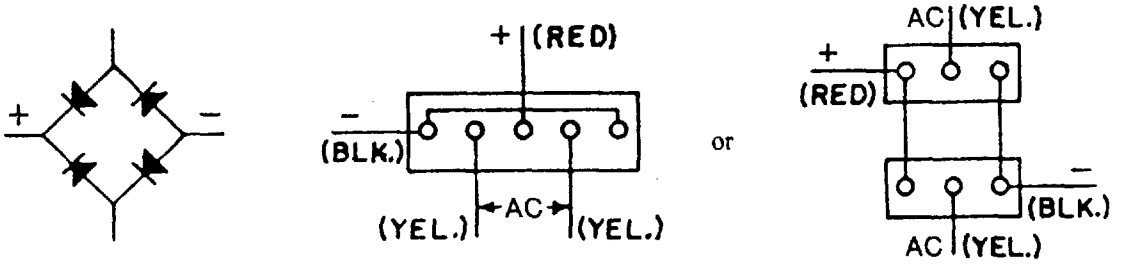
RECTIFIER, GENERAL
Triangle points in direction of forward current as indicated by a dc ammeter. Electron flow is in the opposite direction.

RECTIFIER, SEMICONDUCTOR DIODE, METALLIC OR ELECTROLYTIC
See "Diode, Semiconductor."



‡

RECTIFIER
Application: Full Wave Bridge-type.



Example*

* Example only; approved as Authorized Engineering Information. See 1-101.8.
‡ Use pictorial representation. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

RECTIFIER, GENERAL (Continued)

RECTIFIER, POOL-TYPE CATHODE
See "Mercury-pool Tube."

RECTIFIER, SILICON CONTROLLED
(Thyristor)

P-type Gate  ‡

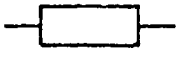
N-type Gate  ‡

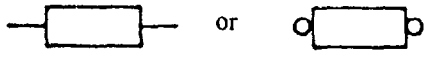
REGULATING GENERATOR
See "Armature, Rotary Amplifier With Shorted Brushes."

RELAY
See "Control Relay" and "Static Relay." For stepping relay use "Switch, Stepping."

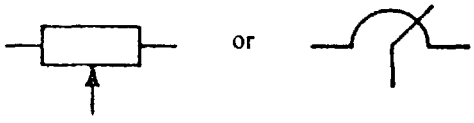
RELAY COIL
See "Coil, Operating."

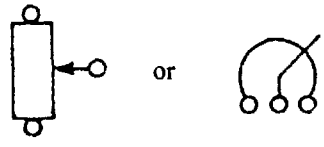
RESISTOR GENERAL





RESISTOR, ADJUSTABLE
On elementary diagrams, use arrows or descriptive terms to show change in function.





‡ Use pictorial representation. See 1-101.8.

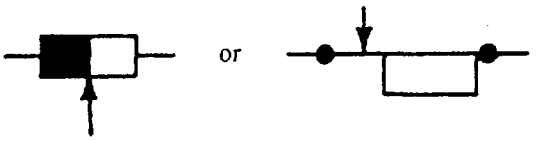
(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

RESISTOR, GENERAL (Continued)

RESISTOR, ADJUSTABLE WITH A SECTION HAVING NEGLIGIBLE RESISTANCE
Open area is resistance. The remaining portion has negligible resistance.



‡

RESISTOR, TAPPED



RHEOSTAT
See "Resistor, Adjustable."

SELECTOR SWITCH
See "Switch, Selector."

SELECTOR PUSHBUTTON
See "Switch—With Pushbutton Type Contact Mechanism" and "Switch—Selector Pushbutton."

SEMICONDUCTOR DEVICE
See "Diode, Semiconductor," "Rectifier, General" and "Transistor."

‡ Use pictorial representation. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

SERIES FIELD
See "Field, Series."

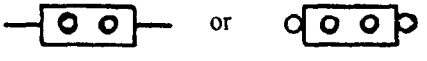
SHIELD, SHIELDING
Used for electrical or magnetic shielding. See "Conductor, Shielded Single or Multiconductor."





SHUNT, INSTRUMENT OR RELAY
Terminals in the rectangle are for the connection of instrument or relay.





SHUNT FIELD
See "Field, Shunt or Separately Excited."

SILICON CONTROLLED RECTIFIER
See "Rectifier, Silicon Controlled."

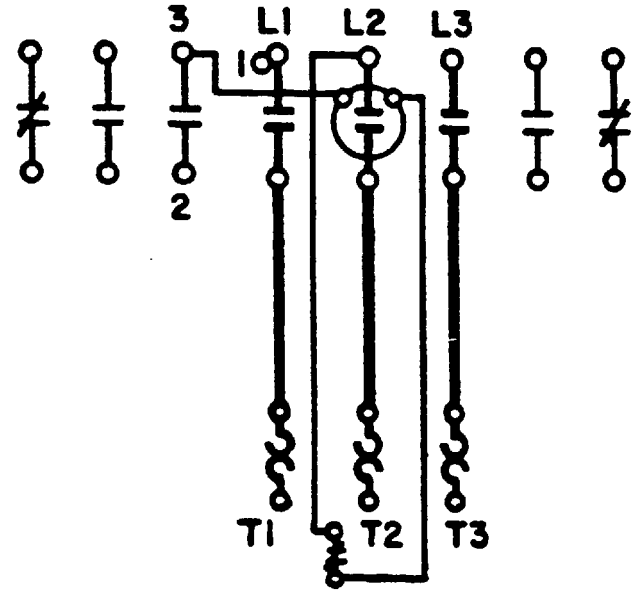
SPEED OPERATED SWITCH
See "Switch, Speed Responsive."

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

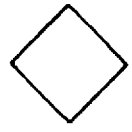
STARTER, WITH INTERLOCKS (EXAMPLE)

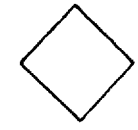


Example* ▲

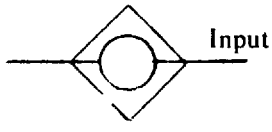
STATIC ELEMENTS OR DEVICES (See 1-101.10)

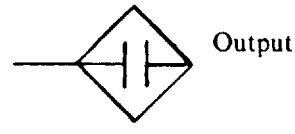
Any circuit symbol enclosed in a diamond denotes a static element or device.

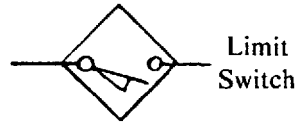




Examples







* Example only; approved as Authorized Engineering Information. See 1-101.8.
▲Revised 7-11-1984.

(*Continued*)

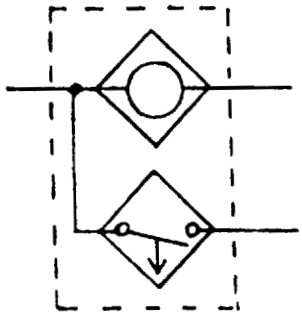
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

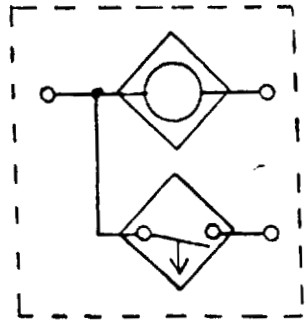
Elementary or Schematic Diagram	Connection or Interconnection Diagram

STATIC ELEMENTS OR DEVICES (Continued)

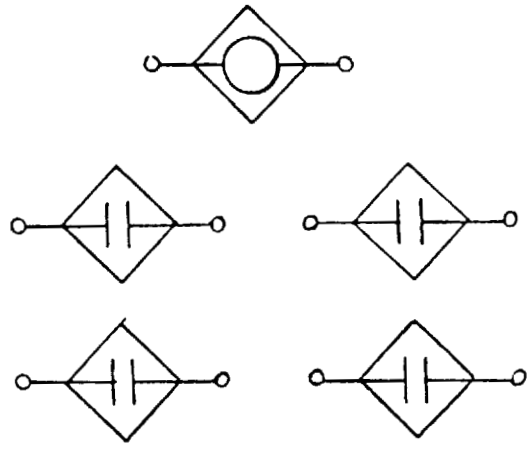
When the input(s) and output(s) of static devices are not isolated, enclose complete device in a box. Show connection between input and output.

Examples



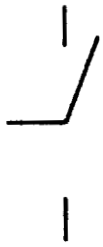


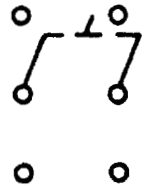
STATIC RELAY



SWITCH
See also "Contact—Basic Assemblies."

SWITCH, DOUBLE THROW





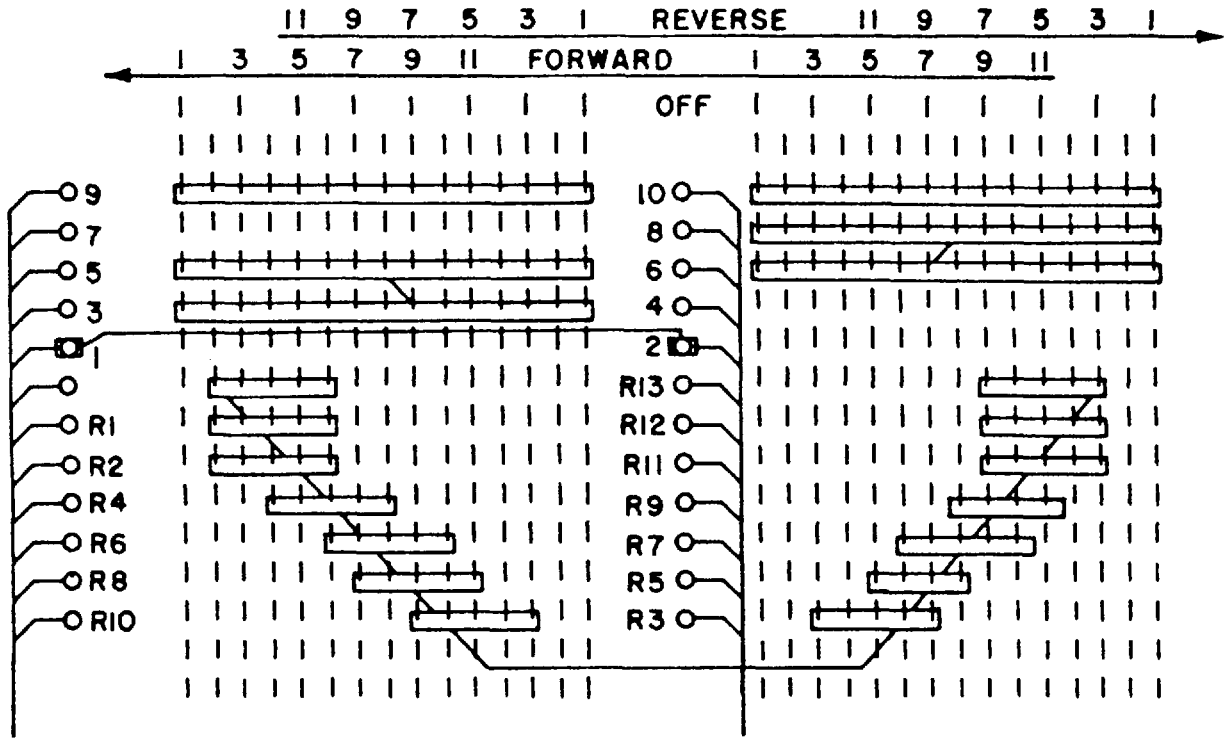
(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

SWITCH (Continued)

SWITCH, DRUM SWITCH, SLIDING CONTACT TYPE
Open rectangles are sliding contact segments.



Example*

On elementary diagram, sections of the switch may be separated. Show position indications for each section.

On interconnection diagram, a uniformly shaped symbol may be used omitting segment details.

SWITCH, FLOW ACTUATED

CLOSING ON INCREASE IN FLOW



OPENING ON INCREASE IN FLOW



* Example only; approved as Authorized Engineering Information. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

SWITCH (Continued)

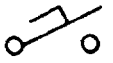
SWITCH, FOOT OPERATED

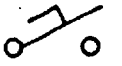
OPENED BY FOOT PRESSURE





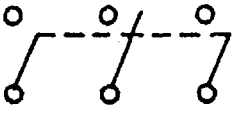
CLOSE BY FOOT PRESSURE



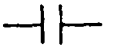
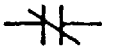


SWITCH, KNIFE





SWITCH, LIMIT

As option to symbols shown below use labeled "____LS" and describe function.  or 

NORMALLY OPEN





NORMALLY OPEN, HELD CLOSED





NORMALLY CLOSED





NORMALLY CLOSED, HELD OPEN





(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

SWITCH (Continued)

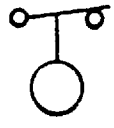
SWITCH, LIQUID LEVEL ACTUATED (FLOAT)

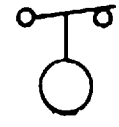
CLOSING ON RISING LEVEL





OPENING ON RISING LEVEL





SWITCH, MASTER OR CONTROL

Show a table of contact operation on the elementary diagram. A typical table is shown below.

CONTACT	INDICATOR POSITION		
	A	B	C
1 – 2			X
3 – 4	X		
5 – 6			X
7 – 8	X		
X- INDICATES CONTACTS CLOSED			

HANDLE END

20	01
40	03
60	05
80	07

Example*

Show detached contacts (see "Contact, Basic Assemblies") elsewhere on diagram.

* Example only; approved as Authorized Engineering Information. See 1-101,8.

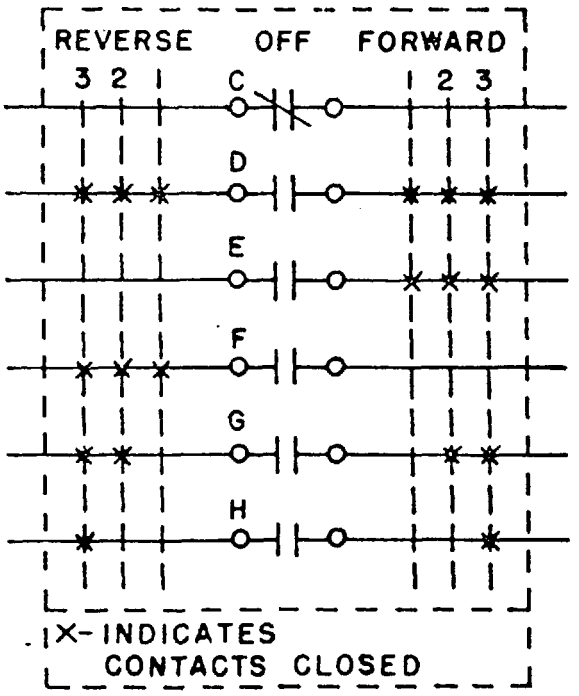
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Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

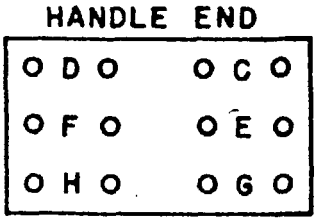
Elementary or Schematic Diagram	Connection or Interconnection Diagram

SWITCH (Continued)

SWITCH, MASTER OR CONTROL, CAM TYPE



On elementary diagram, sections on the switch may be separated. Show position indications for each section



Example*

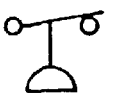
SWITCH, PRESSURE OR VACUUM OPERATED

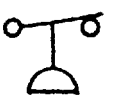
CLOSING ON RISING PRESSURE





OPENING ON RISING PRESSURE





* Example only; approved as Authorized Engineering Information. See 1-101.8.

(Continued)

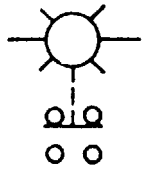
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

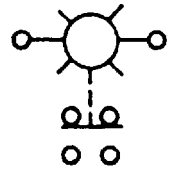
Elementary or Schematic Diagram	Connection or Interconnection Diagram

SWITCH (Continued)

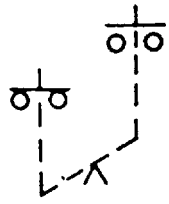
SWITCH, PUSHBUTTON

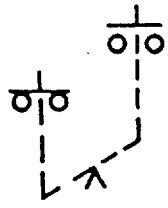
ILLUMINATED





MAINTAINED, TWO CIRCUIT
(Latched or not spring return)





MOMENTARY OR SPRING RETURN,
NORMALLY OPEN CIRCUIT CLOSING—MAKE





MOMENTARY OR SPRING RETURN,
NORMALLY CLOSED CIRCUIT OPENING—BREAK





MOMENTARY OR SPRING RETURN, TWO CIRCUIT,
NORMALLY OPEN AND NORMALLY CLOSED





MUSHROOM HEAD
Applied to two circuit pushbutton.





WOBBLE STICK



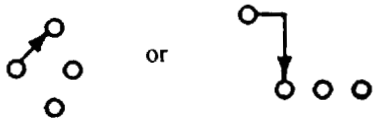


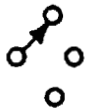
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Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

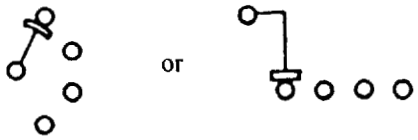
Elementary or Schematic Diagram	Connection or Interconnection Diagram

SWITCH (Continued)
SWITCH, SELECTOR (Multiposition)
BREAK-BEFORE-MAKE
Nonshorting (nonbridging) during contact transfer.





MAKE-BEFORE-BREAK
Shorting (bridging) during contact transfer.



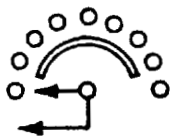


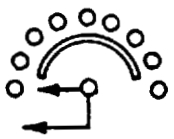
SEGMENTAL CONTACT



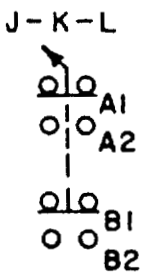


MULTI-POINT WITH FIXED SEGMENT

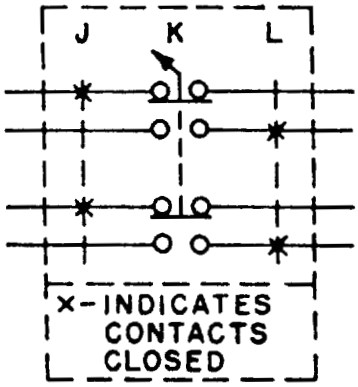


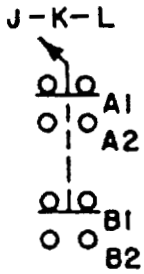


WITH PUSHBUTTON TYPE CONTACT MECHANISM
Show a table of contact operation if necessary. Point the arrow to the position label which identifies the position in which the contacts are shown.



	J	K	L
A1	X		
A2			X
B1	X		
B2			X





(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

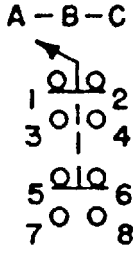
Elementary or Schematic Diagram	Connection or Interconnection Diagram

SWITCH (Continued)

SWITCH, SELECTOR (Continued)

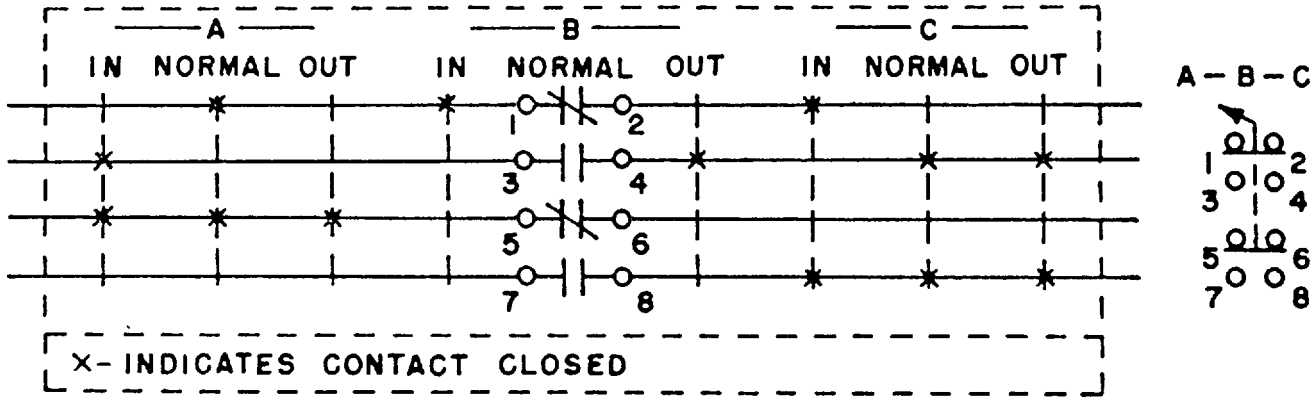
SELECTOR PUSHBUTTON
(Can be pushed into two or more positions and rotated into two or more positions.)

Show a table of contact operation on the diagram. Point the arrow to the position label which identifies the position in which the contacts are shown when the button is in the normal mode.



CONTACTS	SELECTOR POSITION								
	A			B			C		
	BUTTON			BUTTON			BUTTON		
	IN	NORMAL	OUT	IN	NORMAL	OUT	IN	NORMAL	OUT
1-2		X		X	X		X		
3-4	X					X		X	X
5-6	X	X	X		X				
7-8							X	X	X
X- INDICATES CONTACT CLOSED									

or



SWITCH, SINGLE THROW



(Continued)

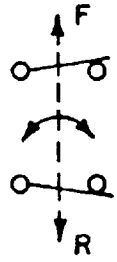
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

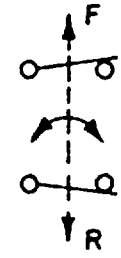
Elementary or Schematic Diagram	Connection or Interconnection Diagram

SWITCH (Continued)

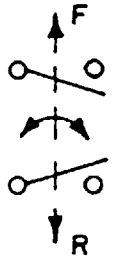
SWITCH, SPEED RESPONSIVE
(Operated by shaft rotation) (F = Forward, R = Reverse)

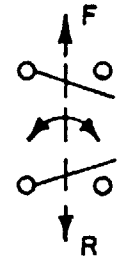
ANTI-PLUGGING SWITCH
(Prevents plugging of drive)





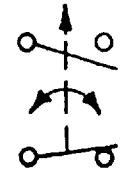
PLUGGING SWITCH
(Stops plugging action after drive has practically come to rest.)



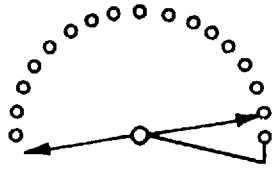


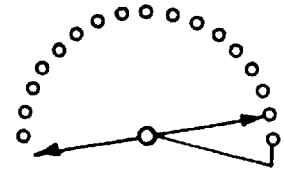
SPEED SWITCH
(Operates at a preset speed)





SWITCH, STEPPING





(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

SWITCH (Continued)

SWITCH, TEMPERATURE ACTUATED

CLOSING ON RISING TEMPERATURE





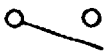
OPENING ON RISING TEMPERATURE

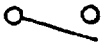




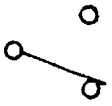
SWITCH, TOGGLE
(Maintained position)

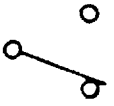
SINGLE POLE



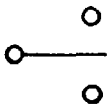


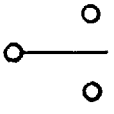
TRANSFER, SINGLE POLE 2 POSITION





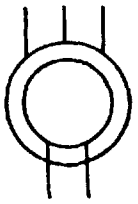
TRANSFER, SINGLE POLE 3 POSITION

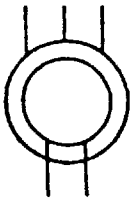




SYNCHRO, (SELSYN)
Identify by note.

CONTROL TRANSFORMER, RECEIVER, OR TRANSMITTER





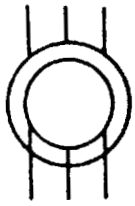
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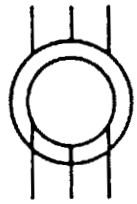
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

SYNCHRO, (SELSYN) (Continued)

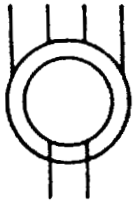
DIFFERENTIAL, RECEIVER, OR TRANSMITTER

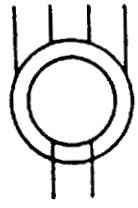




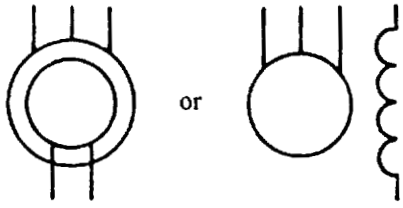
SYNCHRO, RESOLVER

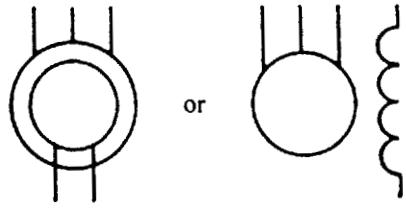
*Example, 1 Phase Rotor and 2 Phase Stator.





SYNCHRONOUS MOTOR, OR AC GENERATOR
Omit the field for synchronous induction, reluctance, or hysteresis motor.





TEMPERATURE OPERATED SWITCH
See "Switch, Temperature Actuated."

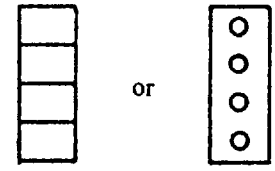
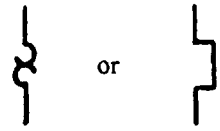
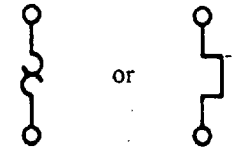
TERMINAL



* Example only; approved as Authorized Engineering Information. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
TERMINAL BOARD	
none	
THERMAL ELEMENT ACTUATING DEVICE	
	
THERMOCOUPLE (Temperature measuring device)	
	
THERMOSTAT See "Switch, Temperature Actuated."	
THYRISTOR See "Rectifier, Silicon Controlled."	
TIME-DELAY SWITCHES See "Contact, Time Delay."	
TOGGLE SWITCH See "Switch, Toggle."	
TORQUE RECEIVER OR TRANSMITTER See "Synchro."	

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

TRANSFORMER, GENERAL (CORE NOT SPECIFIED)

See also "Autotransformer." On elementary diagram, windings of the same transformer may be shown at different locations.



TRANSFORMER, WITH MAGNETIC CORE



TRANSFORMER, CURRENT

With polarity mark (x) when required. Instantaneous direction of current into one polarity mark corresponds to current out of the other polarity mark.



TRANSFORMER, POTENTIAL

With polarity mark (x) when required. Instantaneous direction of current into one polarity mark corresponds to current out of the other polarity mark. In lieu of polarity marking shown, use terminal identification, in accordance with 2.10 of the NEMA Standards Publication for *Specialty Transformers*, Standards Publication No. ST 1.

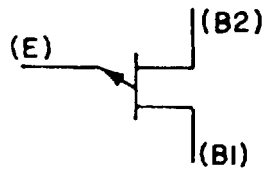
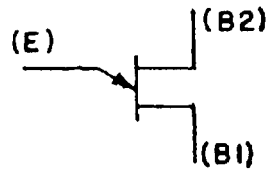
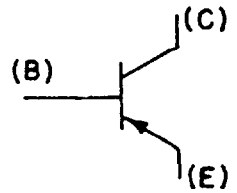
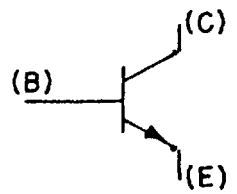
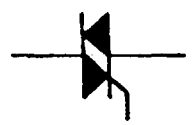


TRANSMITTER, SYNCHRO

See "Synchro."

(Continued)

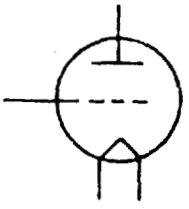
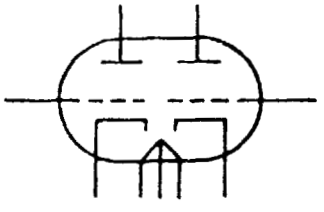
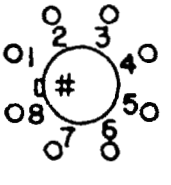
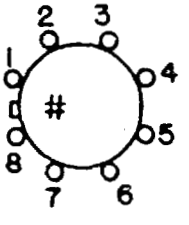
Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
TRANSISTOR	
UNIJUNCTION TRANSISTOR P BASE 	‡
UNIJUNCTION TRANSISTOR N BASE 	‡
PNP TRANSISTOR 	‡
NPN TRANSISTOR 	‡
TRIAC (Bidirectional Triode Thyristor) 	

‡ Use pictorial representation. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram
TRIODE With directly heated filament cathode. 	Use appropriate tube socket symbol and tube type number; see "Tube Socket."
TRIODE, TWIN EQUIPOTENTIAL CATHODE Showing use of elongated envelope. (See also "Envelope, Split.") 	Use appropriate tube socket symbol and tube type number; see "Tube Socket."
TUBE SOCKET none	 or  (Bottom View) Example*

Show tube type number here.

* Example only; approved as Authorized Engineering Information. See 1-101.8.

(Continued)

Table 1-101-3 *(Cont.)*
GRAPHIC SYMBOLS

Elementary or Schematic Diagram	Connection or Interconnection Diagram

VACUUM-OPERATED SWITCH
See "Switch, Pressure or Vacuum Operated."

VACUUM TUBE
See "Electron Tube Components."

VARIABLE
See "Adjustability" and "Resistor, Adjustable."

WINDING
See also "Field" and "Transformer, General."



WIRING
See "Conductor, or Conductive Path."

WOUND-ROTOR INDUCTION MOTOR OR
INDUCTION FREQUENCY CONVERTER



ZENER DIODE
See "Diode, Unidirectional Breakdown (Zener)"
and "Diode, Bidirectional Breakdown."

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Part 1-101A ●

DIAGRAMS, DEVICE DESIGNATIONS, AND SYMBOLS

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified. The definitions contained in Part 1-100 of this Standards Publication also apply to this part. Parts 1-101 and 1-101A are alternative standards for specifying diagrams, device designations, and symbols. Part 1-101A is intended to encourage harmonization with other national and international standards.

1-101A.1 IDENTIFICATION

Diagrams and drawings shall be identified by one of the titles shown in 1-101A.2 or by a combination of titles from 1-101A.2 and 1-101A.3, where applicable, but not solely by the titles given in 1-101A.3.

NEMA Standard 7-11-1984.

1-101A.2 TYPES OF DIAGRAMS AND DRAWINGS

1-101A.2.1 Process Diagram or Flow Diagram

A process or flow diagram is a conceptual diagram of the functional interrelationship of subsystems in block or pictorial form. Process equipment such as machinery is shown for proper understanding.

1-101A.2.2 Control System Diagram

A control system diagram is a conceptual diagram of the functional interrelationship of subsystems, usually in block form. It does not include the process equipment or details of circuits and device elements.

1-101A.2.3 Schematic Diagram or Elementary Diagram

A schematic or elementary diagram is one which shows all circuits and device elements of an equipment and its associated apparatus or any clearly defined functional portion thereof. Such a diagram emphasizes the device elements of a circuit and their functions as distinguished from the physical arrangement of the conductors, devices, or elements of a circuit system.

Circuits which function in a definite sequence

1-101A.2.4 Control Sequence Diagram or Table

A control sequence diagram or table is a portrayal of the contact positions or connections which are made for each successive step of the control action.

1-101A.2.5 Wiring Diagram or Connection Diagram

A wiring or connection diagram is one which locates and identifies electrical devices, terminals, and interconnecting wiring in an assembly. This diagram shall be: (1) in a form showing interconnecting wiring by lines or indicating interconnecting wiring only by terminal designations (wireless diagram), or (2) a panel layout diagram showing the physical location of devices plus:

(a) The elementary diagram, or
(b) A wiring table, or
(c) A computer wiring chart, or
(d) A machine command tape or cards.

The term does not include mechanical drawings, commonly referred to as wiring templates, wiring assemblies, cable assemblies, and so forth.

1-101A.2.6 Interconnection Diagram

An interconnection diagram is one which shows only the external connections between controllers and associated machinery and equipment.

1-101A.2.7 Dimension or Outline Drawing

A dimension or outline drawing (base plan, floor plan, and so forth) is one which shows the physical space and mounting requirements of a piece of equipment. It shall be permitted to also indicate ventilation requirements and space provided for connections or the location to which connections are to be made.

1-101A.2.8 Construction Diagram

A construction diagram is a diagram that shows the physical arrangements of parts, such as wiring, buses, resistor units, and so forth. For example, a diagram showing the arrangement of grids and terminals in a grid-type resistor.

● Added 7-11-1984.

1-101A.2.9 Controller Diagram

A controller diagram is a diagram which shows the electrical connections between the parts comprising the controller and which shows the external connections.

1-101A.2.10 Illustrative Diagram

An illustrative diagram is a diagram whose principal purpose is to show the operating principle of a device or group of devices without necessarily showing actual connections or circuits. Illustrative diagrams shall be permitted to use pictures or symbols to illustrate or represent devices or their elements.

Illustrative diagrams shall be permitted to be made of electric, hydraulic, pneumatic and combination systems. They are applicable chiefly to instruction books, descriptive folders, or other mediums whose purpose is to explain or instruct.

1-101A.2.11 Wireless Connection Diagram

A "wireless" connection diagram shows the general physical arrangement of devices in a control equipment and connections between these devices, terminals, and terminal boards for outgoing connections to external apparatus. Connections are shown in tabular form and not by lines. An elementary (or schematic) diagram shall be permitted to be included in the connection diagram.

NEMA Standard 7-11-1984.

1-101A.2.12 Other Drawings

There may be additional drawings, such as conduit layout drawings, foundatin drawings, and so forth.

Authorized Engineering Information 7-11-1984.

1-101A.3 FORMS OF DIAGRAMS

Diagrams shall be permitted to take one or a combination of the following forms.

1-101A.3.1 Block Diagram

A block diagram is made up of a group of interconnected blocks, each of which represents a device or subsystem.

1-101A.3.2 One-Line Diagram or Single-Line Diagram

A one-line or single-line diagram is one which shows, by means of single lines and graphic symbols, the course of an electrical circuit or circuits and the component devices or parts used therein. Physical relationships are usually disregarded.

1-101A.3.3 Logic Diagram

A logic diagram is a particular form of one-line or single-line diagram of a logic circuit using logic symbols.

NEMA Standard 7-11-1984.

1-101A.4 DIAGRAM PREPARATION

1-101A.4.1 Symbols

Graphic symbols are used on single-line (one-line) diagrams, on schematic or elementary diagrams, or, as applicable, on connection or wiring diagrams. Graphic symbols are correlated with parts lists, descriptions, or instructions by means of designations.

Symbols for the devices shown in diagrams covered by these standards shall be in accordance with 1-101A.8. Detailed device symbols shall be made up to represent the physical arrangement of the main component parts and of the terminals to which connections are made.

Buildups (a combination of symbols) shall be permitted to be devised using the basic symbols in the list, provided they are a reasonable and intelligible use of the symbols. If a specific symbol appears in this standard for an item, however, it shall be used in lieu of buildup symbols of the individual elements unless a clarification of the internal operation of the item is necessary.

All diagrams using the symbols defined in this standard shall refer to or have a note indicating that the diagram conforms to NEMA ICS 1-101A, Diagrams, Device Designations, and Symbols.

1-101A.4.2 Device Designations

Each device in an equipment to which a connection is made shall be assigned a device designation which shall be in accordance with 1-101A.5. These designations shall be distinct, and there shall be no duplication of designations for the devices in any connection diagram. All designations shall correspond to those used in the elementary diagram.

1-101A.4.3 Physical Arrangement

The physical arrangement of devices in a wireless connection diagram shall correspond to the physical arrangement of the equipment. Physical groupings comprising control panel sections, auxiliary panels,

subpanels, overhead racks, resistor compartments, and the like shall be so indicated and marked. See Figure 1-101A-1 for an example of a wireless connection diagram.

1-101A.4.4 Terminal Markings

Each terminal of a device to which a connection is to be made shall be assigned a distinct terminal marking. This marking shall correspond to the one used in the elementary diagram for designating the same circuit.

1-101A.4.5 Control Circuit Connections

Control circuit connections shall be listed in the form of a panel wire table which shall consist of a single continuous column. This table shall list the circuit (terminal) numbers in numerical or alphabetical order, or both. Opposite each circuit (terminal) number shall be listed the designations of the devices to which the circuit will be connected. Short connections between terminals of the same device or between points on a terminal board are sometimes drawn as lines.

1-101A.4.6 Power Circuit Connections

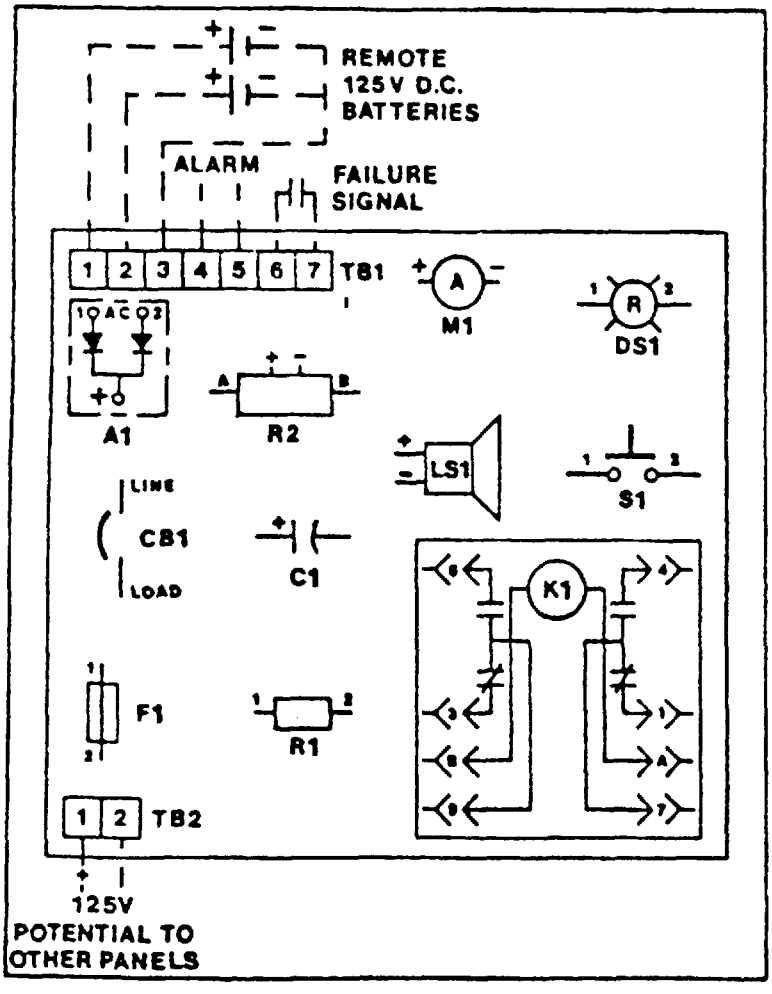
Power circuit connections shall be drawn completely by lines or shall be included in the panel wire table.

NEMA Standard 7-11-1984.

1-101A.5 DEVICE DESIGNATIONS

1-101A.5.1 Application

The device designations of this standard are for use on equipment and related diagrams, drawings, parts lists and in manuals or similar publications. The designations of this standard are intended for uniquely identifying and locating discrete items on diagrams and in a set, and for correlating items in a set, graphic symbols on diagrams, and in parts lists, circuit descriptions, and instructions. Reference designations are not intended to replace other



WIRE RUN LIST		
WIRE NO.	CONNECT TO	
1	TB1-1	A1-AC1
2	TB1-2	A1-AC2
3	TB1-3	TB2-(2), C1-(-), K1-B, LS1-(-), DS1-2
4		A1-(+), CB1-LINE
5		CB1-LOAD, F1-1
6		F1-2, R2-A, C1-(+)
7	TB1-4	R2-B, TB2-1
8		R2-(+), M1-(+)
9		R2-(-), M1-(-)
10	TB1-5	K1-9, S1-1
11		K1-3, R1-1
12		R1-2, LS1-(+)
13		K1-A, K1-6, S1-2, DS1-1
14	TB1-6	K1-4
15	TB1-7	K1-7

Figure 1-101A-1
TYPICAL WIRELESS CONNECTION DIAGRAM

identification numbers, such as drawings, part, type, or stock numbers. Additions or changes to an existing unit or set should follow the designation system originally used.

In these standards, the unit is the highest level to which a reference designation is assigned.

Device function designations for power switchgear are covered in ANSI/IEEE C37.2, *Electrical Power System Device Function Numbers.*

Authorized Engineering Information 7-11-1984.

1-101A.5.2 Definitions

For the purpose of these standards the following definitions apply.

1-101.5.2.1 Basic Part

One piece, or two or more pieces joined together, which are not normally subject to dissassembly without destruction of designed use. (See Figure 1-101A.8.)

NEMA Standard 7-11-1984.

The application, size, and construction of an item may be factors in determining whether an item is regarded as a unit, an assembly, a subassembly, or a basic part. A small electric motor might be considered as a part if it is not normally subject to disassembly. Typical examples: electron tube, resistor, relay, power transformer, microelectronic device.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.2 Subassembly

Two or more basic parts which form a portion of an assembly or a unit, replaceable as a whole, but having a part or parts which are individually replaceable. (See Figure 1-101A-8.)

NEMA Standard 7-11-1984.

NOTES—(1) The application, size, and construction of an item may be factors in determining whether an item is regarded as a unit, an assembly, a sub-assembly, or a basic part. A small electric motor might be considered as a part if it is not normally subject to disassembly. (2) The distinction between an assembly and a subassembly is not always exact; an assembly in one instance may be a subassembly in another where it forms a portion of an assembly. Typical examples: filter network, terminal board with mounted parts.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.3 Assembly

A number of basic parts or subassemblies, or any combination thereof, joined together to perform a specific function. (See Figure 1-101A-8.)

NEMA Standard 7-11-1984.

The application size, and construction of an item may be factors in determining whether an item is regarded as a unit, an assembly, a subassembly, or a basic part. A small electric motor might be considered as a part if it is not normally subject to disassembly. The distinction between an assembly in one instance may be a subassembly in another where it forms a portion of an assembly. Typical examples: electric generator, audio-frequency amplifier, power supply.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.3.1 Assembly, Microelectronic Device

An assembly of inseparable parts, circuits, or combination thereof.

NEMA Standard 7-11-1984.

Typical examples: microcircuit, integrated-circuit package, micromodule.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.4 Unit

A major building block for a set or system consisting of a combination of basic parts, subassemblies, and assemblies packaged together as a physically independent entity. (See Figure 1-101A.8.)

NEMA Standard 7-11-1984.

The application, size, and construction of an item may be factors in determining whether an item is regarded as a unit, an assembly, a subassembly, or a basic part. A small electric motor might be considered as a part if it is not normally subject to disassembly. Typical examples: radio receiver, radio transmitter, electronic power supply, antenna.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.5 Group

A collection of units, assemblies, or subassemblies which is a subdivision of a set or system, but which is not capable of performing a complete operational function. (See Figures 1-101A-7 and 1-101A-8.)

NEMA Standard 7-11-1984.

Typical examples: antenna group, indicator group.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.6 SET

A unit or units and necessary assemblies, subassemblies, and basic parts connected or associated together to perform an operational function. (See Figures 1-101A-7 and 1-101A-8.)

NEMA Standard 7-11-1984.

Typical examples: search radar set, radio transmitting set, sound measuring set; these include such parts, assemblies, and units as cables, microphone, and measuring instruments.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.7 SYSTEM

A combination of two or more sets, generally physically separated when in operation, and such other units, assemblies, and basic parts necessary to perform an operational function or functions. (See Figure 1-101A-7.)

NEMA Standard 7-11-1984.

Typical examples: telephone carrier system, ground-controlled approach (GCA) electronic system, telemetering system, facsimile transmission system.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.8 ACCESSORY

A basic part, subassembly, or assembly designed for use in conjunction with or to supplement another assembly, unit, or set, contributing to the effectiveness thereof without exceeding or varying the basic function of the assembly or set.

NEMA Standard 7-11-1984.

An accessory may be used for testing, adjusting, or calibrating purposes. Typical examples: test instrument, recording camera for radar set, headphones, emergency power supply.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.9 ATTACHMENT

A basic part, subassembly, or assembly designed for use in conjunction with another assembly, unit or set, contributing to the effectiveness thereof by extending or varying the basic function of the assembly, unit or set.

NEMA Standard 7-11-1984.

Typical example: ultra-high-frequency (UHF) converter for very-high-frequency (VHF) receiver.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.10 REFERENCE DESIGNATION

Letters or numbers, or both, used to identify and locate discrete units, portions thereof, and basic parts of a specific set.

NEMA Standard 7-11-1984.

NOTE—A reference designation is not a letter symbol, abbreviation, or functional designation for an item.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.11 BASIC REFERENCE DESIGNATION

The simplest form of a reference designation, consisting only of a class letter portion and a number (namely, without mention of the item within which the reference-designated item is located). The reference designation for a unit consists of only a number.

1-101A.5.2.12 PARTIAL REFERENCE DESIGNATION

A reference designation that consists of a basic reference designation and which shall be permitted to include, as prefixes, some but not all of the reference designations that apply to the subassemblies or assemblies within which the item is located.

1-101A.5.2.13 COMPLETE REFERENCE DESIGNATION

A reference designation that consists of a basic reference designation and, as prefixes, all the reference designations that apply to the subassemblies or assemblies within which one item is located, including those of the highest level needed to designate the item uniquely. The reference designation for a unit consists of only a number.

1-101A.5.2.14 FUNCTIONAL DESIGNATION

Words, abbreviations, or meaningful number or letter combinations, usually derived from the function of an item (for example: slew, yaw), used on drawings, instructional material, and equipment to identify an item in terms of its function.

NEMA Standard 7-11-1984.

NOTE—A functional designation is not a reference designation nor a substitute for it.

Authorized Engineering Information 7-11-1984.

1-101A.5.2.15 RELAY

An electrically controlled, usually two-state device that opens and closes electrical contacts to effect the operation of other devices in the same or another electric circuit.

NEMA Standard 7-11-1984.

NOTES—(A) A relay is a device in which a portion of one or more sets of electrical contacts is moved by an armature and its associated operating coil. (B) This concept is extended to include assembled reed relays in which the armature may act as a contact. For individual magnetic reed switches, see "Switches."

Authorized Engineering Information 7-11-1984.

1-101A.5.2.16 SWITCH

A device for making, breaking, or changing the connections in an electric circuit.

NEMA Standard 7-11-1984.

NOTE—A switch may be operated by manual, mechanical, hydraulic, thermal, barometric, or gravitational means, or by electromechanical means not falling within the definition of "Relay."

Authorized Engineering Information 7-11-1984.

1-101A.2.17 MICROELECTRONIC DEVICE

An item of inseparable parts and hybrid circuits, usually produced by integrated circuit techniques.

NEMA Standard 7-11-1984.

Typical examples: microcircuit, integrated circuit package, micromodule.

Authorized Engineering Information 7-11-1984.

1-101A.5.3 BASIC REFERENCE DESIGNATIONS

A basic reference designation for an item (such as resistor, inductor, electron tube, or subassembly) shall consist of one or more letters, identifying the class, and a number; for example, AR14, C3, and so forth. In some cases a suffix letter shall be permitted to be added, for example, C7A, C7B. All letters shall be in capitals. the designation shall be written with all characters the same size, on the same line, and without separation.

The reference designation for a unit consists of only a number. (See 1-101A.5.4.2.)

The reference designation (generally the basic reference designation) shall be permitted to be used in a parts list in lieu of an item or find number. In this case, if MIL-STD-100 is a requirement, the alphanumerical combination shall be limited to a maximum of six letters and numbers.

1-101A.5.3.1 CLASS LETTER

The letters identifying the class of an item shall be selected from Table 1-101A-1. (See also 1-101A.7.)

1-101A.5.3.1.1 SPECIAL CLASS LETTER CONSIDERATIONS

For reference designation assignment purposes:

(1) The term subassembly as used herein shall apply equally to an assembly.

(2) A group of parts shall not be treated as a subassembly unless it is one or more of the following:
   (a) A plug-in item.
   (b) A significant item covered by a separate schematic.
   (c) A multiapplication item
   (d) Likely to be handled as a replaceable item for maintenance purposes.

(See also 1-101A.5.4.8.3.)

1-101A.5.3.2 NUMBER

The number portion of the reference designation shall differentiate an item from all other items identified by the same class letter.

1-101A.5.3.3 SEQUENTIAL NUMBER ASSIGNMENT

Within each significant item (unit, assembly, subassembly, and so forth), for the parts of each class, numbers shall be assigned sequentially on the schematic diagram in a systematic manner, beginning with 1. Preferably start at the upper left of the schematic diagram and proceed from left to right) and top to bottom for each successive portion of the circuit. Continue (preferably from left to right) until all parts of the circuit have been designated in order of input to output, or functional sequence. If revisions require deletion or addition of items, the original items shall not be renumbered to keep the series consecutive. Added items shall be assigned numbers following the highest number originally used. Numbers assigned to items which have been deleted shall not be reused.

NEMA Standard 7-11-1984.

NOTE—Minor changes, such as a change in characteristics of the *same type* of part (for example, substitution of a 470Ω composition resistor for a 330Ω wire-wound resistor) do not require a change in reference designation.

Figure 1-101A-2 shows a typical application of basic reference designations on a schematic diagram.

Authorized Engineering Information 7-11-1984.

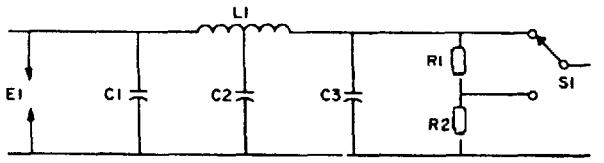


Figure 1-101A-2
TYPICAL BASIC REFERENCE DESIGNATIONS IN A DIAGRAM

1-101A.5.3.4 SUFFIX LETTER

A suffix letter, beginning with A, shall be added to the basic reference designation to identify each portion of a multiple-element part or similar item (such as a dual electron tube, multicontact relay, or multiple-unit capacitor), as follows:

(1) If differentiation is required for explanations in related text.
(2) If portions of the part are shown separated from each other on schematic diagrams.
(3) If it is necessary to identify elements and their terminals for wiring. For example, the parts of a dual electron tube would be designated V2A, V2B.

Suffix letters are also used to identify several separate connectors under the conditions stated in 1-101A.5.3.5.3(5). See Figure 1-101A-3, example (e).

Suffix letters shall be assigned in alphabetic order with the exception of I and O, which shall not be used.

Suffix letters shall not be assigned to items above the lowest reference designation level.

1-101A.5.3.5 SPECIAL CASES

1-101A.5.3.5.1 TERMINALS

To identify terminals of parts (such as sockets, terminal boards, and transformers), the part reference designation shall be suffixed with a dash and the terminal identification. This principle shall also be permitted to be applied, by extension, to relays, key switches, and similar devices, provided the terminals of the devices have or may be assigned numerical identification. Thus, a pair of relay contacts connected to terminals 5 and 6 of relay K7 would be assigned reference designation K7-5, 6. In the above cases, the reference designation class letter E shall be omitted. A typical application of the letter E is for the identification of isolated terminals used for wiring convenience. The class letters WT have been established to identify a tie point on a connection diagram. Terminal numbers, when used on diagrams, shall be placed in or adjacent to the symbol. (See Figure 1-101A-9.)

1-101A.5.3.5.2 SOCKETS

1-101A.5.3.5.2.1 SINGLE—ITEM MOUNTING

A socket, fuseholder, or similar device which is

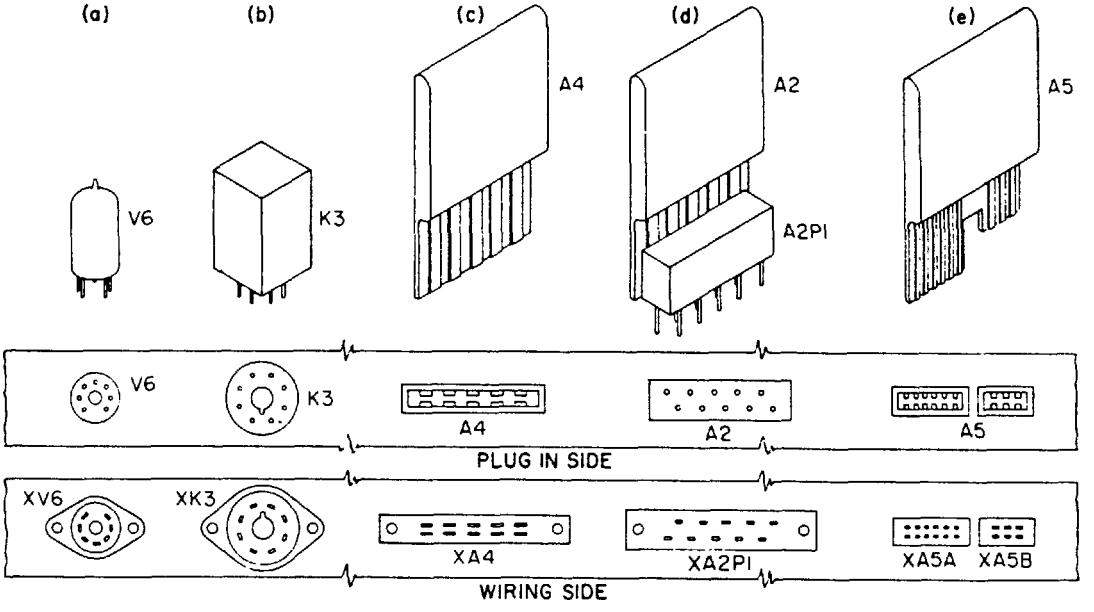


Figure 1-101A-3
SOCKET REFERENCE DESIGNATIONS AND MARKINGS

always associated with a single particular part or subassembly (such as an electron tube, a fuse, or a printed circuit board with or without integral contacts or connectors) shall be identified by a composite reference designation consisting of the class letter X followed by the basic reference designation which identifies the mounted part.

NEMA Standard 7-11-1984.

For example, the socket for electron tube V6 would have a basic reference designation XV6; the only socket for subassembly A4 would have a basic reference designation XA4. (See Figure 1-101A-3.)

Authorized Engineering Information 7-11-1984.

If the mounted item has two or more bases or connectors integral with the item, suffix letters shall be assigned to each base of the item (according to 1-101A.5.3.4). The sockets shall then be identified as indicated above.

NEMA Standard 7-11-1984.

For example, if electron tube V3 has two bases, A and B, the sockets would be identified as XV3A and XV3B.

Authorized Engineering Information 7-11-1984.

1-101A.5.3.5.2.2 MULTIPLE-ITEM MOUNTING

If several items taking the same class letter are mounted in one holder, the designation of this multiple-item mounting shall be derived from the designation of the lowest-numbered item mounted.

NEMA Standard 7-11-1984.

For example, if fuses F1 and F2 are mounted in a dual fuseholder, the fuseholder shall be designated XF1.

Authorized Engineering Information 7-11-1984.

1-101A.5.3.5.3 CONNECTORS

Connector reference designations shall be assigned in accordance with the following principles:

(1) The movable (less fixed) connector of a mating pair shall be designated P. (See Figure 1-101A-4, connector P3 on A7 and connector P1 on W2.)

(2) The stationary (more fixed) connector of a mating pair shall be designated J or X. (See Figure 1-101A-4, connector XA7P3 on A9 and connector J2 on A7.)

(3) A connector designated P on a flexible cable shall mate with a fixed connector designated J rather than X.

(4) If two cables are to be connected to each other, each of the mating cable connectors shall be designated P.

(5) A connector to mount an item, or affixed to the mounting for an item, shall be designated with an X prefix if its mate is directly affixed (not on flexible cable) to the mounted item. See Figure 1-101A-3, example (d). If there is more than one directly affixed connector on the mounted item, the designation of each of mating mounting connectors shall consist of the following in the order listed (see Figure 1-101A-4 connector XA7P3):
   (a) The class code letter X.
   (b) The basic reference designation of the mounted item.
   (c) The basic reference designation of its mating connector on the mounted item.

   If the mounted item has more than one integral connector, as in Figure 1-101A-3, and requires more than one mounting connector, the basic reference designations of the mounting connectors shall have a letter suffix assigned in accordance with 1-101A.5.3.5.2.1.

(6) If a cable has one end connector terminated and another end permanently connected (soldered, and so forth) to the circuit wiring, the connector, and, if necessary, the wire shall be assigned reference designations as individual parts of the circuits rather than as one separate subassembly.

(7) If more than one of different class code items normally plug into one mounting connector, that connector shall be designed X and shall be followed by a sequentially assigned number. For example, the single connector mounting AR2, R7, or Z3 (depending upon circuit instructions) shall be designated X1. (See Figure 1-101A-4.)

(8) If there are alternate connections within a given item (for example, for different supply voltages, low impedance or a patch board), the numeric portion of the basic reference designation for the mating P and J items shall be in a nonduplicating numerical sequence. Preferably avoid assigning the same number to the P and J parts of any mating combination of alternate-connection connectors. Explain in technical data, or by functional designations on the equipment, which connectors should be mated for a given operating condition.

(9) If there is an adapter located between other connecting devices, the adapter shall be permitted to be disregarded in assigning reference

designations to the other connecting devices; however, the adapter shall be assigned a reference designation, for example, CP2.

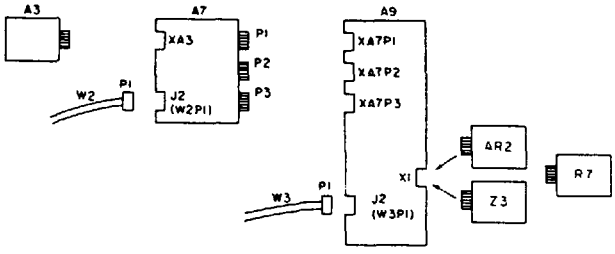


Figure 1-101A-4
CONNECTOR DESIGNATIONS FOR PLUG-IN ITEMS

1-101A.5.3.5.4 SUPPLEMENTARY INFORMATION

If both portions of a connector mating pair are not shown on a schematic diagram, the reference designation for the mating connector or plug-in item shall be indicated in parentheses adjacent to the connector shown.

NEMA Standard 7-11-1984.

Examples are as follows:

J1	J3
(P1)	(CP2)
	(W4P1)

If one connector has as its mate any of the several other connectors, or if the item has multiple uses, a suitable functional designation may be shown in lieu of the reference designations of all of the mating connectors. See also 1-101A.5.3.5.5.

Authorized Engineering Information 7-11-1984.

1-101A.5.3.5.5 INTERSUBASSEMBLY AND INTERUNIT CABLE CONNECTIONS

Each cable shall be identified by a unique reference designation on a diagram. A cable assembly having multiple uses shall be identified by a part number or nomenclature, and this shall be shown on diagrams, near the reference designation.

In a complex set having a large number of interassembly and interunit connections, proper interconnection of items shall be expedited by assigning a unique identification to each mating pair of connectors in the set (if one or both are connected to a cable or flexible waveguide). On diagrams and in technical data, this unique mating pair identification shall be shown in paratheses after the basic reference designation for the connectors. The mating pair identification shall be permitted to be in the form of sequential numbers (preferable), functional designations if suitable, or other mutually agreed upon methods. See Figure 1-101A-5.

NEMA Standard 7-11-1984.

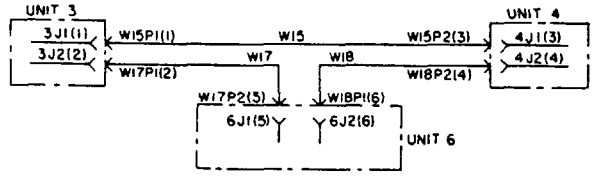


Figure 1-101A-5
TYPICAL CONNECTOR AND INTERUNIT CABLE DESIGNATIONS
(Arbitrary connector mating-pair numbers are shown in parentheses.)

If a cable assembly normally will be made up in the field using bulk cable or using wire already installed in the structure housing the set, the connectors to be installed on the cable, if furnished, may have reference designations assigned as though these connectors were part of the equipment item to which the cable end will connect.

Authorized Engineering Information 7-11-1984.

1-101A.5.3.5.6 REPEATED-USE CIRCUITS

Essentially similar repeated-use circuits shall be identified by assigning the same basic reference designation to corresponding parts within each circuit. Circuit groups shall be distinguished from one another by assigning a separate N designation to each group within a given assembly. For example, N1C1, N2C1, and N3C1 identify corresponding items in each of three groups. On a schematic or other assembly documentation, N-designated circuits shall be clearly defined, with the complete reference designations shown for all separated items. If the physical assembly does not have all parts of each individual N-designated circuit contiguously arranged (namely the parts are distributed over the assembly), either the complete reference designations shall be marked on the assembly or separate documentation shall clarify the locations of the circuit parts. (See Figure 1-101A-6.)

1-101A.5.3.5.7 SELECTED AND MATCHED PARTS

Selected parts are parts whose values are selected to achieve optimum performance. The reference designation of a selected part shall be assigned from the series that applies to the subassembly of which it forms a part, whether or not the selection of the part value is based on

its effect on a higher-level assembly.

Only one reference designation shall be assigned to identify the selected part, even though several parts are supplied with the subassembly to permit selection of the proper value of one part to satisfy the requirement.

If more than one part is required to obtain the proper value (by parallel or series connection), each such part shall be assigned a suffix letter in accordance with 1-101A.5.3.4.

This method also shall be permitted to be applied to a situation where matched parts within an assembly are treated as a single item.

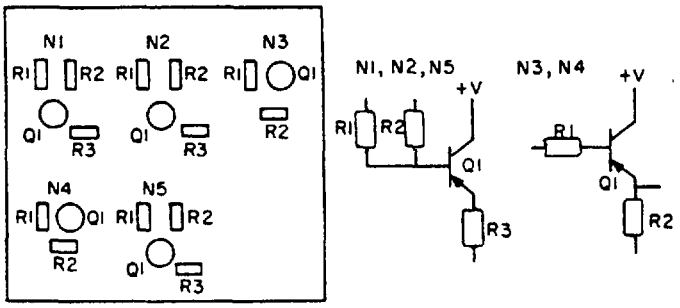


Figure 1-101A-6
PHYSICAL AND CIRCUIT RELATIONSHIP OF N-DESIGNATED CIRCUIT GROUPS

1-101A.5.3.6 Reference Designations for Relays

1-101A.5.3.6.1 Class Letter

Relays as defined in 1-101A.5.2.15 shall be assigned the class letter K.

1-101A.5.3.6.2 Elements of Relays

If the individual elements of a relay must be identified, it shall be done by one of the following methods. (Method (1) is preferred for maintenance diagrams, while methods (2) and (3) shall be limited to applications where terminal identification is unnecessary.) Only one method shall be used on any one diagram or set of diagrams:

(1) The elements of the relay shall be identified by suffixing the basic relay reference designation with a dash, followed by the assigned terminal designations for the elements, separated by a comma; for example, K7-5,6.

(2) If elements of a relay are shown separated on a drawing, they shall be identified by adding a suffix letter (other than I or O) to the reference designation of the composite item. The suffix letters shall start with A (preferably beginning with the operating device) and run consecutively.

(3) If relays or contactors have readily removable elements (such as coils or contact sets) that are subject to replacement in normal use or, if reference to individual elements is required for adequate operating or maintenance information, these elements shall be identified by suffixing the basic relay reference designation with a class letter and number characteristic of the element. Examples are as follows:

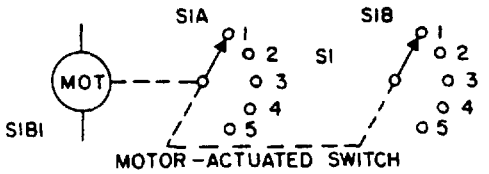
Relay or contactor	K3
Operating coil	K3L1
First set of contacts	K3S1
Second set of contacts	K3S2

1-101A.5.3.7 Reference Designations for Switches

1-101A.5.3.7.1 Class Letter

Switches as defined in 1-101A.5.2.16 shall be assigned the class letter S.

Standard graphic symbols have been developed for certain types of switches operated by means other than manual (for example, interlock switch, liquid-level-actuated switch). In such cases, the class letter applies to the entire graphic symbol. If symbols required to fill a particular need have not been standardized, the proper graphic symbol for the actuating means shall be drawn adjacent to the switch symbol and identified by a suitable reference designation. An example is as follows:



1-101A.5.3.7.2 Elements of Switches

If the individual elements of a switch must be identified, it shall be done in a manner similar to that prescribed for relays in 1-101A.5.3.6.2.

1-101A.5.3.8 Actual Versus Intended Function

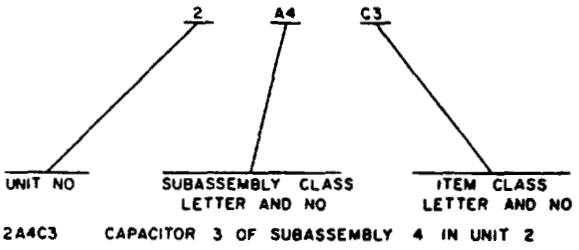
If a part serves a purpose other than its intended one, the function actually performed shall be represented by the graphic symbol used on the schematic diagram; the reference designation shall be chosen from Table 1-101A-1 and shall be indicative of its physical characteristics. For example, a semiconductor diode used as a fuse would be represented by the graphic symbol for a fuse (actual function), but the reference designation would be D or CR (class of part). If a part has a dual function, the class letter for

the principal physical characteristic of the part shall apply.

1-101A.5.4 Complete Reference Designations

For a piece of equipment consisting of one simple assembly, such as a small volt-ohmmeter or a radio receiver, only a basic reference designation (see 1-101A.5.2.11) shall be necessary to completely identify each part in the equipment.

For more complex sets, involving two or more units or one or more levels of subassemblies, to completely identify an item within the set, the basic reference designation shall be prefixed with the designations assigned to the subassemblies and the unit incorporating the item as shown in the following example.



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Figure 1-101A-7 shows a typical subdivision of a system. A typical set corresponding generally to set A of Figure 1-101A-7 is shown pictorially in Figure 1-101A-8. A schematic diagram incorporating typical complete reference designations assigned according to the principles of the unit numbering method is shown in Figure 1-101A-9.

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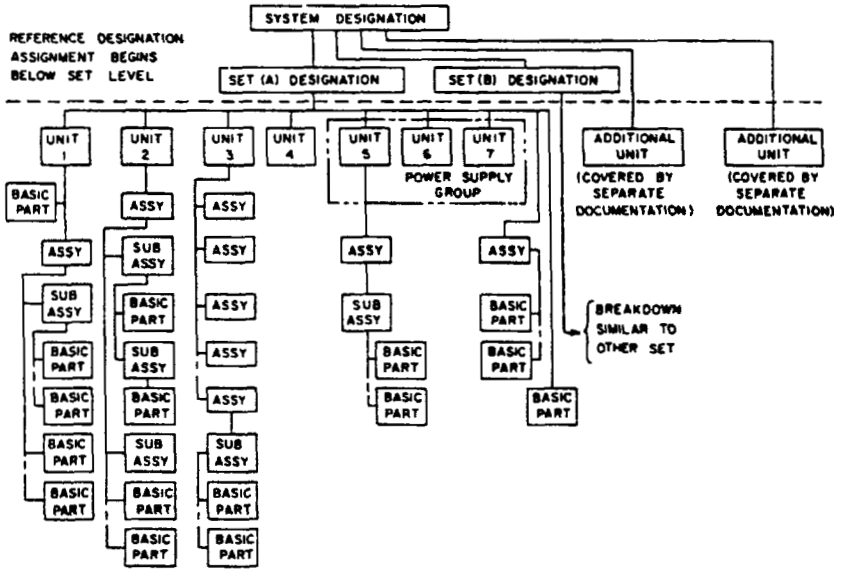


Figure 1-101A-7
TYPICAL SYSTEM SUBDIVISION

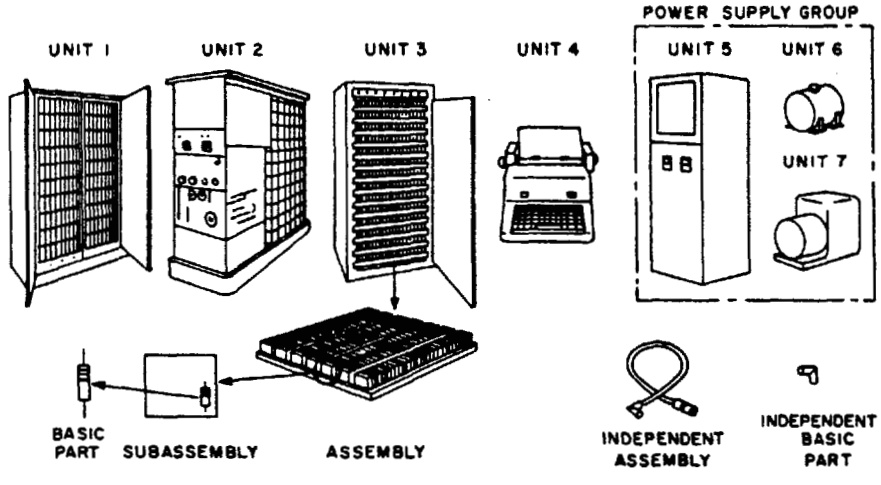


Figure 1-101A-8
A TYPICAL SET

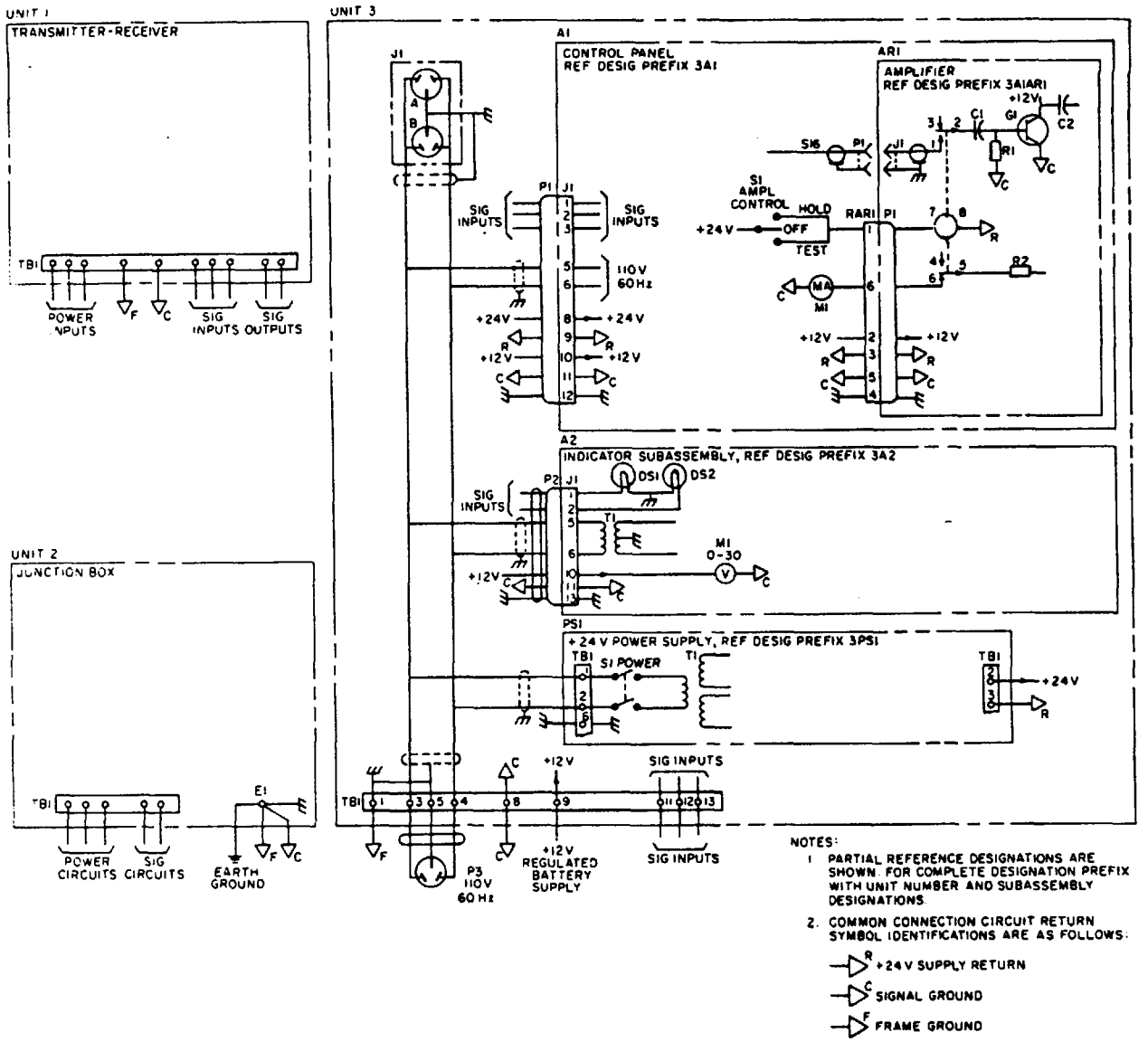


Figure 1-101A-9
REFERENCE DESIGNATIONS IN A TYPICAL SCHEMATIC DIAGRAM

1-101A.5.4.1 Systems, Sets, and Groups

If reference designations are used to identify systems, sets, or groups, an explanation of the method used shall be furnished with the technical data supplied.

1-101A.5.4.2 Units of a Set

Each unit within a set shall be assigned an identifying number. This number shall begin with 1 and preferably run consecutively for all units of the set. This number is the reference designation of the unit. If there is only one unit, the unit number shall be permitted to be omitted.

Units that are enclosed within the same cabinet, mounted in a common rack, or otherwise similarly joined with other units, subassemblies, and so forth, shall be treated as assemblies.

1-101A.5.4.2.1 Units of a Group

Units of a group not covered by separate documenation shall be numbered as though they were units of the set of which they form a part, without group identification.

Units of a group covered by separate documentation shall be treated as though they were units of a separate set.

1-101A.5.4.2.2 UNITS NOT PART OF A SET

Units of a system that are not part of a set shall be assigned unit identifying numbers if covered by system technical data. Such units shall not be assigned unit identifying numbers if covered by separate technical data (for example, existing designs, standard units, oscilloscopes).

1-101A.5.4.3 IDENTIFICATION OF ITEMS IN A UNIT WHICH ARE NOT IN A SUBASSEMBLY

The complete reference designation of an item that is in a unit, but not in a subassembly, shall consist of the unit number identifying the specific unit, followed by the basic reference designation for the item assigned according to 1-101A.5.3. For typical examples, see 1R1, 2J1, and 3R1 of Figure 1-101A-10.

1-101A.5.4.4 IDENTIFICATION OF ITEMS OF SUBASSEMBLIES

The complete reference designation of an item (subassembly or basic part), which is a portion of a subassembly, shall consist of the following, in the order listed:

(1) The unit number identifying the unit incorporating the particular subassembly
(2) The basic reference designation for the particular subassembly
(3) The basic reference designation for the part located in the particular subassembly

For typical examples, see Figure 1-101A-11.

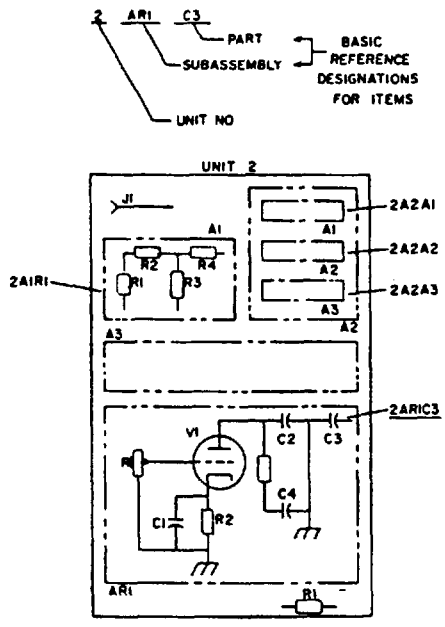


Figure 1-101A-11
IDENTIFICATION OF ITEMS OF SUBASSEMBLIES

1-101A.5.4.5 EXPANSION OF METHOD

In a multilevel unit, subassemblies of subassemblies shall be identified as though they were parts of subassemblies. The reference designation method can be expanded as necessary to permit identification of items resulting from any degree of subdivision required for fabricating, stocking, or maintenance purpose. Every effort shall be made, however, to keep the designations as short as practicable. Reference designations shall not contain more than the five levels

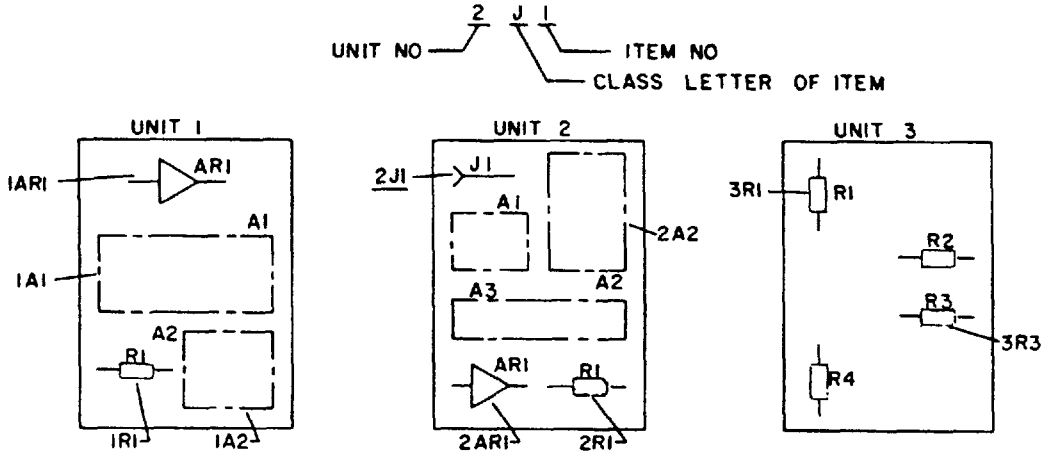


Figure 1-101A-10
IDENTIFICATION OF SUBASSEMBLIES AND PARTS OF UNITS

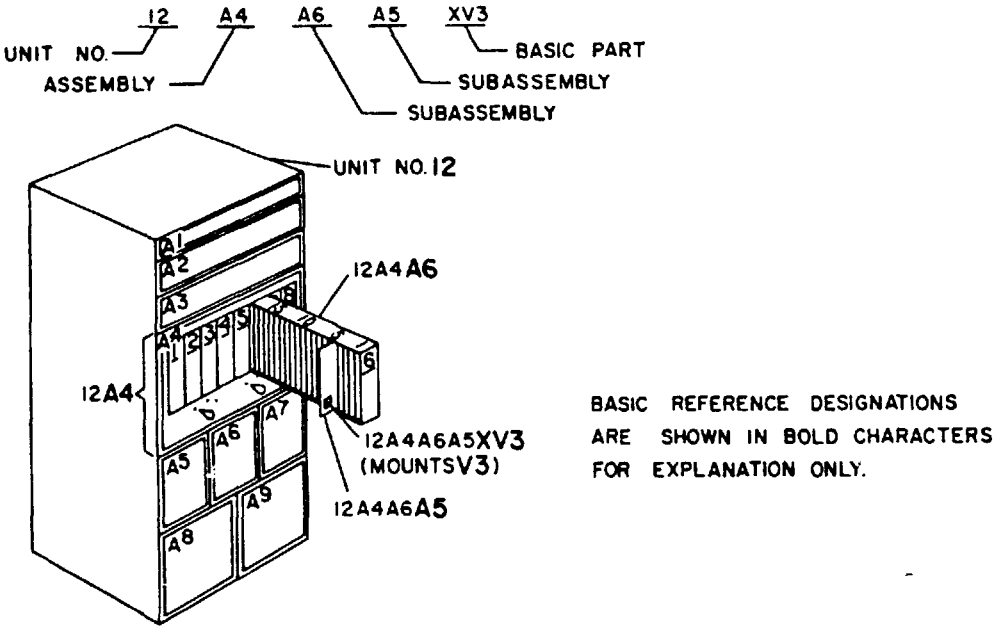


Figure 1-101A-12
APPLICATION OF REFERENCE DESIGNATIONS TO A UNIT

shown in the example of Figure 1-101A-12, unless required by the number of plug-in levels.

1-101A.5.4.6 Subassemblies and Parts Not Integral with Units

Subassemblies (such as interconnecting cables) and parts that are not incorporated within units shall be identified by the use of sequential numbers in the same manner as those that are integral with units, except for the omission of the unit number; for example, cable assembly W15 having a connector at each end, designated W15P1 and W15P2. (See Figure 1-101A-5.)

1-101A.5.4.7 Partial Reference Designations

Partial or basic reference designations shall be used in text, on diagrams, and on units if the appropriate unit and subassemblies are evident. For these applications, the reference designations used shall be permitted to be limited to a sufficient portion of the complete reference designation to identify the subassembly or part; for example, AR1C1, A1AR1, A2, and so forth. (See Figure 1-101A-9.) If parts composing more than one unit are scattered throughout a drawing, a sufficient portion of the complete reference designation shall be included to permit positive identification; for example, A1S1 for switch 1 of assembly 1, where the unit number is evident and has been omitted. On diagrams and units, either complete designations (with respect to the highest level illustrated) or partial designations shall be permitted to be used, if partial reference designations are permitted to be used, a note on the diagram shall be provided; for example:

REF DES PREFIX_____

The appropriate reference designation prefix shall be inserted in the blank space.

When more than one prefix is involved, a note having the intent of note 1, Figure 1-101A-9, shall be added to the drawing.

1-101A.5.4.8 Special Cases

1-101A.5.4.8.1 Identical Units

Different unit numbers shall be used to identify identical units of a set. Except for the unit number, however, the basic reference designations of all subassemblies and parts shall be the same for corresponding items of identical units. For example, if units 3 and 9 are identical, and a particular resistor of unit 3 is designated 3R10, the corresponding resistor of unit 9 shall be 9R10.

1-101A.5.4.8.2 Identical Assemblies and Subassemblies

Different complete reference designations shall be used to identify the following:

1. Identical assemblies in a unit or set, and
2. Identical subassemblies that are part of higher-level subassemblies.

The basic reference designations assigned to the parts within the subassemblies, however, shall correspond in all of the identical, multiple use item. For example, if assembly 3 of unit 6 (designated 6A3) and assembly 4 of unit 8 (designated 8A4) are identical, and a particular capacitor in 6A3 is designated 6A3C11, the corresponding capacitor in 8A4 shall bee 8A4C11.

1-101A.5.4.8.3 INSEPARABLE SUBASSEMBLIES, MODULAR ASSEMBLIES, PRINTED-CIRCUIT BOARDS, AND INTEGRATED-CIRCUIT PACKAGES

Potted, embedded, riveted, or hermetically sealed subassemblies, modular assemblies, printed-circuit boards, integrated-circuit packages and similar items that ordinarily are replaced as a single item of supply shall be treated as parts. Reference designations shall be assigned to identify the items (elements) within such subassemblies if reference to individual items (elements) is required for adequate operation or maintenance information.

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1-101A.6 MARKING ON EQUIPMENT

1-101A.6.1 Marking Requirements for Reference Designations

Equipment shall be permanently and legibly marked with the reference designation for each subassembly and part, except in the following cases:

(1) Where space limitations preclude such marking.
(2) When the customer specifically requires that markings be omitted.
(3) Where it is customary in industry to omit markings on specific nonmilitary products, in which case reference designation markings shall be optional; this exception does not apply to military procurements invoking this standard.

As an alternative in the case of exception (1), diagrams showing the location of parts or subassemblies shall be placed on the subassembly or unit, respectively. The diagrams shall be placed where they will be visible when the parts or assemblies are viewed. If the equipment is not completely marked, or if diagrams are not placed on the unit for any reason, parts location diagrams shall be included in the maintenance data for the set.

1-101A.6.2 Location of Markings

Reference designations shall be located adjacent to each subassembly or part, and shall be marked on the chassis, back of the front panel, on partitions, on insulating mounting strip, and so forth, as appropriate. Reference designations shall not be marked on parts and subassemblies that are subject to replacement if other means are feasible (this does not preclude marking for parts within such subassemblies). The reference designations shall be marked in such a position as to physically locate the parts and yet be readily visible for purposes of maintenance without removal of the part or other parts. The primary intent of this requirement is that removal of a part or subassembly shall not result in the loss of the identification of the physical location of that part or subassembly.

Assemblies or parts that are not integral with units shall be marked on the assembly or part unless they are multiple-use items, which shall carry only part numbers or nomenclature. (See cables in Figure 1-101A-4.)

When equipment is designed for more than one type of mounting (for example, rack-and-panel or transit case), consideration shall be given to maximum visibility of reference designations under all conditions.

Unit numbers shall be marked on the outside of units in a prominent location, to facilitate operation and maintenance.

1-101A.6.2.1 ENCLOSED PARTS

Reference designations for parts that are enclosed in separate removable shields or compartments shall not be marked on the shields or supporting structures for such parts unless the replacement of such parts does not require destruction of the original shields or supporting structures and provided that such shields or supporting structures are not interchangeable with other shields or supporting structures within the unit. Reference designations shall not appear on electron tube shields.

1-101A.6.2.2 PLUG-IN SUBASSEMBLIES AND PARTS, MOUNTING SOCKETS, CONNECTORS

Reference designations for plug-in assemblies and such parts as electron tubes shall be marked next to the sockets, on the plug-in side of the chassis or supporting structure. Reference designations for sockets shall be marked next to the sockets, on the wiring side of the chassis. (See Figure 1-101A-3.)

A fixed connector shall have its reference designation marked adjacent to the connector on the wiring

side. On the plug-in side, a suitable functional designation or the reference designation of the mating connector (see 1-101A.5.3.5.4) shall be marked. If required, the fixed connector reference designation shall also be permitted to be marked on the plug-in side. If space limitations preclude such marking, see 1-101A.6.1.

1-101A.6.2.3 CABLE ASSEMBLIES

Multiple-use cable assemblies or field-fabricated cable runs need not be marked with their reference designations (W) or mating connector designations before installation in the field. The marking of such cables and their connectors with reference designations and mating-connectors identification shall be determined by the permanency of the installation, whether the cable run is completely visible or hidden, and by the actual need for reference designation identification. Cable assemblies having completely identical connectors and connections at both ends shall be marked only with their nomenclature or part number and, if they are single-use special-purpose cables, the W designation assigned. Mating connector identification shall be marked on or adjacent to mating items. Prefabricated special-purpose cables shall have their cable and connector reference designations marked adjacent to the ends.

1-101A.6.3 Partial Reference Designations

If partial reference designations are marked within a unit, a prominent note shall be placed on the unit; for example:

REF DES PREFIX_____

The proper prefix shall be inserted in the blank space.

For those units that are duplicated within a set or are used in more than one set, the unit number shall be omitted in the note and the surface (satin finish) of a space shall be roughened where the reference designation prefix can be marked in by hand. Instructions shall be provided to assure that this space will be filled in before the completion of an installation.

1-101A.6.4 Multiple-Use Assemblies

Reference designations marked on an "identical assembly," as defined in 1-101A.5.4.8.2, or on any subassembly thereof, shall be partial designations as necessary to permit these subassemblies to be used in multiple applications.

1-101A.6.5 Functional Designations

If functional designations that are not in the form of full words or standard abbreviations are used as a result of the requirements of this standard, these functional designations, with their meanings, shall be listed on the drawings and diagrams or in a separate document referenced on the drawings or diagrams, and shall be explained in manuals.

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1-101A.7 CLASS DESIGNATION SYMBOLS

1-101A.7.1 Assignment of Class Designation Letter

The letters identifying the class of an item shall be selected from Table 1-101A-1.

Parts not specifically included in this table shall be assigned a letter or letters from the table below for the part or class most similar in function.

NEMA Standard 7-11-1984.

1-101A.8 GRAPHIC SYMBOLS

1-101A.8.1 Purpose

The purpose of this section is to provide graphic symbols applicable to industrial control, electrical, and electronic diagrams. The symbols are listed in alphabetical order and are typical of symbols used in the electrical control industry. All symbols in this standard are referenced to ANSI Y32.2, *Graphic Symbols for Electrical and Electronic Diagrams,* unless otherwise noted. Symbols and buildups using symbols that have been recommended by the International Electrotechnical Commission are indicated by "IEC." Symbols and buildups that are *unique* to the National Electrical Manufacturers Association are indicated by "NEMA." All other symbols and buildups in this standard are referenced to ANSI Y32.2.

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1-101A.8.2 Definition and Use

Graphic symbols for electrical engineering are a shorthand used to show graphically the functioning or interconnections of a circuit. A graphic symbol represents the *function* of a part in the circuit. Graphic symbols are used on single-line (one-line) diagrams, on schematic or elementary diagrams, or, as applicable, on connection or wiring diagrams. Graphic symbols are correlated with parts lists, descriptions, or instructions by means of designations. See Table 1-101A-2.

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1-101A.8.3 Symbol Principles

(1) The graphic symbols given in Table 1-101A-2 are in general use on industrial control diagrams. Symbols not readily recognizable have been excluded. Other symbols may be used on industrial control diagrams provided a suitable explanation is given as to their meaning.

(2) The orientation of a symbol on a drawing, including a mirror image presentation, does not alter the meaning of the symbol.

(3) The width of a line does not affect the meaning of the symbol. A wider line may be used

Table 1-101A-1
CLASS DESIGNATION

Name	Class Designation Letter
Amplifier, Rotary (all)	G
Annunciator	DS
Armature (Commutor and Brushes)	E
Arrester, Lightning	E
Audible Signal Device,	
Bell	LS
Buzzer	LS
Horn	LS
Assembly,	
Inseparable	U
Separable	A
Battery	BT
Capacitor,	
General	C
Polarized	C
Shielded	C
Circuit Breaker (all)	CB
Coil,	
Blowout	L
Brake	L
Operating	L
Conductor,	
Associated	W
Multiconductor	W
Not Connected	E
Shielded	W
Conductor, General	W
Connector,	
Disconnecting Device, Female	J
Disconnecting Device, Male	P
Contact,	
Electrical	E
Fixed	E
Momentary	E
Time Closing	S
Time Opening	S
Time Sequence	S
Transfer	S
Contact Assembly, Basic	S
Contactor	K
Core,	
Magnetic	E
Diode,	
Bidirectional Breakdown	D, CR
Light Emitting	DS
Metallic Rectifier	D, CR
Semiconductor Rectifier	D, CR
Tunnel	D, CR
Unidirectional Breakdown	D, CR
Field,	
Commutating	L
Compensating	L
Generator or Motor	L
Separately Excited	L
Series	L
Shunt	L
Flasher	S
Fuse	F
Gap, Protective	E
Generator, A.C.	G
Horn Gap	E
Induction Machine Squirrel Cage Induction Generator	G
Induction Machine, Squirrel Cage Induction Motor	B

(cont.)

Table 1-101A-1 (Cont.)
CLASS DESIGNATION

Name	Class Designation Letter
Inductor	L
Jack,	
Receptacle, Female	J
Receptacle, Male	P
Lamp,	
Fluorescent	DS
Incandescent	DS
Indicating	DS
Magnet, Permanent	E
Meter, Instrument	M
Pentode, Equipotential Cathode	V
Photosensitive Cell, Semiconductor	D, CR
Phototube, Single Unit, Vaccum Type	V
Reactor, Saturable Core	L
Rectifier, Full Wave Bridge	D, CR
Relay	K
Resistor,	
Adjustable	R
Heating	R
Tapped	R
Rheostat	R
Shunt,	
Field	L
Instrument	R
Relay	R
Switch,	
Combination Locking and Nonlocking	S
Disconnect	S
Double Throw	S
Drum	S
Flow-Actuated	S
Foot Operated	S
Key-Type	S
Knife	S
Limit	S
Liquid-Level Actuated	S
Locking	S
Master	S
Mushroom Head	S
Pressure or Vacuum Operated	S
Pushbutton	S
Pushbutton Illuminated	S
Rotary	S
Selector	S
Single-Throw	S
Speed	S
Stepping	S
Temperature-Actuated	S
Time Delay	S
Toggle	S
Transfer	S
Wobble Stick	S
Synchro, General	B
Control Transformer	B
Control Transmitter	B
Control Receiver	B
Differential Receiver	B
Differential Transmitter	B
Resolver	B
Torque Receiver	B
Torque Transmitter	B
Synchronous Motor	B
Terminal	E
Terminal Board	TB
Thermal Element Actuating Device	HR
Thermocouple	TC
Thermostat	S
Thyristor	Q
Transformer,	
Current	T
General	T
Polyphase	T
Potential	T

(cont.)

Table 1-101A-1 *(Cont.)*
CLASS DESIGNATION

Name	Class Designation Letter	Name	Class Designation Letter
Transistor, NPN	Q	Winding, General	L
PNP	Q	Wound-Rotor Induction Motor or Induction Frequency Convertor	B
Triode	V	Zener Diode	D, VR
Tube, Mercury Pool	V		
Tube Socket	X		

for emphasis or for power wiring in contrast to control wiring.

(4) The arrowhead or triangle of a symbol may be closed or open, unless otherwise noted.

(5) On a schematic diagram, parts of a symbol for a device, such as a relay or contactor, electron tube or transformer, may be separated. Each of the parts of the device then must carry the same designation.

(6) In general, the angle at which a connecting line is brought to a symbol has no particular significance unless otherwise noted.

(7) Future or optional conductor paths, or associated or optional equipment should be shown by lines composed of short dashes: ------.

(8) An enclosure of device or panel outline may be shown on a wiring or interconnection diagram as a solid line or a series of long dashes.

(9) A pictorial representation may be used as an alternate for any of the wiring and interconnection diagram symbols shown in this standard.

This list mainly contains schematic symbols; some composite symbols are included. However, symbols such as for starters and relays which are built up from several basic symbols are not included.

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1-101A.8.4 Uniformly Shaped Symbols

Rather than create new distinctively shaped symbols for new devices, a uniformly shaped symbol shall be used. The uniformly shaped symbol shall also be permitted to be used as an alternate for any distinctively shaped symbol shown in this standard. The uniformly shaped symbol is a rectangle, properly labeled at the top to designate the type of device it represents and at the bottom to identify the device in a particular circuit. Terminal identification shall be immediately outside the rectangle.

NEMA Standard 7-11-1984.

Examples to illustrate the use of uniformly shaped symbols are shown in Figure 1-101A-13.

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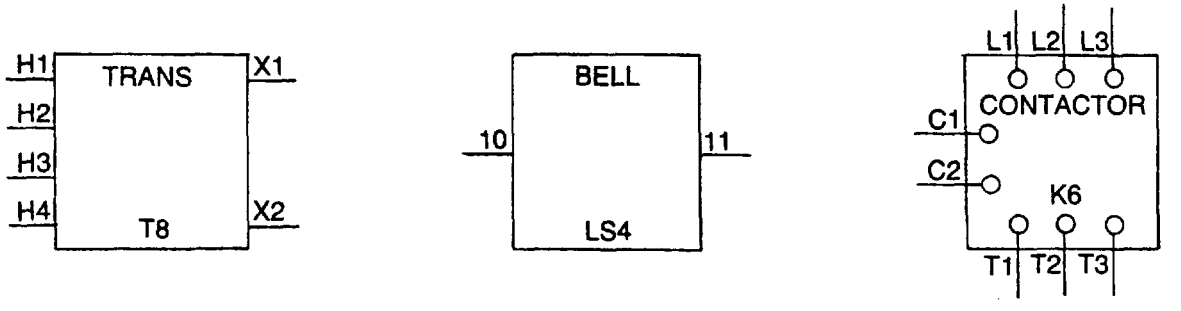


Figure 1-101A-13
UNIFORMLY SHAPED SYMBOLS

1-101A.8.5 Organization of Symbols

Listings identified with a dagger have been approved as Authorized Engineering Information and not as NEMA Standards. The wiring diagram symbol for each such device shall consist of the basic NEMA Standard symbols arranged to represent the particular device and is permitted to vary with the manufacturer.

NEMA Standard 7-11-1984.

When more than one symbol is shown, the first one shown is preferred.

The phrase "see also . . ." is used when there are alternate symbols.

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1-101A.9 TERMINAL MARKINGS

Terminal markings used on connection diagrams for designating connections shall conform to those shown in the applicable standards of NEMA Standards Publication No. ICS 2.

NEMA Standard 7-11-1984.

1-101A.10 SOLID STATE ELEMENTS OR DEVICES

Graphic Symbols for solid state elements used in industrial control and systems diagrams shall comply with ANSI/IEEE Y32.14, *Graphic Symbols for Logic Functions.*

NEMA Standard 7-11-1984.

Table 1-101A-2
GRAPHIC SYMBOLS

ac machine
See **induction machine** and **wound-rotor induction motor**

adjustability

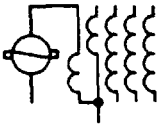
IEC 

adjustable resistor
See **resistor, adjustable**

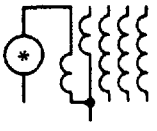
air circuit breaker
See **circuit breaker**

air core
See **core, air**

amplifier, rotary, shunt wound with compensating field winding and short-circuited brushes (regulating generator)

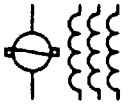


amplifier, rotary, shunt wound with compensating field winding without short-circuited brushes (regulating generator)

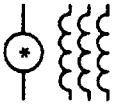


* The asterisk is not part of the symbol. Always add "Arm" within or adjacent to the symbol.

amplifier, rotary, shunt wound with short-circuited brushes (regulating generator)



amplifier, rotary, shunt wound without short-circuited brushes (regulating generator)



* The asterisk is not part of the symbol. Always add "Arm" within or adjacent to the symbol.

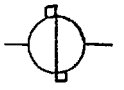
annunciator



anode or plate

IEC 

armature, rotary amplifier with shorted brushes

NEMA 

armature with commutator and brushes



* The asterisk is not part of the symbol. Always add "Arm" within or adjacent to the symbol.

arrester, lightning
See also **gap, protective** and **horn gap**

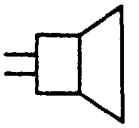
audible signal device (bell)

IEC 

audible signal device (buzzer)

IEC 

audible signal device (horn)



autotransformer

IEC 

battery
The long line is always positive, but polarity may be indicated in addition. Example:

IEC

bell
See **audible signal device**

blowout coil, magnetic
See **coil, blowout**

brake coil
See **coil, brake**

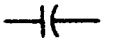
breaker
See **circuit breaker**

bridge rectifier
See **rectifier, full wave bridge**

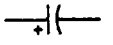
buzzer
See **audible signal device**

cable
See **conductor, general**

capacitor, general

IEC 

capacitor, polarized



(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

capacitor, shielded

IEC 

cathode, cold (including ionically heating cathode)

IEC

cathode, directly heated (filamentary)

Leads shall be permitted to be connected in any convenient manner to ends of the  provided the identity of the is retained.

IEC 

cathode, indirectly heated

Lead shall be permitted to be connected to either extreme end of the  or, if required, to both ends, in any convenient manner.

IEC

cathode, photocathode

IEC 

cathode, pool

IEC 

cell

See **battery**

chassis connection

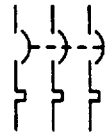
A conducting connection to a chassis or frame, or equivalent chassis connection of a printed-wiring board. The chassis or frame (or equivalent chassis connection of a printed-wiring board) may be at substantial potential with respect to the earth or structure in which this chassis or frame (or printed-wiring board) is mounted.

IEC 

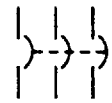
circuit breaker (1 pole nonautomatic without trip unit)

IEC 

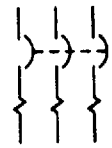
circuit breaker (3 pole automatic with thermal or thermomagnetic trip units

IEC 

circuit breaker (3 pole nonautomagnetic without trip units)

IEC 

circuit breaker (3 pole with only magnetic trip units)

IEC 

clockwise rotation

See **motion, mechanical rotation one direction**

coil, blowout



coil, brake

NEMA  OR  IEC

NEMA Suggested Standard for For Future Design 7-11-1984.

* The asterisk is not part of the symbol. Always replace the asterisk by a Class Designation Letter within or adjacent to the symbol. See Table 1-101A-1.

coil, operating

NEMA OR  IEC

NEMA Suggested Standard for Future Design 7-11-1984.

* The asterisk is not part of the symbol. Always replace the asterisk by a Class Designation Letter within or adjacent to symbol. See Table 1-101A-1.

conductor, associated or future

These are short dashes.



conductor, crossing of paths or conductors not connected

IEC 

conductor, junctions of connected paths, conductors or wires

IEC 

OR ONLY IF REQUIRED BY LAYOUT CONSIDERATIONS

IEC 

conductor, multiconductor cable

Bend of line indicates direction in which other end of path will be found.

IEC 

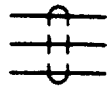
conductor, or conductive path (general)

IEC

conductor, shielded

IEC 

conductor, multiple, shielded



(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

connection, mechanical

IEC

connection, mechanical with interlock

These are short dashes.

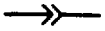
connector, disconnecting device, female

IEC 

connector, disconnecting device, male

IEC 

connector, separable or jacks engaged

IEC 

contact assemblies, basic

The standard method of showing a contact is by a symbol indicating a circuit condition it produces when the actuating device is in the deenergized or nonoperated position. The actuating device may be of a mechanical, electrical, or other nature, and a clarifying note may be necessary with the symbol to explain the proper point at which the contact functions; for example, the point where a contact closes or opens as a function of changing pressure, level, flow, voltage, current, and so forth. In cases where it is desirable to show contacts in the energized or operated condition and where confusion may result, a clarifying note shall be added to the drawing.

Auxiliary switches or contacts for circuit breakers, and so forth, may be designated as follows:

(a) Closed when device is in energized or operated position.

(b) Closed when device is in deenergized or nonoperated position.

(aa) Closed when operating mechanism of main device is in energized or operated position.

(bb) Closed when operated mechanism of main device is in deenergized or nonoperated position.

contact, fixed

IEC 

contact, momentary

IEC 

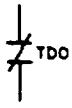
contact, normally closed-break

IEC 

contact, normally closed with time delay closing (off delay)

NEMA 

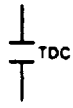
contact, normally closed with time delay opening (on delay)



contact, normally open—make

IEC 

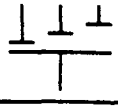
contact, normally open with time delay closing (on delay)



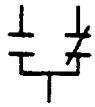
contact, normally open with time delay opening (off delay)

NEMA 

contact, time sequence closing



contact, transfer

IEC 

control switch

See **switch, master**

control transformer

See **transformer, general**

control transmitter

See **synchro**

core, air

If it is necessary to identify an air core, a note should appear adjacent to the symbol of the inductor or transformer.

NO SYMBOL

core, magnetic

Not to be used unless it is necessary to identify a magnetic core



current transformer

See **transformer, current**

d.c. machines

See **armature, field,** and **machine, rotating**

d.c. source

See **battery**

delta connection

IEC △

differential receiver, transmitter

See **synchro-differential receiver, differential transmitter**

diode, bidirectional breakdown

IEC 

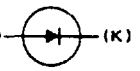
(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

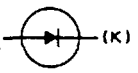
diode, light emitting

IEC 

diode, metallic rectifier

IEC (A) (K) 

diode, semiconductor rectifier

IEC (A) (K) 

diode tunnel

IEC 

diode, unidirectional breakdown (zener)



direct current

IEC

directly heated cathode
See **cathode, directly heated**

disconnect switch
See **switch, disconnect**

double-throw switch
See **switch, double-throw**

drum switch
See **switch, drum**

electrical contact
See **contact**

electrode, anode
See **anode**

electrode, cathode
See **cathode**

electron tube heater
See **heater, electron tube**

envelope

The general envelope symbol identifies the envelope or enclosure regardless of evacuation or pressure. When used with electron-tube component symbols, the general envelope symbol indicates a vacuum enclosure unless otherwise specified. A gas-filled device shall be permitted to be indicated by a dot within the envelope symbol.

IEC 

OR

IEC 

envelope, split

IEC 

equipotential cathode pentode
See **pentode, equipotential cathode**

field, compensating or commutating

IEC 

field, series

IEC 

field, shunt or separately excited

IEC 

fixed contact
See **contact, fixed**

flasher



flow-actuated switch
See **switch, flow-actuated**

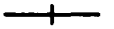
fluorescent lamp
See **lamp, flourescent**

foot operated switch
See **switch, foot operated**

frame connection
See **chassis connection**

full wave bridge
See **rectifier, full wave bridge**

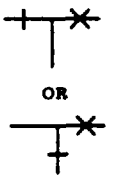
function, switching-conducting, closed contact (break)



function, switching-nonconducting open contact (make)



function, switching-transfer application



fuse

NEMA  OR  IEC

NEMA Suggested Standard for Future Design 7-11-1984.

gap, protective
See also **arrester, lightning** and **horn gap**

These triangles shall not be filled.



generator, ac
See also **armature with commutator and brushes** and **field**

IEC 

generator field
See **field**

(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

generator, regulating
See **amplifier, rotary**

grid, including beam-confining or beam-forming electrodes

IEC

ground, chassis or frame
See also **chassis connection**

(1) A direct conducting connection to the earth or body of water that is a part thereof.

(2) A conducting connection to structure that serves a function similar to that of an earth ground (that is, a structure such as a frame of an air, space, or land vehicle that is not conductively connected to earth).

IEC 

low-noise ground (IEC noiseless, clean earth)

IEC 

safety of protective ground

This symbol shall be permitted to be used in place of the **ground, chassis,** or **frame** symbol to indicate a ground connection having a specified protective function (e.g. for protection against electrical shock in case of a fault).

IEC 

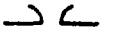
heater, electron tube

IEC

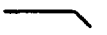
heating resistor
See **resistor, heating**

horn
See **audible signal device**

horn gap
See also **arrester, lightning** and **gap protective**



ignitor, pool tube

IEC 

illuminated pushbutton switch
See **switch, pushbutton, illuminated**

incandescent lamp
See **lamp, incandescent**

indicating lamp
See **lamp, indicating** and **lamp, indicating, push-to-test**

indirectly heated cathode
See **cathode, indirectly heated**

induction machine, squirrel-cage induction motor or generator



inductor
See also **field** and **transformer, general**

IEC

instantaneous polarity marking
See **polarity marking, instantaneous**

instrument meter
See **meter, instrument**

instrument or relay shunt
See **shunt, instrument or relay**

interlock, mechanical
See **connection, mechanical with interlock**

ionically heated cathode
See **cathode, cold**

jack (receptacle, female)

IEC

jack (receptacle, male)

IEC 

key-type switch
See **switch, key-type**

knife switch
See **switch, knife**

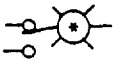
lamp, flourescent (For other than indicating purposes)



lamp, incandescent (For other than indicating purposes)



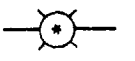
lamp, indicating, push-to-test

NEMA 

* The asterisk is not part of the circular symbol. Always add the letter or letters for colors specified within or adjacent to the circle. To avoid confusion with meter or basic relay symbols, add suffix L or IL to the letter or letters, for example, RL or RIL placed within or adjacent to the circle.

Lamp Indicating Colors:
A - Amber
B - Blue
C - Clear
G - Green
NE - Neon
O - Orange
OP - Opalescent
P - Purple
R - Red
W - White
Y - Yellow

lamp, indicating

NEMA 

* The asterisk is not part of the circular

(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

symbol. Always add the letter or letters for colors specified within or adjacent to the circle. To avoid confusion with meter or basic relay symbols, add suffix L or IL to letter or letters, for example, RL or RIL placed within or adjacent to the circle.

Lamp Indicating Colors:
A - Amber
B - Blue
C - Clear
G - Green
NE - Neon
O - Orange
OP - Opalescent
P - Purple
R - Red
W - White
Y - Yellow

light emitting diode
See **diode, light emitting**

lightning arrester
See **arrester, lightning**

limit switch
See **switch, limit**

liquid-level switch
See **switch, liquid-level actuated**

locking-type switch
See **switch, combination locking and nonlocking** and **switch, locking**

machine, a.c.
See **induction machine** and **wound-rotor induction machine**

machine, rotating
See **induction machine, squirrel-cage motor or generator, wound-rotor induction motor or induction frequency convertor, armature with commutator and brushes,** and **field**

magnet, permanent

IEC 

magnetic blowout coil
See **coil, blowout**

magnetic core of inductor or transformer
See **core, magnetic**

master switch
See **switch, master**

mechanical connection
See **connection, mechanical**

mechanical interlock
See **connection, mechanical with interlock**

mercury pool tube
See **tube, mercury pool**

metallic rectifier diode
See **diode, metallic rectifier**

meter instrument



• The asterisk is not part of the symbol. Always replace the asterisk by one of the following letter combinations, depending on the function of the meter or instrument, unless some other identification is provided in the circle and explained on the diagram.

Function Code:
A - Ammeter IEC
AH - Ampere-Hour Meter
MA - Milliammeter
PF - Power Factor Meter
UA - Microammeter
V- Voltmeter IEC
VA-Volt-Ammeter
VAR-Varmeter
VARH-Varhour Meter
W - Wattmeter IEC
WH - Watthour Meter
(For other functions, use adequate descriptions)

momentary contact
See **contact, momentary**

motion, mechanical, rotation, both directions

IEC 

motion, mechanical, rotation, one direction

IEC 

motion, mechanical, translation, both directions

motion, mechanical, translation, one direction

motor
See **induction machine, squirrel-cage induction motor or generator, wound-rotor induction motor or induction frequency converter armature with commutator and brushes,** and **field**

motor field
See **field**

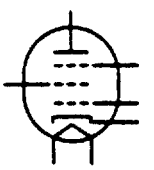
multiconductor cable
See **conductor, multi-conductor cable**

negative polarity
See **polarity marking, negative**

NPN transistor
See **transistor NPN**

operating coil
See **coil, operating**

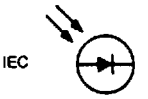
pentode, equipotential cathode

IEC 

permanent magnet
See **magnet, permanent**

photocathode
See **cathode, photocathode**

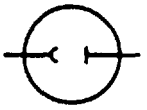
photosensitive cell, semiconductor

IEC 

(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

phototube, single unit, vacuum type

IEC 

pilot light
See **lamp, indicating** and **lamp, indicating, push-to-test**

plate
See **anode or plate**

plug
See **connector, disconnecting device**

PNP transistor
See **transistor, PNP**

polarity marking, instantaneous
The polarity marks shall be placed near one end of each coil or winding symbol. The exact location is immaterial as long as they are unambiguously placed, especially where other windings are drawn nearby. There shall be only one polarity mark per winding, even if the winding is tapped.

IEC 

polarity marking, negative

IEC −

polarity marking, positive

IEC +

polarized capacitor
See **capacitor, polarized**

polyphase transformer
See **transformer, polyphase**

pool cathode
See **cathode, pool**

pool tube ignitor
See **ignitor, pool tube**

positive polarity
See **polarity marking, positive**

potential transformer
See **transformer, potential**

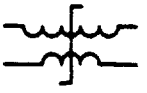
potentiometer
See **resistor, adjustable**

pressure operated switch
See **switch, pressure or vacuum operated**

protective gap
See **gap, protective**

pushbutton
See **switch, pushbutton**

reactor, saturable core

IEC 

receiver, synchro
See **synchro**

receptacle
See **connector, disconnecting device**

receptacle jack, female
See **jack (receptacle, female)**

receptacle jack, male
See **jack (receptacle, male)**

rectifier, diode
See **diode, semiconductor rectifier**

rectifier, full wave bridge

IEC 

rectifier, pool-type cathode
See **tube, mercury pool**

rectifier, silicon controlled
See **thyristor**

regulating generator
See **armature, rotary amplifier with shorted brushes** and **amplifier, rotary**

relay coil
See **coil, operating**

relay shunt
See **shunt, instrument or relay**

resistor

IEC 

• The asterisk is not part of the symbol. Always replace the asterisk by a Class Designation Letter within or adjacent to the symbol. See Table 1-101A-1.

resistor, adjustable

IEC 

• The asterisk is not part of the symbol. Always replace the asterisk by a Class Designation Letter within or adjacent to the symbol. See Table 1-101A-1.

resistor, heating



• The asterisk is not part of the symbol. Always replace the asterisk by a Class Designation Letter within or adjacent to the symbol. See Table 1-101A-1.

resistor, tapped

IEC 

• The asterisk is not part of the symbol. Always replace the asterisk by a Class Designation Letter within or adjacent to the symbol. See Table 1-101A-1.

rheostat
See **resistor, adjustable**

rotary amplifier
See **armature with commutator and brushes, armature, rotary amplifier with shorted brushes,**

(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

machine rotating, and amplifier, rotary

rotary switch
See **switch, rotary**

saturable core reactor
See **reactor, saturable core**

selector pushbutton
See **switch selector, multiposition, with pushbutton type contact mechanism** and **switch, selector, multiposition, pushbutton**

selector switch
See **switch, selector**

semiconductor device
See **diode, rectifier, thyristor,** and **transistor**

series field
See **field, series**

shield, shielding
See **conductor, shielded**

shielded cable or conductor
See **conductor, shielded**

shielded capacitor
See **capacitor, shielded**

shunt field
See **field, shunt, or separately excited**

shunt, instrument or relay
Connect instrument or relay to terminals in the rectangle



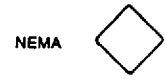
silicon controlled rectifier
See **thyristor, reverse blocking triode type**

speed operated switch
See **switch, speed**

split envelope
See **envelope, split**

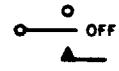
squirrel-cage induction motor or generator
See **induction machine**

static elements or devices†
Any circuit symbol enclosed in a diamond denotes a static element or device.

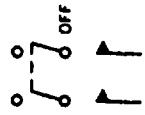


stepping switch
See **switch, stepping**

switch, combination locking and nonlocking, 3 position, 1-pole

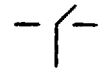


switch, combination locking and nonlocking, 3 position, 2-pole



switch contacts
see **contacts**

switch, disconnect, double-throw, general



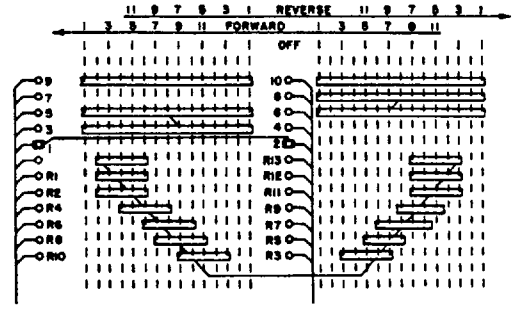
switch, disconnect, single-throw, general



switch, double-throw, general
See **switch, disconnect, double-throw, general**

switch, drum
On elementary diagram, sections of the switch shall be permitted to be separated. Show position indications for each section.

On interconnection diagram, a uniformly shaped symbol shall be permitted to be used omitting segment details.



switch, flow-actuated, closes on increase in flow



switch, flow-actuated, opens on increase in flow



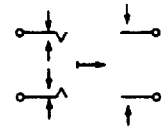
switch, foot-operated, closes by foot pressure



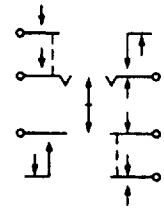
switch, foot-operated, opens by foot pressure



switch, key-type, half of key switch normally operated, multicontact combination



switch, key-type, 3-position, multicontact combination



† Listings identified with a dagger have been approved as Authorized Engineering Information and not as NEMA Standards. The wiring diagram symbol for each such device will consist of the basic NEMA Standard symbols arranged to represent the particular device and will vary with the manufacturer.

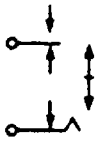
(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

switch, key-type, 2-position with locking transfer and break contacts



switch, key-type, 3-position with nonlocking transfer and locking break contacts



switch, knife, general



switch, limit, directly actuated, spring return normally closed



switch, limit, directly actuated, spring return normally closed—held open



switch, limit, directly actuated, spring return normally open



switch, limit, directly actuated, spring return normally open—held closed



switch, liquid-level-actuated, closes on rising level



switch, liquid-level-actuated, opens on rising level



switch, locking, circuit closing (make)



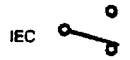
switch, locking, circuit opening (break)



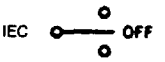
switch, locking, make-before-break



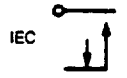
switch, locking, transfer, 2-position



switch, locking, transfer, 3-position



switch, make-before-break



switch, master or control

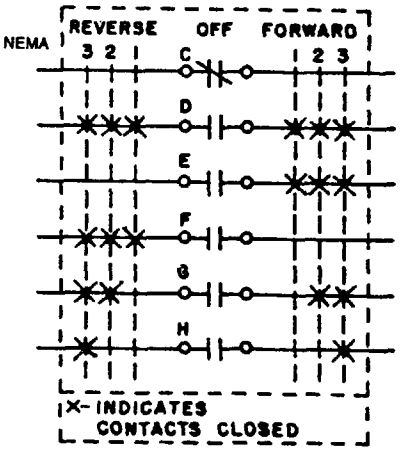
A table of contact operation must be shown on the diagram. A typical table is shown below.

DETACHED CONTACTS SHOWN ELSEWHERE ON DIAGRAM

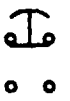
CONTACT	INDICATOR POSITION		
	A	B	C
1 - 2			X
3 - 4	X		
5 - 6			X
7 - 8	X		
X-INDICATES CONTACT CLOSED			

switch, master or control, cam-operated

A table of contact operation must be shown on the diagram. A typical table is shown below. Tabulate special features in note.



switch, mushroom-head, two circuit



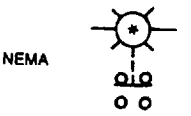
switch, pressure or vacuum operated, closes on rising level



switch, pressure or vacuum operated, opens on rising level



switch, pushbutton, illuminated



* The asterisk is not part of the circular symbol. Always add the letter or letters for colors specified within or adjacent to the circle. To avoid confusion with meter or basic relay symbols, add suffix L or IL to the letter or letters, for example, RL or RIL placed within or adjacent to the circle.

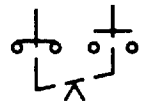
Lamp Indicating Colors:
A - Amber
B - Blue
C - Clear

(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

G - Green
NE - Neon
O - Orange
OP - Opalescent
P - Purple
R - Red
W - White
Y - Yellow

switch, pushbutton, maintained two-circuit



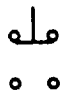
switch, pushbutton, momentary, circuit closing (make)



switch, pushbutton, momentary circuit opening (break)

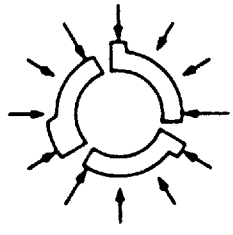


switch, pushbutton, momentary, two-circuit



switch, rotary

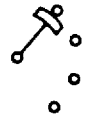
See also **switch, selector**. Viewed from end opposite control knob or actuator unless otherwise indicated. For more than one section, the first section is the one nearest control knob or actuator. When contacts are on both sides, front contacts are nearest control knob.



switch, selector, multiposition, break-before-make

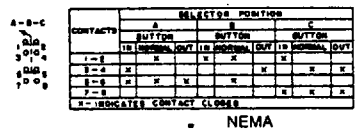


switch, selector, multiposition, make-before-break

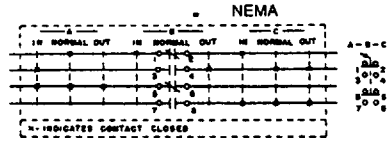


switch, selector, multiposition, push-button†

Show a table of contact operation on the diagram. Point the arrow to the position label which identifies the position in which the contacts are shown when the button is in the normal mode.



NEMA

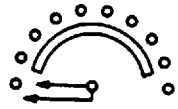


NEMA

switch, selector, multiposition, segmental contact

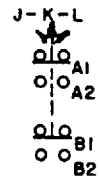


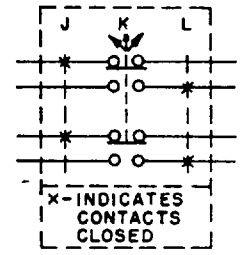
switch, selector, mulitposition, with fixed segment



switch, selector, multiposition, with pushbutton type contact mechanism

Show a table of contact operation if necessary. Point the arrow to the position label which identifies the position in which the contacts are shown.





	J	K	L
A1	X		
A2			X
B1	X		
B2			X

NEMA

switch, single-throw, general

See **switch disconnect, single-throw, general**

switch, speed



switch, speed, anti-plugging



switch, speed, plugging

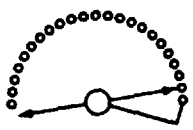


† Listings identified with a dagger have been approved as Authorized Engineering Information and not as NEMA Standards. The wiring diagram symbol for each such device will consist of the basic NEMA Standard symbols arranged to represent the particular device and will vary with the manufacturer.

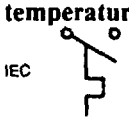
(Cont.)

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

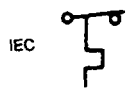
switch, stepping



switch, temperature-actuated, closes on rising temperature



switch, temperature-actuated, opens on rising temperature



switch, time delay, closed switch with time-delay closing (TDC) feature



switch, time delay, closed switch with time-delay opening (TDO) feature



switch, time delay, open switch with time-delay closing (TDC) feature



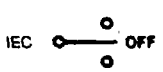
switch, time delay, open switch with time-delay opening (TDO) feature



switch, toggle, maintained, single pole



switch, toggle, maintained, transfer, single pole, three position



switch, toggle, maintained, transfer, single pole, two position



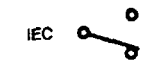
switch, toggle, momentary, circuit closing (make)



switch, toggle, momentary, circuit opening (break)



switch, transfer



switch, wobble stick†



switching, function
See **function, switching**

synchro, control transformer, receiver, transmitter



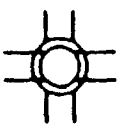
synchro, differential receiver, differential transmitter



synchro, general



synchro, resolver



Type shown: 2-phase rotor and 2-phase stator

synchronous motor



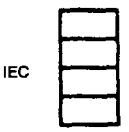
tapped resistor
See **resistor, tapped**

temperature operated switch
See **switch, temperature actuated**

terminal



terminal board



terminal, circuit
See **terminal**

thermal element actuating device



thermocouple



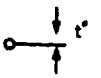
thermostat, closes on rising temperature
See also **switch, temperature activated**



thermostat, opens on rising temperature
See also **switch, temperature activated**



thermostat, transfers on rising temperature
See also **switch, temperature activated**



† Listings identified with a dagger have been approved as Authorized Engineering Information and not as NEMA Standards. The wiring diagram symbol for each such device will consist of the basic NEMA Standard symbols arranged to represent the particular device and will vary with the manufacturer.

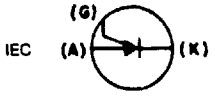
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Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

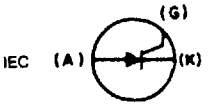
thyristor, bidirectional triode-type; triac; gated switch



thyristor, reverse blocking triode-type, N-type gate



thyristor, reverse blocking triode-type, P-type gate



time delay switch
See **switch, time delay**; see also **contact, time delay**

toggle switch
See **switch, toggle**

torque receiver or transmitter
See **synchro**

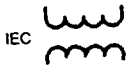
transfer contact
See **contact, transfer**

transfer switch
See **switch, transfer**

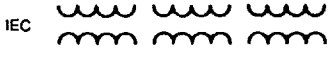
transformer, current
See also **polarity marking, instantaneous**



transformer, general



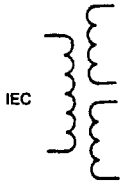
transformer, polyphase



transformer, potential
See also **polarity marking, instantaneous**



transformer, single phase, three winding type



transformer, with magnetic core



transistor, NPN



transistor, PNP



transistor, unijunction, N-type base



transistor, unijunction, P-type base

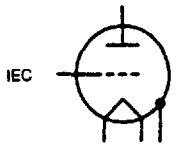


transmission Path
See **conductor**

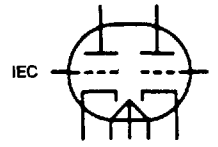
transmitter, synchro
See **synchro**

triac
See **thyristor, bidirectional triode-type; triac; gated switch**

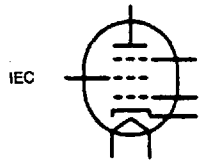
triode, directly heated filamentary cathode



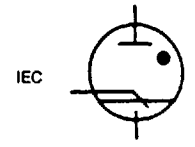
triode, twin equipotential-cathode



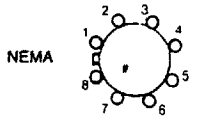
tube, equipotential-cathode pentode



tube, mercury pool, single-anode pool-type rectifier with ignitor



tube, socket



Show tube type number here.

tunnel diode
See **diode, tunnel**

vacuum-operated switch
See **switch, pressure or vacuum operated**

vacuum type phototube, single unit
See **phototube, single unit, vacuum type**

variable
See **adjustability**

(Cont.)

9009279 0000344 883

Table 1-101A-2 *(Cont.)*
GRAPHIC SYMBOLS

winding, general
See also **field** and **transformer**
IEC 

wiring
See **conductor**

wobble stick switch
See **switch, wobble stick**

wound-rotor induction motor or induction frequency converter


wye connection, grounded
IEC 

wye connection, ungrounded
IEC 

zener diode
See **diode, unidirectional breakdown**

Part 1-102

GRAPHIC SYMBOLS FOR LOGIC DIAGRAMS

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified.

Part 1-102 establishes graphic symbols specifically designed for use in the preparation of logic diagrams for systems of two-state devices and sets forth principles governing the formation of graphic symbols for logic diagrams in which connections between symbols are generally shown with lines. See 1-101.3.

The definitions contained in Part 1-100 of this Standards Publication also apply to this part.

DEFINITIONS

1-102.1 DEFINITIONS

application. The standards of 1-102.1 through 1-102.5 are applicable to either positive or negative logic, but no provision has been made for a combination of both within a single system.

Authorized Engineering Information 1-21-1964.

binary notation. A numerical system in which the digits are coefficients of the powers of the radix 2. There are two symbols, 0 and 1.

NEMA Standard 5-21-1962.

For example, binary number 101 is the notation for:

$$1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$

Authorized Engineering Information 5-21-1962.

elements.

FLIP-FLOP. A bistable device which assumes a given stable state depending upon the history of its input or inputs.

NAND. An element which produces an output under all input conditions except when all inputs are energized.

NOR. An element which produces an output if and only if all inputs are deenergized.

NOT. An element which produces an output if and only if its input is deenergized.

OR. An element which produces an output if and only if one or more inputs is energized.

OR, EXCLUSIVE. An element with two inputs which produces an output if and only if either one but not both of its inputs is energized.

NEMA Standard 5-21-1962.

logic function. A storage, delay, or sequential function expressing a relationship between signal input(s) to an element or device and the resultant output(s).

NEMA Standard 1-21-1964.

logic symbol. The graphical representation in diagrammatic form of a logic function.

NEMA Standard 1-21-1964.

negative logic. If the less positive potential (current) is consistently selected as the 1-state, the resultant system or device is said to have negative logic.

NEMA Standard 1-21-1964.

positive logic. If all signal line terminals in a logic diagram of a system or device have the same pair of physical states, and if both are electrical potentials (currents), and if the more positive potential (current) is consistently selected as the 1-state, the resultant system or device is said to have positive logic.

NEMA Standard 1-21-1964.

states in binary logic. The two physical states on each terminal of each signal line shall be referred to as the "0-state" and the "1-state." The 0-state may be called the deenergized (reference) state, and the 1-state the energized (significant) state. This must not be construed as implying that the 1-state requires more power, contains more energy, or is at a higher potential than the 0-state. The state designations are purely arbitrary as far as the physical interpretation is concerned.

NEMA Standard 1-21-1964.

1-102.2 ASSIGNMENT OF LOGIC LEVELS TO BINARY LOGIC ELEMENTS

1-102.2.1 Boolean Truth Tables

Consider a circuit whose output (F) is a function of two variables (A, B), and whose output and input levels are capable of assuming only +2 volts and −3 volts independent of time. Assume that the circuit behaves according to the following table of combinations:

Inputs		Output
A	B	F
−3 volts	−3 volts	−3 volts
−3 volts	+2 volts	−3 volts
+2 volts	−3 volts	−3 volts
+2 volts	+2 volts	+2 volts

In positive logic, the −3 volt level is the 0-state and the +2 volt level is the 1-state. (See 1-102.1.4.) Substitution of the logic values for the voltage levels results in the following Boolean truth table:

Inputs		Output
A	B	F
0	0	0
0	1	0
1	0	0
1	1	1

This is the truth table for the AND function.

In negative logic, the −3 volt level is the 1-state and +2 volt level is the 0-state. (See 1-102.1.5.) Substitution of the logic values for the voltage levels results in the following Boolean truth table:

Inputs		Output
A	B	F
1	1	1
1	0	1
0	1	1
0	0	0

This is the truth table for the OR function.

Each row of the Boolean truth table uniquely describes the behavior of the device for a particular combination of input states. The truth table must include all possible combinations of input states, with one row for each combination. Each row is a complete and independent statement of the behavior of the device and, therefore, need not be read in any particular sequence. The Boolean truth table does not take into account previous history or time dependence of the device.

1-102.2.2 Sequential Truth Tables

Sequential truth tables are extensions of Boolean truth tables, in which time and history are accounted for. These are used to describe the operation of functions, such as FLIP-FLOPS, TIME DELAY and others, in which time or history, or both, are necessary to obtain an understanding of the operation.

Sequential truth tables are read with each horizontal line independent of the others, and the values at a given instant of time are those shown in corresponding vertical columns in each group of multiple columns. The first digit of the group under each input or output shows the state of that input or output during the first time increment. Digits further to the right in the same line show the states at later time increments. A horizontal bar between digits represents time delay in changing from one state to the other state. It is assumed that input signals are maintained long enough to effect complete reset or time delay functions.

Two digits are generally sufficient to describe a TIME DELAY while three or more are required for other functions, such as FLIP-FLOPS.

The following example shows a portion of a FLIP-FLOP truth table:

Inputs			Outputs	
S (Set)	C (Clear)	T (Trigger)	1	0
010	000	000	011	100
010	000	000	111	000

During the first time increment, the first horizontal row in the table shows that the FLIP-FLOP is in the clear (reset) state by showing that the 1 and 0 outputs are respectively in the 0 and 1 states. At the start of the second time increment, the table shows that the FLIP-FLOP changes to the set state by showing that the 1 and the 0 outputs change respectively to the 1 and 0 state. During the third time increment the truth table shows the FLIP-FLOP remains in the set state by showing that the 1 and 0 outputs do not change even though the set input changes to a 0 state.

The apparent anomaly in the table shown here, in which the same input conditions during all time increments result in different output conditions during the first time increment, is basic to any FLIP-FLOP. This indicates the necessity for considering history. It is important to realize that the first column of each group is the result of the history of the element or its starting

point for the sequence being considered on any given row.

NEMA Standard 1-21-1964.

1-102.3 PRESENTATION TECHNIQUES

1-102.3.1 Symbol Shape

Symbol Shape shall be rectangular and preferably square.

1-102.3.2 Symbol Size

Symbol size shall not affect the meaning of the symbol. An effort shall be made to keep all basic symbols of like shape and size.

1-102.3.3 Symbol Line Thickness

Symbol line thickness shall not affect the meaning of the symbol.

1-102.3.5 Symbol Orientation

Symbol orientation shall not affect the meaning of the symbol.

1-102.3.5 Inputs

All inputs shall enter the basic symbols at the leading edge opposite the output only. If more inputs have to enter a symbol than the symbol provides room for, the leading edge shall be extended to provide entry space for these inputs. The extended leading edge shall be permitted to be shown even though not required for this purpose.

1-102.3.6 Signal Flow Direction

When logic diagrams do not completely indicate direction of signal flow by the symbols themselves, the leading edge of the logic symbols shall be extended to show the signal flow direction. Arrowheads superimposed on lines shall be permitted to be used as an additional aid if required.

1-102.3.7 Functional Identification

Functional identification is part of the symbol and shall be located inside and at the top center of the symbol. It shall be larger than any other character contained within the symbol.

When internal input and output identifications are part of the symbol, they shall be permitted to be placed above the identification of the logic function, depending upon symbol orientation.

1-102.3.8 Supplementary Information

Supplementary information, when required, shall be located inside the symbol below the functional identification on tagging lines. Typical supplementary information shall be: physical location, characteristics, and other pertinent data.

NEMA Standard 1-24-1964.

1-102.4 COMBINATION SYMBOLS

NOR, NOT, and NAND, which are actually combinations of basic logic functions rather than being basic logic functions themselves, are frequently implemented as specific elements.

This requires the use of two types of graphic symbology: a unique symbol and a combination symbol. The unique symbol is an application of the general symbol and the combination symbol is an application of the basic symbols of this standard, such as AND and LOGIC NEGATION. (See Table 1-102-1.) Either the unique or the combination symbol shall be used on a single drawing; they shall not be mixed.

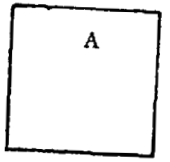
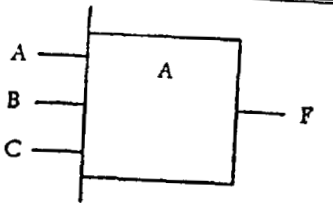
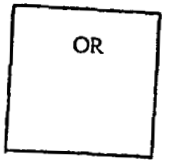
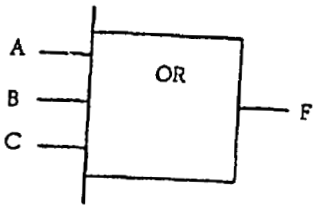
In the case of the combination symbols, the choice of whether to use the AND or the OR approach will be determined in each case by whether negation occurs on the input or the output of the basic element.

It is expected that more complex logic will evolve in the future which will use both negative and positive logic in combination. In such cases the specialized symbols do not lend themselves well to diagram needs.

NEMA Standard 1-21-1964.

1-102.5 GENERAL LIST OF GRAPHIC SYMBOLS

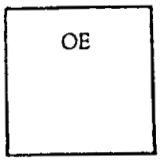
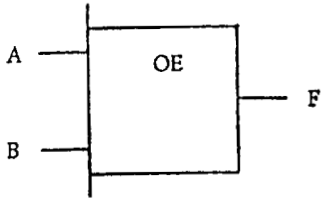
Table 1-102-1
GRAPHIC SYMBOLS

Logic Function	Symbol	Definition	Examples*
AND		The output of an AND assumes the 1-state if and only if all of the inputs assume the 1-state.	 Truth Table: Inputs A B C / Output F: 0 0 0 / 0; 0 0 1 / 0; 0 1 0 / 0; 0 1 1 / 0; 1 0 0 / 0; 1 0 1 / 0; 1 1 0 / 0; 1 1 1 / 1
OR		The output of an OR assumes the 1-state if one or more of the inputs assume the 1-state.	 Truth Table: Inputs A B C / Output F: 0 0 0 / 0; 0 0 1 / 1; 0 1 0 / 1; 0 1 1 / 1; 1 0 0 / 1; 1 0 1 / 1; 1 1 0 / 1; 1 1 1 / 1

* These examples were approved as Authorized Engineering Information 8-19-1964.
All other columns were approved as NEMA Standard 8-19-1964.

(*Continued*)

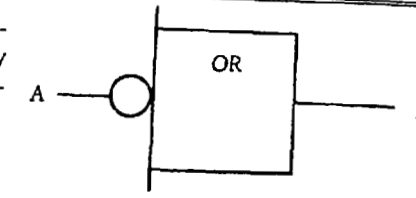
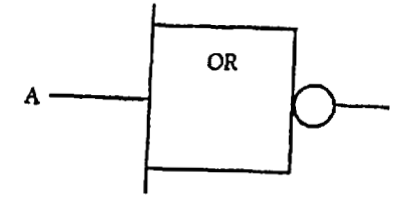
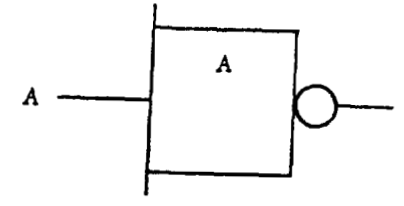
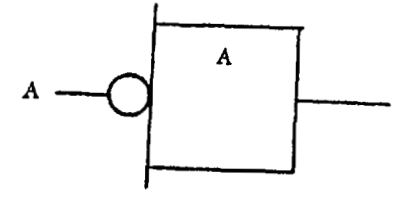
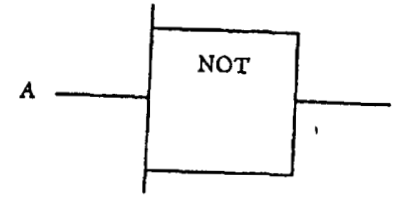
Table 1-102-1 (*Cont.*)
GRAPHIC SYMBOLS

Logic Function	Symbol	Definition	Examples*
EXCLUSIVE OR		The output of an EXCLUSIVE OR with two inputs assumes the 1-state if one and only one input assumes the 1-state.	 Truth Table: Inputs A, B; Output F — 0 0 0; 1 0 1; 0 1 1; 1 1 0
LOGIC NEGATION		The output of LOGIC NEGATION operation takes on the 1-state if and only if the input does not take on the 1-state. It is an auxiliary symbol to be used only with one of the regular symbols to indicate logic negation. A small circle drawn at the point where a signal line joins a logic symbol indicates logic negation.	

* These examples were approved as Authorized Engineering Information 8-19-1964.
All other columns were approved as a NEMA Standard 8-19-1964.

(*Continued*)

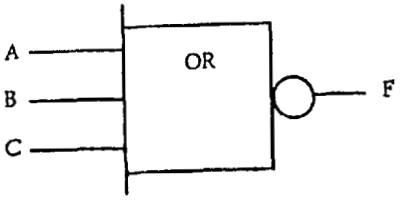
Table 1-102-1 (*Cont.*)
GRAPHIC SYMBOLS

Logic Function	Symbol	Definition	Examples*
NOT	(NOT is not a basic logic function. It can be represented as shown in the examples at the right. See 1-102.4.)	The output of a NOT assumes the 1-state if and only if the input assumes the 0-state.	 Truth Table Input A / Output F 1 / 0 0 / 1
			 Combinational logic representations of the NOT function, such as these first four examples, should be used on drawings made up of basic logic functions.
			
			
			 This last example is a unique representation for the NOT function. Combinational forms shown in the preceding four examples are preferred.

* These examples were approved as Authorized Engineering Information 8-19-1964.
All other columns were approved as a NEMA Standard 8-19-1964.

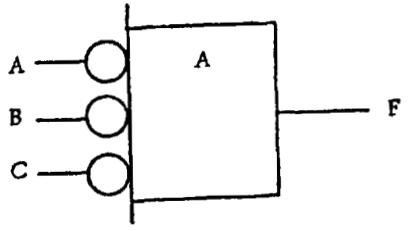
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Table 1-102-1 (*Cont.*)
GRAPHIC SYMBOLS

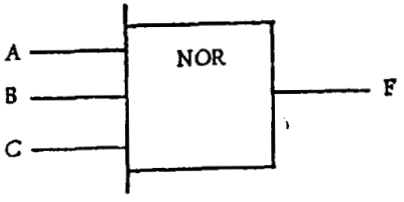
Logic Function	Symbol	Definition	Examples*
NOR	(NOR is not a basic logic function. It can be represented as shown in the examples at the right. See 1-102.4.)	The output of a NOR assumes the 1-state if and only if all inputs assume the 0-state.	

Truth Table (Three-input)

Inputs			Output
A	B	C	F
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0



Combinational logic representations of the NOR function, such as these first two examples, should be used on drawings made up of basic logic functions.

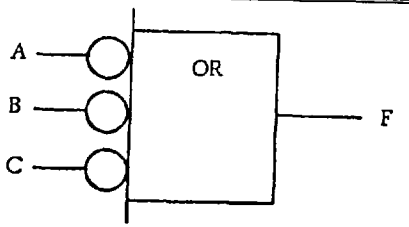


This last example is a unique logic representation for the NOR function and may be used on drawings for systems made up of NOR elements.

* These examples were approved as Authorized Engineering Information 8-19-1964.
All other columns were approved as a NEMA Standard 8-19-1964.

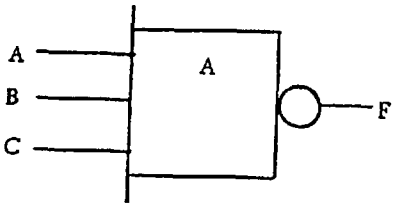
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Table 1-201-1 (*Cont.*)
GRAPHIC SYMBOLS

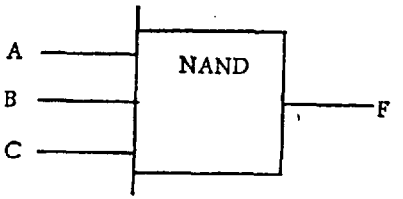
Logic Function	Symbol	Definition	Examples*
NAND	(NAND is not a basic logic function. It can be represented as shown in the examples at the right. See 1-102.4.)	The output of a NAND assumes the 0-state if and only if all inputs assume the 1-state.	

Truth Table (Three-element)

Inputs			Output
A	B	C	F
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0



Combinational logic representations of the NAND function should be used on drawings made up of basic logic functions.

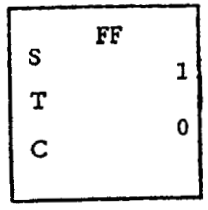
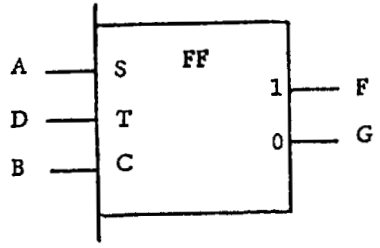


This last example is a unique logic representation for the NAND function and may be used on drawings for systems made up of NAND elements.

* These examples were approved as Authorized Engineering Information 8-19-1964.
All other columns were approved as a NEMA Standard 8-19-1964.

(*Continued*)

Table 1-102-1 (*Cont.*)
GRAPHIC SYMBOLS

Logic Function	Symbol	Definition	Examples*
FLIP-FLOP		A FLIP-FLOP assumes one of two stable states depending upon the history of the input or inputs.	

Truth Table

Inputs			Outputs	
A (S)	B (C)	D (T)	F (1)	G (0)
000	000	010	100	011
000	000	010	011	100
010	000	000	111	000
010	000	000	011	100
000	010	000	100	011
000	010	000	000	111

[The internal designations S (Set), T (Trigger), C (Clear), 1 and 0, when present, are part of the symbol. The set input shall be in proximity to the 1-output; the clear input shall be in proximity to the 0-output.]

There are many forms of a FLIP-FLOP. It frequently has two inputs (set S and clear C) and may have a third input [toggle (trigger) T] and complementary outputs.

A 1 is stored in a FLIP-FLOP when a 1 is first applied to the set input. The 1 (normal) output assumes the 1-state, and the 0 (complementary) output assumes the 0-state.

A 0 is stored in the FLIP-FLOP when a 1 is first applied to the clear input. The outputs then are in the opposite states from what they were when the FLIP-FLOP stored a 1.

The application of a 1-state signal to the toggle reverses the states of the FLIP-FLOP.

When necessary, the results of applying simultaneous signals to the inputs should be explained by means of an accompanying truth table.

* These examples were approved as Authorized Engineering Information 8-19-1964.
All other columns were approved as a NEMA Standard 8-19-1964.

(*Continued*)

Table 1-102-1 (*Cont.*)
GRAPHIC SYMBOLS

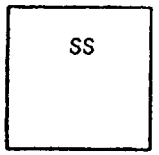
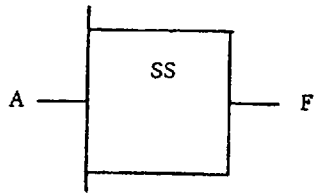
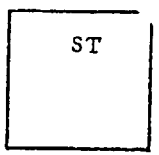
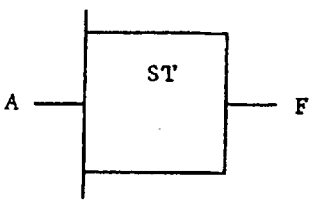
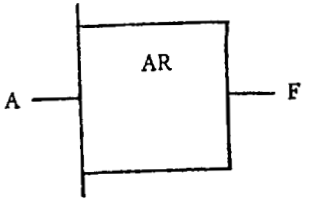
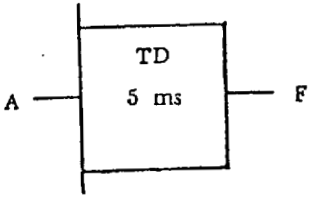
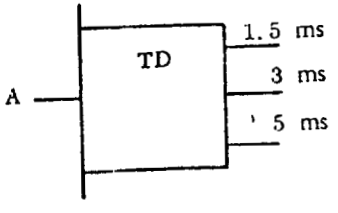
Logic Function	Symbol	Definition	Examples*
SINGLE SHOT		A SINGLE SHOT produces a 1-state output of significant shape and duration when its input assumes a 1-state.	 Truth Table Input A / Output F 0 to 1 to 0 / 0 to 1 to 0 0 to 1 to 1 / 0 to 1 to 0 1 to 1 to 1 / 0 to 0 to 0 1 to 0 to 0 / 0 to 0 to 0 Output signal shape, amplitude, duration and polarity are determined by the circuit characteristics of the SINGLE SHOT, not by the input signal. The normal (inactive) state of the SINGLE SHOT output is the 0-state. When activated by a 1-state input, its output changes to the indicated 1-state, remains there for the characteristic time of the device, and returns to the 0-state. The duration of the on-time of the SINGLE SHOT will normally need to be included on a tag line inside the symbol. When required, waveforms indicating duration, amplitude, and rise and fall time may be used. There may be a complementary output in addition to the output shown.
LEVEL TRIGGER (SCHMITT TRIGGER)		The output of a LEVEL TRIGGER whose inactive state is the 0-state, assumes the 1-state when the input exceeds a specified turn-on level, going in the direction of the 1-state, and the output continues until the input falls below a specified turn-off value going in the direction of the 0-state.	 There may be a complementary output in addition to the output shown.

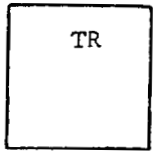
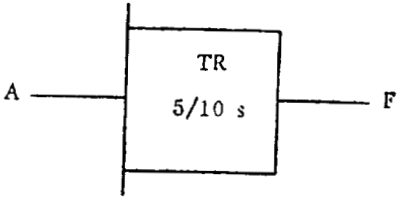
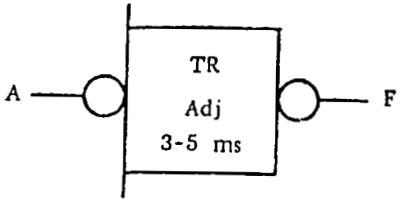
Table 1-102-1 (*Cont.*)
GRAPHIC SYMBOLS

Logic Function	Symbol	Definition	Examples*
SWITCHING AMPLIFIER	AR	The output of a SWITCHING AMPLIFIER assumes the 1-state if and only if the input assumes the 1-state.	 Truth Table: Input A / Output F: 0 / 0; 1 / 1
	(The SWITCHING AMPLIFIER shall be permitted to be either linear or nonlinear. This symbol shall not be used for a proportional amplifier.)		
SIGNAL (TIME) DELAY	TD	In a SIGNAL (TIME) DELAY element, the output reproduces the input after a predetermined time delay.	 The duration of the SIGNAL (TIME) DELAY is included with the symbol on a tagging line.
	(This symbol can be used to represent what is called a delay line.)		 If the element is tapped, the delays with respect to the input should be included at the tap output.

* These examples were approved as Authorized Engineering Information 8-19-1964.
All other columns were approved as a NEMA Standard 8-19-1964.

(*Continued*)

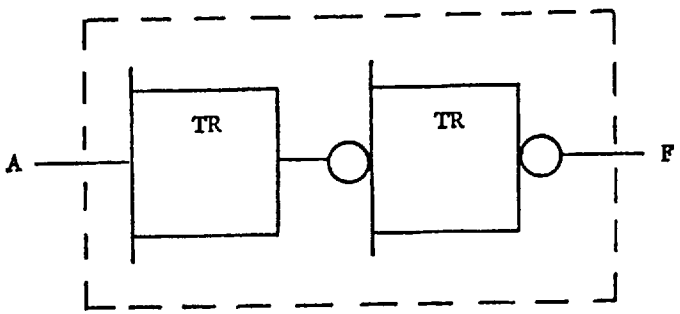
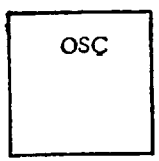
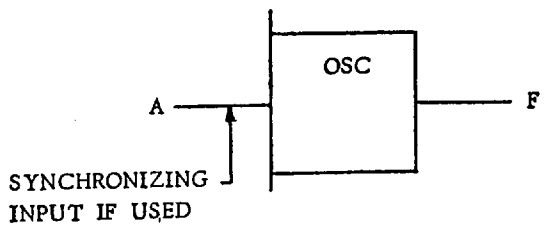
Table 1-102-1 (*Cont.*)
GRAPHIC SYMBOLS

Logic Function	Symbol	Definition	Examples*
TIME DELAY, ON	 (Tag lines shall show the amount of delay or range if adjustable.) (There shall be permitted to be a complementary output in addition to the one shown in the examples.)	The output of a TIME DELAY, ON assumes the 1-state following a definite intentional time interval after its input assumes the 1-state. The output returns to the 0-state with no intentional delay after the input returns to the 0-state. It is assumed that the input signal states are maintained long enough to effect complete time delay or reset functions.	 (either 5-second or 10-second delay) Truth Table Input A / Output F 0 to 0 / 0 to 0 0 to 1 / 0 — 1 1 to 1 / 1 to 1 1 to 0 / 1 to 0 The bar (—) denotes time delay.
TIME DELAY, OFF	 (time delay adjustable from 3 to 5 milliseconds)	The following examples of logic negation in conjunction with the TIME DELAY, ON symbol provide combinational symbols for TIME DELAY, OFF and TIME DELAY, ON AND OFF.	Truth Table Input A / Output F 1 to 1 / 1 to 1 1 to 0 / 1 — 0 0 to 0 / 0 to 0 0 to 1 / 0 to 1 The bar (—) denotes time delay.

* These examples were approved as Authorized Engineering Information 8-19-1964.
All other columns were approved as NEMA Standard 8-19-1964.

(*Continued*)

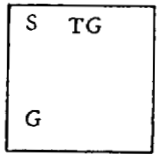
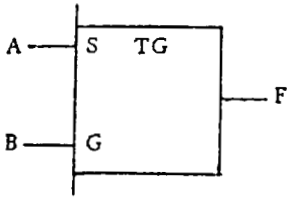
Table 1-102-1 (*Cont.*)
GRAPHIC SYMBOLS

Logic Function	Symbol	Definition	Examples*
TIME DELAY, ON AND OFF			Truth Table Input A: 0 to 0; 0 to 1; 1 to 1; 1 to 0 Output F: 0 to 0; 0 — 1; 1 to 1; 1 — 0 The bar (—) denotes time delay. 
OSCILLATOR		An OSCILLATOR produces an alternating or fluctuating output of a frequency which is self-determined.	 (On tagging lines, indicate the frequency and range of adjustments if applicable.)

* These examples were approved as Authorized Engineering Information 8-19-1964.
All other columns were approved as a NEMA Standard 8-19-1964.

(*Continued*)

Table 1-102-1 (*Cont.*)
GRAPHIC SYMBOLS

Logic Function	Symbol	Definition	Examples*
TRANSMISSION GATE		The input signal (X) to a TRANSMISSION GATE appears at the output only if the gate assumes the 1-state. S = Signal G = Gate	 Truth Table Inputs A B / Output F X 0 / 0 X 1 / X
GENERAL SYMBOL NOT PREVIOUSLY IDENTIFIED	(FUNCTION)	Symbol for functions not elsewhere specified. The symbol shall be adequately labeled to identify the function performed. This shall not be used to describe a function which can be conveniently expressed by a combination of basic logic symbols in this publication. The longer side of the rectangle shall be permitted to be in either the horizontal or vertical plane. Inputs and outputs shall not be on the same side and should perferably be on opposite sides.	Engineering data including a truth table, if applicable, should be provided.

* These examples were approved as Authorized Engineering Information 8-19-1964.

All other columns were approved as NEMA Standard 8-19-1964.

Part 1-103

STATIC SWITCHING CONTROL DEVICES

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified.

The definitions contained in Part 1-100 of this Standards Publication also apply to this part.

1-103.1 GENERAL

Static switching control is a method of switching electrical circuits without the use of contacts (the control primarily includes magnetic amplifiers and solid-state devices).

Static switching control performs functions similar to those of conventionally used relays but without switching contacts. Relays convert a single input to a coil into various outputs by means of its moving armature closing or opening contacts. Static switching control elements convert a single or combination of inputs into outputs by controlling the circuit's impedance or modulation, or both.

The logic terminology associated with static switching control is included herein to illustrate some operating logic functions. The same type of device may perform different control functions in the same equipment depending upon the required functions.

NEMA Standard 11-17-1960.

1-103.2 LOGIC FUNCTIONS, SYMBOLS, AND DEFINITIONS

Device logic functions and symbols are illustrated and defined in Table 1-103-1. They are intended for use on electrical elementary and schematic diagrams to indicate the operating functions. The symbols are a shorthand graphical representation and are not necessarily intended to represent the physical likeness of the device nor certain complete electrical connections.

The symbols may be combined into various circuit adaptations as required by the particular application.

Input terminals on symbols and truth tables are designated by the letters A, B and C, and the output by the letter X. These markings are only for purposes of reference, to explain the functions, and are not terminal or wire markings.

Input terminals are shown on the left side of symbols and output terminals are shown on the right side of symbols.

The number of the symbol inputs may vary because of different designs. They represent typical examples and are not all-inclusive.

With reference to MEMORY, RETENTIVE MEMORY and OFF RETURN MEMORY, the memory input "on" terminals are the upper lines on the symbols. The "off" input terminals (and output terminals, when required) are on the lower lines.

For GATE symbols, the control input is the top left terminal. The power circuit terminals are the right and lower left terminals. (See GATE, NONISOLATED and ISOLATED.)

Return circuit terminals are not shown when directly connected to common or ground. When return circuits need to be shown, the control circuit shall be connected as a top vertical terminal. (For example, see GATES AND SIGNAL CONVERTER WITH RETURN CIRCUITS.)

The term "input" or "output" denotes a signal which is useful or significant to elements of the system.

The terms "on" and "off" denote the presence or absence of an output, respectively. The "off" condition does not necessarily mean that there is no signal.

NEMA Standard 7-12-1961.

1-103.3 DEVICE IDENTIFICATION

Markings on static units shall include the following:

(a) Catalog number.
(b) Manufacturer's identification.
(c) Functional marking (does not apply to multifunction units; e.g., AND, OR, NOT, etc.) as required by the particular application.

NEMA Standard 11-17-1960.

1-103.4 VOLTAGE VARIATION

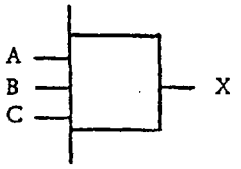
The control system shall operate on a supply voltage from minus 10 percent to plus 10 percent of the rated control system voltage.

NEMA Standard 9-29-1960.

Table 1-103-1
DEVICE LOGIC FUNCTIONS AND SYMBOLS

Logic Function	Symbol	Definitions	Truth Tables

AND

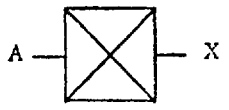


A device which produces an output only when every input is energized.

Truth Table—AND

A	B	C	X
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

NOT

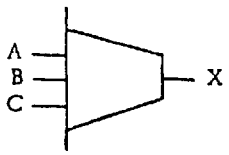


A device which produces an output only when the input is not energized.

Truth Table—NOT

A	X
0	1
1	0

NOR

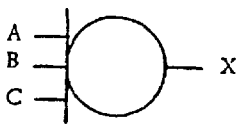


A device which produces an output only when every input is not energized.

Truth Table—NOR

A	B	C	X
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

OR



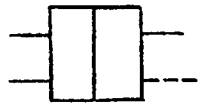
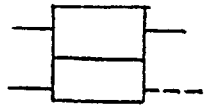
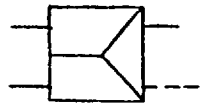
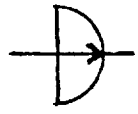
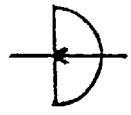
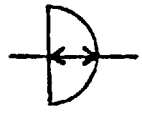
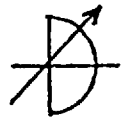
A device which produces an output when one input (or more) is energized.

Truth Table—OR

A	B	C	X
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

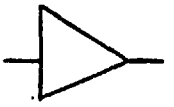
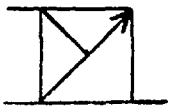
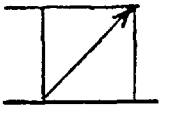
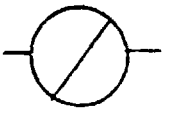
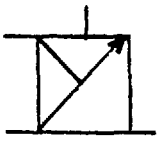
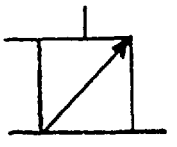
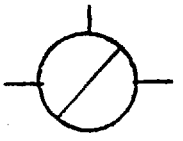
(*Continued*)

Table 1-103-1 (*Cont.*)
DEVICE LOGIC FUNCTIONS AND SYMBOLS

Logic Function	Symbol	Definitions
MEMORY		A device which retains the condition of output corresponding to the input last energized as long as power is maintained.
RETENTIVE MEMORY		A device which retains the conditions of output corresponding to the input last energized.
OFF RETURN MEMORY		A device which retains the condition of output corresponding to the input last energized, except upon interruption of power it returns to the off condition.
TIME DELAY ENERGIZING		A device which produces an output following definite intentional time delay after its input is energized.
TIME DELAY DEENERGIZING		A device whose output is deenergized following a definite intentional time delay after its input is deenergized.
TIME DELAY ENERGIZING AND DEENERGIZING		A device which produces an output following a definite intentional time delay after its input is energized and whose output is deenergized following a definite intentional time delay after its input is deenergized.
ADJUSTABLE TIME DELAY		Otherwise similar to time delay energizing, time delay deenergizing, and time delay energizing and deenergizing.

(*Continued*)

Table 1-103-1 (*Cont.*)
DEVICE LOGIC FUNCTIONS AND SYMBOLS

Logic Function	Symbol	Definitions
AMPLIFIER		A device in which an input signal controls a local source of power to produce an output enlarged relative to the input.
GATE (NON-ISOLATED)		A device which permits current flow in a non-isolated circuit when the control input is energized.
GATE (ISOLATED)		A device which permits current flow in an isolated circuit when the control input is energized.
SIGNAL CONVERTER		A device for changing a pilot signal to a logic input.
GATES AND SIGNAL CONVERTER WITH RETURN CIRCUITS		
GATE		A device which permits current flow in a non-isolated circuit when the control input is energized.
GATE		A device which permits current flow in an isolated circuit when the control input is energized.
SIGNAL CONVERTER		A device for changing a pilot signal to a logic input.

1-103.5 GENERAL ELEMENTS FOR LOGIC DIAGRAM

The general elements for logic diagrams are illustrated in Figure 1-103-1 using the following principles:

(a) Sequence is from left to right.
(b) Inputs to logic elements are shown on left side and outputs on the right side.
(c) "On" input and output for memory are the upper lines and "off" input and output are the lower lines.
(d) Single-line diagram is used and return circuits are omitted.
(e) Power supply is shown at the top.

NEMA Standard 11-17-1960.

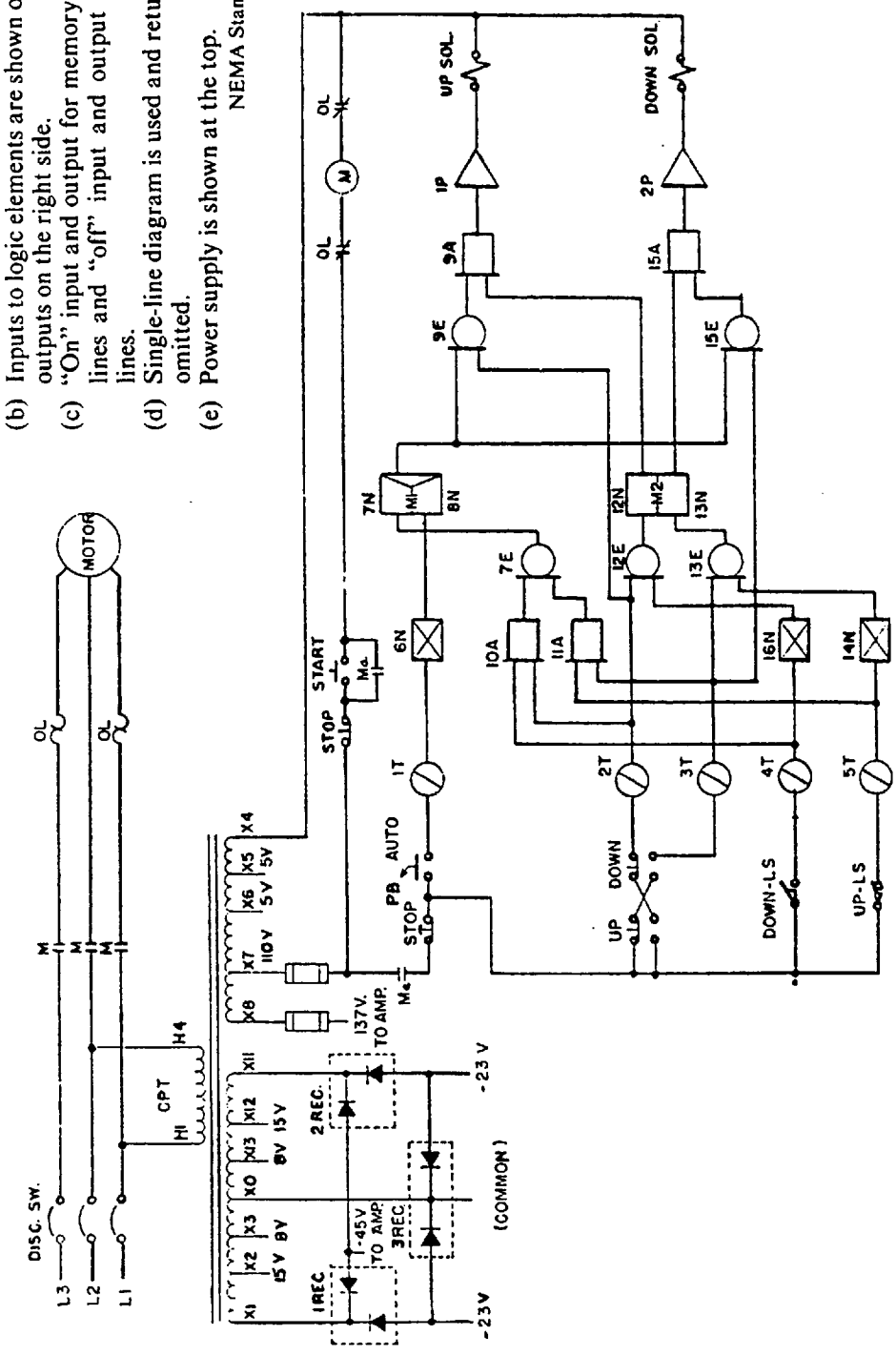
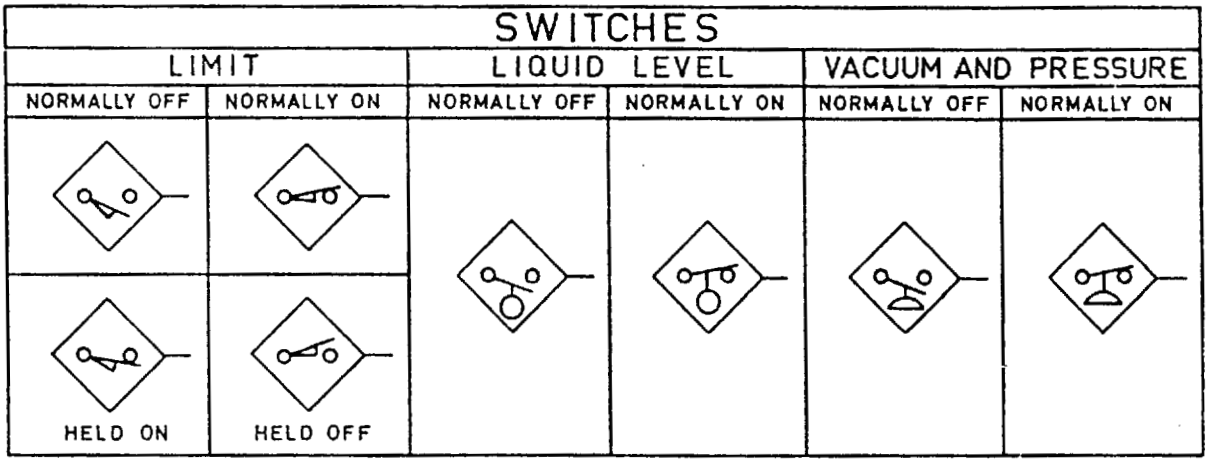


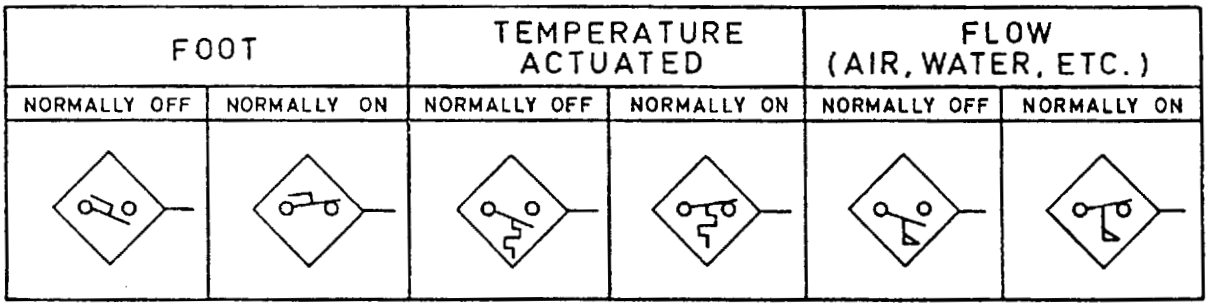
Figure 1-103-1
GENERAL ELEMENTS FOR LOGIC DIAGRAM

1-103.6 SYMBOLS FOR STATIC PILOT DEVICES

The symbols for static pilot devices are given in Figure 1-103-2.

NEMA Standard 3-15-1961.





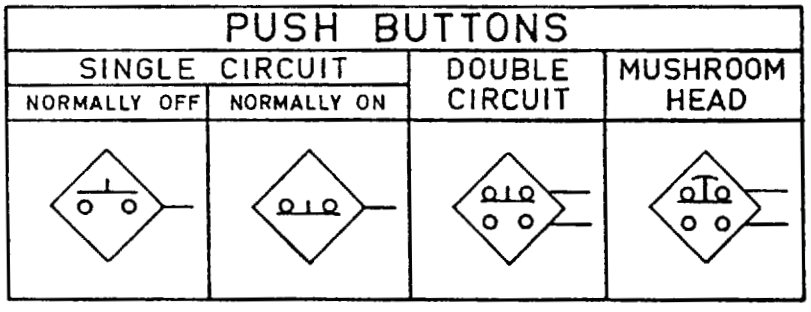


Figure 1-103-2
SYMBOLS FOR STATIC PILOT DEVICES

Part 1-108

SERVICE AND INSTALLATION CONDITIONS

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified.

The definitions contained in Part 1-100 of this Standards Publication also apply to this part.

1-108.1 USUAL SERVICE AND INSTALLATION CONDITIONS

Unless modified by other standards in this publication, apparatus within the scope of the Industrial Control and Systems Section conforming to these standards shall be capable of operation within its performance specifications under the following conditions:

1-108.1.1 Range of Application Temperatures

(a) For equipment that is cooled by air, either ventilated or nonventilated, the temperature of the air outside of the enclosure and the ambient temperature shall be above 0°C but shall not exceed 40°C. For enclosed nonventilated equipment that is cooled by natural air convection, the ambient temperature is the temperature of the air outside of the enclosure in the immediate neighborhood of the equipment. For enclosed ventilated equipment, the ambient temperature is the temperature of the ingoing air.

(b) For equipment that includes water-cooled devices, the ambient temperature surrounding the enclosure shall be above 5°C but shall not exceed 40°C, and the cooling water inlet temperature shall be above 5°C but shall not exceed 30°C.

NEMA Standard 7-17-1973.

(c) If equipment is to be operated at ambient air temperatures exceeding 40°C or at inlet water temperatures exceeding 30°C, the manufacturer should be consulted.

Enclosed industrial control apparatus is designed to operate where the temperature of the air inside the enclosure is above that of the ambient temperature. The specific temperature differential depends upon the heat generated by components and upon the enclosure design; it generally occurs within the range of 5 to 25 °C. The permissible internal air temperature limit depends upon the temperature rating of the components used.

Authorized Engineering Information 7-17-73.

1-108.1.2 Altitude

Altitude Class 1 kM designates equipment for installation where the altitude does not exceed 3300 feet (1000 meters). Altitude Class 2 kM designates equipment for installation where the altitude does not exceed 6600 feet (2000 meters).

NEMA Standard 5-25-1988.

Systems using power semiconductors are usually Class 1 kM. Electromagnetic and manual devices are Class 2 kM.

Authorized Engineering Information 7-17-1973.

1-108.1.3 Storage Temperature

When equipment is stored, the ambient temperature should be above −30°C but should not exceed 65°C. If the storage temperature is below the freezing point of the cooling liquid, the coolant should be removed. If equipment is to be stored for more than 1 week, it may be necessary to cover the equipment and provide a source of heat to prevent condensation. Equipment which is not operated for extended periods may require protection by an internal heater.

Authorized Engineering Information 7-17-1973.

1-108.1.4 Installation and Maintenance

Installation and maintenance should be performed by a qualified person and in accordance with the *National Electrical Code,* ANSI/NFPA Publication No. 70.

Authorized Engineering Information 7-14-1982.

1-108.1.5 Range of Operating Voltage and Frequency

The rms supply voltage shall not deviate more than 10 percent from the rated nameplate value except that, for systems using semiconductor power converters, it shall not deviate more than 10 percent above nor 5 percent below the rated nameplate value.

The supply frequency shall not deviate more than 1 percent from the rated nameplate value.

NEMA Standard 7-17-1973.

1-108.2 TERMINATIONS

Industrial control apparatus is provided with terminations which are suitable for use with copper wire but which may or may not be suitable for use with aluminum wire. If industrial control apparatus is field-wired with aluminum wire, care must be taken to use suitable terminations and wiring techniques.

Authorized Engineering Information 7-17-1973.

1-108.3 ENVIRONMENTAL PROTECTION

Industrial control devices and systems are designed for use in a wide range of environments provided the apparatus is suitably enclosed. (See NEMA Standards Publication No. ICS 6.)

Enclosures cannot protect devices against conditions such as condensation, icing, corrosion, or contamination that originate within the enclosure or that enter via the conduit or unsealed openings. These internal and external conditions, except for the test limits, require considerations beyond the scope of this publication, and the apparatus manufacturer should be consulted.

Authorized Engineering Information 7-17-1973.

1-108.4 OTHER SERVICE AND INSTALLATION CONDITIONS

Conditions that equipment will experience should be evaluated in terms of the manufacturer's designated ratings and limitations. Service conditions that are outside the limits described in ICS 1-108.1 through 1-108.3, or elsewhere in these publications, should be called to the control manufacturer's attention, since special construction or protection may be required. These may include, but are not limited to, the following:

(a) Moisture.
(b) Steam.
(c) Corrosive conditions.
(d) Changes in temperature.
(e) Fungus, insects, vermin, dust, and comparable conditions.
(f) Nuclear radiation.
(g) Unbalanced polyphase power supply system.
(h) Alternating-current power supply with nonsinusoidal wave form.
(i) Vibration and shock.
(j) Radio interference including that generated by the equipment.
(k) Operating duty.
(l) Restriction of ventilation.
(m) Radiated or conducted heat from other sources.
(n) Electrical noise from other sources, such as strong electromagnetic or electrostatic fields.
(o) Power system transient voltages such as those caused by lightning or capacitive and inductive switching.

Authorized Engineering Information 11-14-1985.

Part 1-109

TESTS AND TEST PROCEDURES

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Control and Systems unless otherwise specified.

Part 1-109 covers design (type), production, and application test procedures. For specific design test requirements, see the appropriate product standards. The definitions contained in Part 1-100 of this Standards Publication also apply to this part.

DESIGN TESTS

1-109.1 GENERAL

Design tests shall be performed, as applicable, on one or more representative new samples of apparatus, to demonstrate the conformance of a product design with these standards.

The apparatus to be tested shall be mounted and wired as intended for use in service.

When an enclosure is provided as part of the apparatus, tests shall be made with the apparatus in its enclosure.

NEMA Standard 1-5-1977.

1-109.2 COPPER CONDUCTOR SIZE SELECTION FOR TESTING

The performance of a given industrial control product is often significantly influenced by the size of the wires attached to its terminals while being tested.

1-109.2.1 Control Circuit Devices

For control circuit devices, copper wire should be selected in accordance with Part 2-125 of NEMA Standards Publication No. ICS 2.

1-109.2.2 Power Circuit Devices

For power circuit devices, copper wire should be selected in accordance with Table 1-109-1.

1-109.2.3 Specified Wires

Table 1-109-1 is based on ampacity values as shown in the *National Electrical Code* for three copper conductors in conduit for an ambient temperature of 30 °C using a 60 °C or 75 °C wire insulation temperature as specified by the controller manufacturer with No. 14 AWG wire minimum and 500 MCM wire as a maximum. Size 9 controllers are tested with bus bar or cable.

(a) The wire specified for temperature rise tests for other than motor and resistance heater loads of motor controllers is the smallest wire having an ampacity equal to or greater than the continuous current rating of the controller.

(b) The wire specified for temperature rise and short-time capability tests for motor and resistance heater loads is the smallest wire having an ampacity equal to or greater than 1.25 times the continuous current rating of the controller.

(c) The wire specified for make and break design testing and for fault withstandability (short circuit) testing is the smallest wire having an ampacity equal to or greater than 1.25 times the full-load motor current.

(d) For power apparatus other than motor controllers, the wire size is the smallest wire having an ampacity equal to or greater than the rated continuous current of the apparatus. Conductor sizes are based on the *National Electrical Code* ampacity table for three copper conductors in raceway or cable with 60 °C or 75 °C wire insulation temperature as specified by the controller manufacturer.

(e) It is sometimes necessary for the controller manufacturer to specify wire size as well as insulation temperature in order to maintain overload relay calibration. In such cases, all tests are conducted using the conductor specified.

Authorized Engineering Information 6-12-1985.

Table 1-109-1
COPPER CONDUCTOR SIZE FOR CONTROLLER TESTING (1)

Controller Size	Continuous Current Rating Amperes	Wire Insulation Temperature°C	Temperature Rise. Test (2)	Temp. Rise and Short Time Capability Test (3)	Make and Break Tests and Fault Withstandability Tests of Motor Controller (3PH 60Hz)				
					@200V	@230V	@380V(50Hz)	@460V	@575V
00	9	60 or 75	# 14AWG	#14AWG	#14AWG	#14AWG	#14AWG	#14AWG	#14AWG
0	18	60 or 75	#12AWG	# 10AWG	# 14AWG	# 14AWG	# 14AWG	# 14AWG	# 14AWG
1	27	60	# 10AWG	# 8AWG	# 8AWG	# 10AWG	# 10AWG	#12AWG	# 14AWG
1	27	75	# 10AWG	# 8AWG	#10AWG	#10AWG	#10AWG	#12AWG	# 14AWG
2	45	60	# 6AWG	# 4AWG	# 8AWG	# 6AWG	# 6AWG	# 6AWG	# 8AWG
2	45	75	# 8AWG	# 6AWG	# 8AWG	# 6AWG	# 6AWG	# 8AWG	# 8AWG
3	90	60	# 2AWG	# 0AWG	# 1AWG	# 1AWG	# 1AWG	# 3AWG	# 4AWG
3	90	75	# 3AWG	# 2AWG	# 3AWG	# 3AWG	# 2AWG	# 4AWG	# 6AWG
4	135	75	# 0AWG	# 00AWG	# 0AWG	# 00AWG	# 0AWG	# 00AWG	# 1AWG
5	270	75	300MCM	500MCM	300MCM	350MCM	300MCM	350MCM	250MCM
6	540	75	2-300MCM	2-500MCM	2-300MCM	2-350MCM	2-300MCM	2-350MCM	2-250MCM
7	810	75	3-300MCM	3-500MCM	–	3-350MCM	–	3-350MCM	3-250MCM
8	1215	75	4-350MCM	4-500MCM	–	4-500MCM	–	4-400MCM	4-300MCM
9	2250 (4)								

(1) On size 6 and larger where parallel conductors are used, the conductor sizes are based on the use of not more than three conductors per conduit.

(2) Use wire size in this column when controller does not include overload relays and, in addition, includes a current rating equal to the continuous current rating.

(3) Use wire size in this column when controller includes overload relay selection tables for currents up to the continuous current rating. Different wire sizes may apply for temperature rise test when different maximum currents are implied.

(4) Busbar or cable-connected, as specified between control manufacturer and user.

TEMPERATURE RISE DESIGN TESTS

1-109.10 TEMPERATURE RISE TEST PROCEDURE

For temperature rise tests, operating coils and heat generating components shall be energized and contacts shall carry rated current.

The wire size shall be in accordance with Table 1-109-1, unless wire size is specified by the control manufacturer. The type of insulation is not specified, but its color shall be black. If the insulation temperature specified by the controller manufacturer is 60°/75°C, the wire size selection shall be for 75°C insulation.

NEMA Standard 6-12-1985.

1-109.10.1 Ambient Temperature During Tests

Temperature rise tests shall be made at any ambient temperature between 10 and 40°C. It is assumed that the temperature rise is identical for all ambient temperatures between 10 and 40°C.

The ambient temperature shall be measured by several thermometers or thermocouples placed at different points around the apparatus, and protected from drafts and abnormal heat radiation. For forced cooled equipment, thermometers or thermocouples shall be located in the incoming path of the cooling medium.

The ambient temperature during a test is the average of the ambient readings taken at equal intervals of time during the last quarter of the duration of the test. The ambient temperature during this period shall have stabilized to within a range of 2°C.

NEMA Standard 1-5-1977.

1-109.10.2 Altitude

Temperature tests shall be made at any altitude of 3300 feet (1000 meters) or less for Class 1 kM apparatus and 6600 feet (2000 meters) or less for Class 2 kM apparatus, and no correction shall be applied to the observed temperature rise.

NEMA Standard 1-5-1977.

1-109.10.3 Temperature by Direct Measurement

Temperature shall be determined by thermocouples applied to the hottest points accessible to a thermocouple or by other methods giving equivalent results. The junction of a thermocouple shall be in intimate thermal contact with the part under evaluation to assure reading the true temperature of the part to be measured.

NEMA Standard 1-5-1977.

The size of thermocouple wires should be small enough so that they will not conduct sufficient heat away from the part and materially change its temperature. Wire size 30 AWG is recommended. If the part whose temperature is to be measured is a spring loaded part, such as a movable contact, the thermocouple wires should be arranged so as not to materially affect the spring loading.

Authorized Engineering Information 1-5-1977.

The temperature of stationary parts shall be measured during the progress of the test. Temperatures of movable parts shall be taken during the test if practicable and, in any case, as soon as possible after completion of the test run. When the temperature shall also be measured after the completion of the test run, and the highest figures obtained shall be used.

When ratings require test for very short periods or at very heavy loads, the specified rating shall be permitted to be replaced for test purposes by an equivalent continuous rating, or by an equivalent periodic rating having a longer duration than that specified in the following paragraphs:

(a) *Continuous Rating*—The temperature test shall be continued until the temperature rise has attained a steady final value as indicated by no more than 2 percent change in temperature rise in three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 10-minute intervals.

(b) *Periodic Rating (Including Intermittent Duty)*—The temperature test shall be made in accordance with the periods of load and rest specified by the rating of the apparatus and shall be continued for the total time required by the rating, with the final temperature reading taken at the end of the last "ON" period.

(c) *Continuous Rating (Equivalent to Periodic Rating)*—A continuous rating equivalent to the periodic rating shall be calculated for devices that carry intermittent heavy loads for short periods by the following formula:

$$I_{equivalent} = \sqrt{\frac{I_1^2 t_1 + I_2^2 t_2 + I_3^2 t_3 + \ldots I_n^2 t_n}{t_1 + t_2 + t_3 + \ldots . t_n}}$$

Where—

The sum of $t_1 + t_2 + t_3$ and so forth, through t_n totals the averaging period, including times "t" when I is zero.

NEMA Standard 1-5-1977.

1-109.10.4 Temperature by Resistance Method

The average coil temperature can be determined by measuring its resistance, if the resistance at some other temperature is known. The calculations are based on the fact that metals have zero resistance at "inferred absolute zero," which for electrical grade copper is −234.5°C, and for electrical grade aluminum is −225°C.

Thus—

For copper:

$$\frac{R_2}{R_1} = \frac{T_2 + 234.5}{T_1 + 234.5} \text{ and } T_2 = \frac{R_2}{R_1}(234.5 + T_1) - 234.5$$

For aluminum:

$$\frac{R_2}{R_1} = \frac{T_2 + 225}{T_1 + 225} \text{ and } T_2 = \frac{R_2}{R_1}(225 + T_1) - 225$$

Where—

R_1 and R_2 are resistances, measured in ohms, and T_1 and T_2 are corresponding coil temperatures in degrees Celsius.

The temperature rise is the difference between the calculated temperature and the ambient temperature.

Authorized Engineering Information 1-5-1977.

1-109.11 TEMPERATURE RISE OF COILS

The temperature rise of coils above the ambient temperature, when the coils are tested in accordance with their ratings while mounted in the device with which they are intended to function, shall not exceed the values given in Table 1-109-2. The temperature rise of shunt coils shall be determined by the resistance method. The temperature rise of series coils shall be determined by either the resistance method or direct measurement, whichever is more practicable.

NEMA Standard 1-5-1977.

1-109.12 INSULATION CLASSES

The temperature limits on which the ratings of electrical apparatus are based are largely determined by the character of the insulation materials used.

Insulation is considered to be "impregnated" when a suitable substance provides a bond between components of the structure and also a degree of filling and surface coverage sufficient to give adequate performance under the extremes of temperature, surface contamination (moisture, dirt, etc.) and mechanical stress expected in service. The impregnant must not flow or deteriorate enough at operating temperature so as to seriously affect performance in service.

The electrical and mechanical properties of the insulation must not be impaired by the prolonged application of the limiting insulation temperature permitted for the specific insulation class. The word "impaired" is used here in the sense of causing any change which could disqualify the insulating material for continuously performing its intended function, whether creepage spacing, mechanical support, or dielectric barrier action.

For the purpose of establishing temperature limits, insulating materials are classified as follows:

1-109.12.1 Class A Insulation

Materials or combinations of materials such as cotton, silk, and paper when suitably impregnated or coated or when immersed in a dielectric liquid such as oil. Other materials or combinations of materials shall be permitted to be included in this class if, by experience or accepted tests, they can be shown to be capable of operation in control equipment at the temperature rises shown in Table 1-109-2.

1-109.12.2 Class B Insulation

Materials or combinations of materials such as mica, glass fiber, asbestos, and so forth, with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, shall be permitted to be included in this class if, by experience or accepted tests, they can be shown to be capable of operation in control equipment at the temperature rises shown in Table 1-109-2.

1-109.12.3 Class C Insulation

Insulation that consists entirely of mica, porcelain,

Table 1-109-2
LIMIT OF TEMPERATURE RISE ABOVE AMBIENT TEMPERATURE (40°C MAXIMUM), DEGREES C

Type of Coil	Method of Temperature Determination (See 1-109.10 and 1-109.11)	Class of Insulation[1]				
		O	A	B	C	H
Insulated shunt coils	Resistance	70	85	105	No limit specified	160
Insulated series coils	Direct Measurement	50	65	85	No limit specified	125
Insulated series coils	Resistance	70	85	105	No limit specified	160
Single-layer series coils with uninsulated or enameled exposed surfaces	Direct Measurement	...	90[2]	...	No limit specified	...

[1] The temperature rises shown in this table are based on many years of satisfactory experience and many tests by the industrial control industry with coils designed to, and operated at, the temperature rise limits indicated.

[2] This applies to coil having a fiber or some other similar insulating sleeve or collar which insulates the coil from the frame or core.

glass, quartz, and similar inorganic materials. Other materials or combinations of materials shall be permitted to be included in this class if, by experience or accepted tests, they can be shown to be capable of operation in control equipment at temperatures above 220°C.

1-109.12.4 Class O Insulation

Materials or combinations of materials such as cotton, silk, and paper without impregnation. Other materials or combinations of materials shall be permitted to be included in this class if, by experience or accepted tests, they can be shown to be capable of operation in control equipment at the temperature rises in Table 1-109-2.

1-109.12.5 Class H Insulation

Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, and so forth, with suitable bonding substances such as appropriate silicone resins. Other materials or cominations of materials shall be permitted to be included in this class if, by experience or accepted tests, they can be shown to be capable of operation in control equipment at the temperature rises shown in Table 1-109-2.

NEMA Standard 8-20-1962.

1-109.13 TEMPERATURE RISE OF CONTACTS

The temperature rise of contacts above the ambient temperature, when the contacts are tested in accordance with their ratings, shall not exceed the following:

(a) *Silver, Silver-faced and Silver-cadmium-oxide Contacts*—The temperature rise is limited solely by the necessity to avoid damage to the contacts themselves or to adjacent parts.

Damage is any deterioration such as loosening of parts, cracking, flaking of material, loss of temper of springs, annealing of parts, etc., which would impair the normal life of the device.

(b) *Copper Contacts*
(1) Laminated Brush Contacts—50°C.
(2) Solid Contacts in Air (8-Hour, Duty)—65°C.

(c) *Contacts in Oil*—65°C.

(d) *All Other Contacts in Air (8-Hour, Duty)*—65°C.

The temperature rise shall be determined by direct measurement. See 1-109.10.3.

This standard does not apply to contacts which are mounted directly on resistor elements.

NEMA Standard 1-5-1977.

1-109.14 TEMPERATURE RISE OF BUSES AND CONNECTING STRAPS

The temperature rise of buses and connecting straps, above the ambient temperature, when this equipment is tested in accordance with its rating, shall not exceed 65°C. The temperature rise shall be determined by direct measurement. See 1-109.10.3.

This standard does not apply to connectors to a source of heat (for example, resistors, thermal heaters, power-tube anodes, power semiconductors, or magnetic devices with insulation Classes B or higher).

NEMA Standard 5-17-1971.

1-109.15 TEMPERATURE RISE OF FIELD WIRING TERMINALS

The temperature rise of field wiring terminals, above the ambient temperature, when the equipment is tested in accordance with its rating, shall not exceed the following:

Conductor Insulation Rating Specified by Controller Manufacturer	Temperature Rating of Conductor*	Maximum Temperature Rise of Terminal
60°C	60°C	50°C
60°C/75°C	60°C 75°C	50°C 65°C
75°C only	75°C	65°C

*for conductor size selected from the *National Electrical Code*, Table 310-16.

The temperature rise shall be determined by direct measurement. See ICS 1-109.10.03

NEMA Standard 6-12-1985.

1-109.20 DIELECTRIC TEST FUNDAMENTALS

A representative new sample apparatus designed in accordance with Part 1-111, having appropriate insulation material, proper configuration, and properly assembled will pass the dielectric tests for Part 1-109 under normal laboratory conditions.

A representative new sample apparatus designed in accordance with Part 1-111A will pass the dielectric Tests for Part ICS 1-111A under normal laboratory conditions.

Authorized Engineering Information 9-26-1988.

Insulation deterioration during the service life of electrical apparatus results from various combinations of such causes as progressive aging, moisture, mechanical damage, and excessive voltage stress. In addition, the electrical apparatus is usually exposed to pollution and

transient overvoltages. Because of the impracticability of making tests involving all these factors, it has been the practice to test new insulation at a voltage appreciably greater than its rated insulation voltage.

A dielectric test consists of the application of a voltage higher than the rated insulation voltage for a specific time for the purpose of determining the adequacy against breakdown of insulation under the transient overvoltage conditions which are likely to be encountered in normal installations.

A contactor make and break design test, short time capability test, etc., is often followed by a power frequency (50, 60 Hertz or dc) dielectric test as a check on possible insulation deterioration.

Power frequency dielectric tests may be used as production tests to check for pinched wires, tramp metal, etc.

Impulse tests are dielectric tests conducted to simulate overvoltage due to lightning or switching. The impulse is a single voltage pulse with a specified rise time, decay time, and crest value.

Authorized Engineering Information 1-5-1977.

1-109.21 POWER FREQUENCY DIELECTRIC TEST PROCEDURES

The procedures for power frequency dielectric design tests are described in the following paragraphs:

1-109.21.1 Precautions

Since the dielectric test voltage is greater than rated voltage, care must be taken not to apply the test voltage in a manner that simulates energization of a circuit. For example, a power frequency dielectric test voltage higher than the rated voltage of a starter coil should not be applied across the terminals of the coil. Higher than rated voltage applied to a coil winding is not considered an adequate check for shorted turns. Power frequency dielectric testing of coils should be limited to checking for isolation between coil and external metal parts such as the magnet assembly of a relay or between coils that should be isolated, such as the primary and secondary windings of a control transformer. Likewise, power frequency dielectric test voltages should not be applied across meter terminals, lamp terminals, motor terminals, semiconductor components, varistors, and the like. For apparatus assemblies that include such components, the recommendation of the applicable standard should be used.

Authorized Engineering Information 5-25-1988.

1-109.21.2 Points of Application

The output of the power frequency high potential (dielectric) tester shall be applied:

(a) Between each field wiring terminal which is designed to be isolated from the chassis and the chassis (ground). Field wiring terminals of circuits containing contacts shall be tested with the contacts in both the open and closed positions.

(b) Between terminals of opposite polarity. If a power frequency dielectric test is used with conductive components such as thyristors, coils, varistor, etc., connected between these terminals, one side shall be disconnected in order to prevent damage to these components.

(c) Between each circuit and each other circuit which is designed to be isolated from each other. The input terminals of each circuit rated less than 51 volts ac rms or dc shall be shorted and tied to a common point and the isolation from each other circuit rated more than 50 volts ac rms or dc, verified.

(d) Between each circuit which is designed to be isolated from the chassis, and the chassis (ground).

NEMA Standard 5-25-1988.

1-109.21.3 DC Dielectric Tests

Some products may be constructed with capacitance coupling which results in undesirable ac current while undergoing a power frequency dielectric test. This undesired current may be very small but sufficient to damage (overheat or overvoltage, or both) components or may appear to be a high leakage current. In such cases, a dc test voltage equivalent to the peak ac value specified may be used.

Authorized Engineering Information 1-5-1977.

1-109.21.4 Test Apparatus

Power frequency design dielectric testing shall be done with a high potential dielectric strength tester having a means of adjusting output voltage. The test apparatus shall have a means to eliminate overshoot or transients.

The ac test voltage shall be 50 or 60 Hertz and shall approximate a sinewave. The test voltage shall not drop more than 10 percent when the load is increased from zero to the indicating current.

NEMA Standard 1-5-1977.

The light or buzzer, or both, used to indicate breakdown shall have a response time of not more than 25 milliseconds at an output current of 2 milliamperes per 1000 volts applied and should be calibrated to indicate failure with an output current between 1.5 and 2.0 miliamperes per 1000 volts applied (the indicating current).

NEMA Standard 5-25-1988.

1-109.21.5 Measurement of Test Voltage

The test voltage shall be measured by a voltmeter. In measuring the voltage, the voltmeter shall derive its voltage from the high voltage circuit either directly or, when alternating current, through an auxiliary ratio transformer, or from the voltmeter winding of the testing transformer.

NEMA Standard 1-5-1977.

1-109.21.6 Duration of Test Voltage

The test voltage for all switching and control apparatus shall be applied continuously for a period of 60 seconds. Apparatus or devices shall be permitted to be tested for 1 second with a test voltage which is 20 percent higher than the 60-second test voltage.

NEMA Standard 1-5-1977.

1-109.21.7 Ambient Test Conditions

Dielectric tests shall be conducted at room temperature and up to 95 percent relative humidity at a test location up to 2000 meters in altitude, with the apparatus under test deenergized.

NEMA Standard 1-5-1977.

1-109.21.8 Test Values

The voltage used for power frequency dielectric testing shall be as shown in Table 1-109-3.

Working voltage is the voltage to which the parts concerned are subjected under conditions of normal use when the equipment is applied on a circuit having a nominal system voltage corresponding to the equipment rated voltage. See Part 1-112.

For parts supplied with a voltage different from the main system voltage, working voltage is the voltage measured across the parts in normal service.

For testing isolation between circuits having different voltage ratings, the test voltage shall be based on the higher rating.

NEMA Standard 9-15-1982.

For clearances only, and for point to plane electrodes, the empirical data have shown that a power frequency dielectric test of "P" volts rms is approximately equivalent to an impulse dielectric test crest voltage of 1.85P. A power frequency dielectric test has a higher energy content than an equivalent impulse dielectric test. As a matter of convenience a power frequency test may be substituted for an impulse test where the tested apparatus can withstand the higher energy content.

Authorized Engineering Information 1-5-1977.

1-109.21.9 Test Criteria

An apparatus which is tested for loss of isolation or insulation is considered to have met the performance requirements if all of the following criteria are met:

(a) The light or buzzer indicator set in accordance with 1-109.21.4 does not operate.

(b) There is no indication, such as smoke, odor, sparkover or sustained arching, that the insulation is deteriorating.

NEMA Standard 5-25-1988.

Table 1-109-3
POWER FREQUENCY DIELECTRIC TEST VOLTAGES FOR GENERAL USE (WHERE TRANSIENT VOLTAGES ARE NOT KNOWN AND CONTROLLED)

Voltage Rating, Volts (RMS) or DC	Test Voltage (RMS) for Groups A, B, and C
0–50	500 volts
51–600	1000 Volts + (2 × nominal voltage rating)
601–5000	2000 Volts + (2-1/4 × nominal voltage ratings)

Figure 1-109-1
IMPULSE VOLTAGE TEST CIRCUIT
(Under consideration)

1-109.22.1 Impulse Test Apparatus

(Under consideration)

1-109.22.2 Calibration

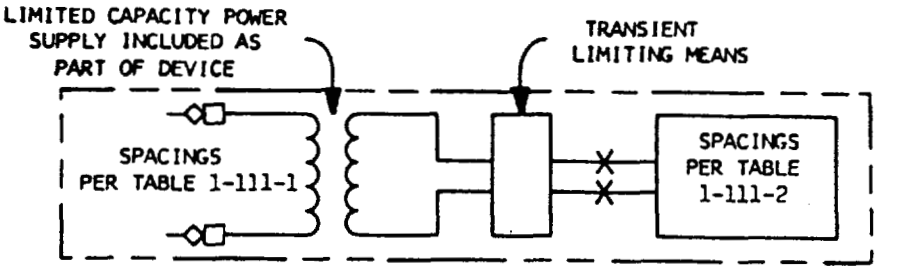
(Under consideration)

1-109.22.3 Ambient Test Conditions

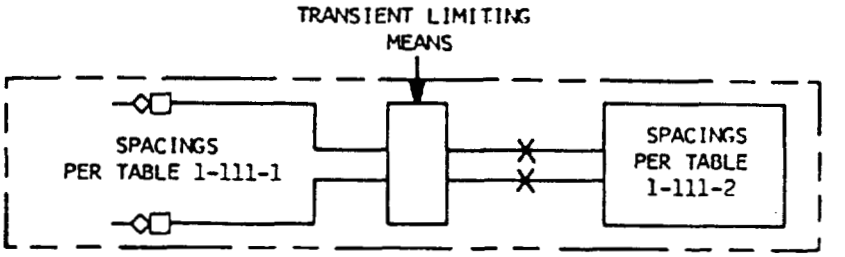
(Under consideration.)

1-109.22.4 Points of Application

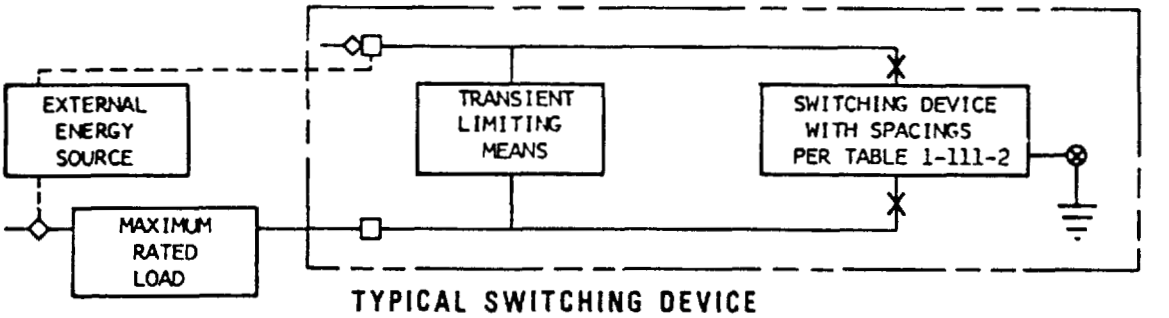
(Under consideration.)



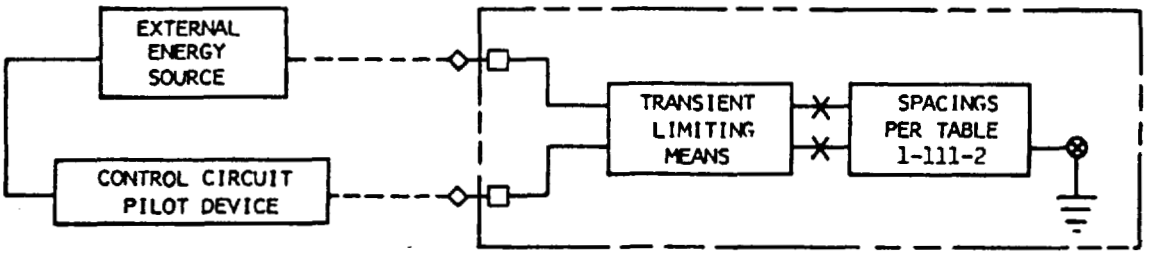
TYPICAL FOR GROUPS F & G



TYPICAL FOR GROUP E



TYPICAL SWITCHING DEVICE



TYPICAL CONTROL CIRCUIT INPUT

DEFINITIONS OF SYMBOLS:
◇ = POINTS OF APPLICATION.
X = POINTS WHERE OVERVOLTAGES ARE MEASURED.
□ = UNRESTRICTED FIELD WIRING TERMINALS.
– – – – – = CONNECTIONS REMOVED FOR TEST.
——– – – ——= SCOPE OF DEVICE BEING TESTED.

Figure 1-109-2
IMPULSE TEST POINTS

1-109.22.5 Points of Transient Voltage Measurement

(Under consideration)

1-109.22.6 Extent of Test

(Under consideration.)

1-109.22.7 Test Criteria

(Under consideration.)

1-109.23 OVERVOLTAGE WITHSTANDABILITY REQUIREMENTS

(Under consideration.)

OPERATING DESIGN TESTS

1-109.30 OPERATING VOLTAGE TESTS

The ability of an operating coil which is part of a control device to withstand a specified percentage above its rated voltage shall be verified by applying the specified overvoltage until the temperature of the coil has stabilized in a 40°C ambient. There shall be no evidence of insulation deterioration during the test.

The ability of a device with an operating coil to perform successfully at less than rated voltage shall be demonstrated by applying the specified undervoltage suddenly to the coil after the coil has reached a constant temperature at rated coil voltage in a 40°C ambient, or an equivalent coil temperature.

NEMA Standard 1-5-1977.

1-109.31 VIBRATION TEST PROCEDURE

1-109.31.1 Requirements

Vibration withstand tests, when specified in a product standard, shall require industrial control equipment to be capable of operating in its intended mannner after being subjected to a sinusoidal vibration of a specified excursion, over a specified range of frequencies that change at a specified rate for a specified time period.

For equipment with contacts the vibration withstand test requirement shall additionally include a maximum time period for contact change of state (from open to closed or vice versa) during the test.

NEMA Standard 5-25-1988.

The amplitude and highest frequency combine to produce a maximum acceleration. A typical vibration withstandability requirement should include:

Excursion
(double amplitude): _____inches, peak to peak
Frequency: _____Hertz, linear
(or logarithmic) ramp
Duration: _____minute
Maximum acceleration: _____g
Maximum contact discontinuity: _____milliseconds
Other evaluation criteria: _____

The vibration caused by an earthquake is usually at a frequency less than 60 Hertz. The natural frequency of a large rigidly mounted punch press is likely to be greater than 1000 Hertz.

Authorized Engineering Information 1-5-1977.

1-109.31.2 Test Method

The equipment being tested shall be mounted as intended for service except no conduit shall be attached to enclosed devices nor shall auxiliary supports such as capillary tubes for temperature switches, pipes for pressure switches, couplings for rotary cam or speed switches, and so forth, be attached. The device being tested shall be unwired except as required to monitor contact operation. The equipment being tested shall be vibrated in each of three mutually perpendicular planes, one plane to be parallel to the plane of the panel to which the device is mounted for the specified time period. Devices with contacts shall be tested in both the operated and unoperated states. The test load specified in 1-109.52 shall be used to detect circuit discontinuity.

NEMA Standard 5-25-1988.

1-109.31.3 Test Criteria

Equipment that is capable of operating in its intended manner after the vibration withstand test and has no essential adjustment disturbed is considered to have met the vibration withstand test requirements. In addition, equipment with contacts must not have a contact change of state (from open to closed or vice versa) for a longer time period than specified in the vibration withstand requirement.

NEMA Standard 5-25-1988.

1-109.32 SHOCK TEST PROCEDURE

1-109.32.1 Requirements

When shock withstand requirements are specified for industrial control equipment, they shall be expressed as a requirement to withstand without damage or excessive contact discontinuity four half sine shock pulses of a specified acceleration amplitude delivered over a specified time period (duration) in each direction along three mutually perpendicular axes, as six separate tests.

NEMA Standard 5-25-1988.

The velocity change (V_i) associated with an ideal half sine shock pulse is related to the specified pulse peak amplitude (A) and the specified pulse duration (D) as follows: $V_i = 2AD/\pi$.

A typical shock withstandability requirement should include:

Half sine wave duration (D): _____milliseconds
Peak acceleration (A) on X axis _____g
Peak acceleration (A) on Y axis _____g
Peak acceleration (A) on Z axis _____g
Maximum contact discontinuity: _____milliseconds
Other evaluation criteria: _____
Definitions of axes X, Y and Z: _____

Authorized Engineering Information 1-5-1977.

1-109.32.2 Test Method

The equipment being tested shall be mounted as intended for service, except that no conduit shall be attached to enclosed devices nor shall auxiliary supports such as capillary tubes for temperature switches, pipes

for pressure switches, couplings for rotary cam or speed switches, etc., be attached. The equipment being tested shall be unwired except as required to monitor contact operation. The leads to monitor contact operation and energize coils shall be the minimum cross section considered necessary to safely handle the electrical load. They shall be extremely flexible and have sufficient slack that they do not have a dampening effect on the device being tested. No accelerometer shall be attached to the equipment under test. The equipment being tested shall be mounted in place of an identical item used to calibrate the shock machine. Four shocks of the specified peak acceleration and duration shall be applied in each direction along each of the three mutually perpendicular axes. Devices with contacts shall be tested with one-half the number of shocks in each of the operated and unoperated states. The load specified in 1-109.52 shall be used to detect contact discontinuity. Contacts are considered to be open or closed when the device is deenergized by virtue of the state they assume after the device is mounted for test, e.g., a normally open contact on a vertical action magnetic relay may become a closed contact when the device is deenergized and mounted upside down on a free fall shock machine.

NEMA Standard 1-5-1977.

1-109.32.3 Shock Machine Calibration

The device being tested or an identical device in terms of mass and center of gravity shall be mounted as prescribed for testing except that no leads for coils or contacts shall be attached. An accelerometer having a fundamental resonant frequency greater than 30,000 Hertz shall be rigidly secured to the mounting panel for the device being tested as near as possible to an attachment point for the specimen but not on the specimen itself. Instrumentation shall be used to convert the accelerometer output to an oscillogram or retained oscillograph trace of acceleration versus time. The shock machine shall be adjusted to produce a trace within the ±15 percent tolerances shown in Figure 1-109-3 and thus produce an actual velocity change (V) which is within 10 percent of the velocity change (V_i) of an ideal acceleration (shock) pulse. The actual velocity change (V) is calculated by the formula: $V = 2(A_{actual})(D_{actual}) \div \pi$, provided A_{actual} falls within the limits (0.85 to 1.15) shown in Figure 1-109-3.

NEMA Standard 5-25-1988.

1-109.32.4 Test Criteria

If after completing the prescribed number of shock pulses the equipment is damaged or has disturbed an adjustment essential to its proper operation, the equipment is considered to have failed. In addition, if the device being tested had a contact which changed state (from open to closed or vice versa) for a longer time period than specified in the shock withstand requirements, the device is considered to have failed. Equipment which is not damaged by the 24 shock pulses and does not have a contact discontinuity which exceeds the specified limit is considered to have met the shock withstand requirements.

NEMA Standard 5-25-1988.

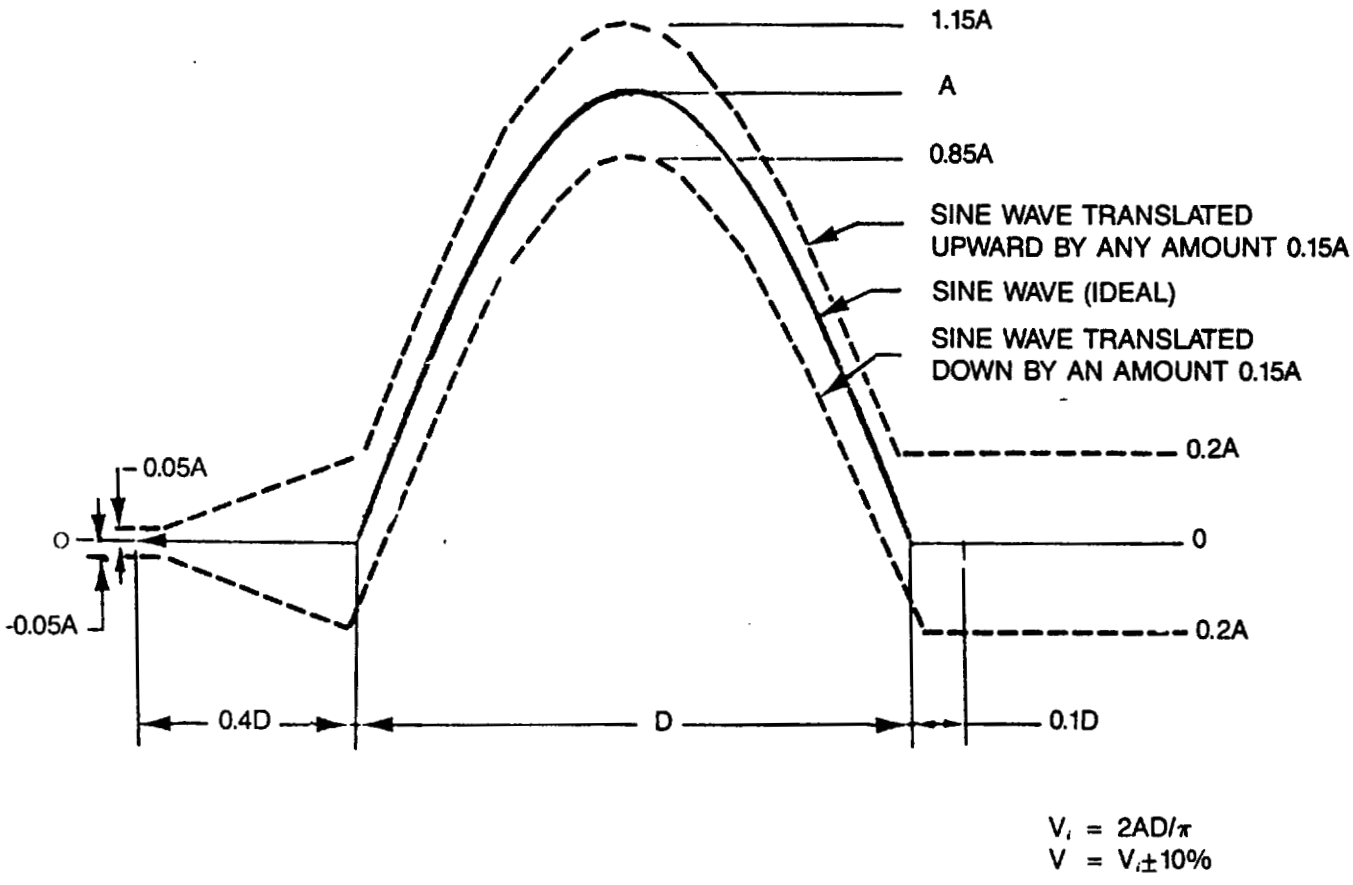


Figure 1-109-3
TOLERANCE FOR HALF SINE SHOCK PULSE

NOTE—The oscillogram should include a time about 3D long with the pulse located approximately in the center. The integration to determine velocity change should extend from 0.4D before the pulse to 0.1D beyond the pulse. The acceleration amplitude of the ideal half sine pulse is A and its duration is D. Any measured acceleration pulse which can be contained between the broken line boundaries is a nominal half sine pulse of nominal amplitude A and nominal duration D. The velocity change associated with the measured acceleration pulse is V. (This note is approved as Authorized Engineering Information.)

PRODUCTION TESTS

1-109.40 FACTORY TEST FOR INDUSTRIAL SYSTEMS

An industrial automatic system may consist of a number of coordinated subsystems, components and sensors. The overall system, including its subsystems, may be tested as a unit. Where this is not done, reasonably equivalent reference inputs, sensors and directly controlled variables shall be used to make factory adjustments and to check sequencing and overall operation.

The purpose of simulation during factory testing is to aid the manufacturer in making factory adjustments and checks. In most circumstances, it is not the purpose to demonstrate final performance by simulation nor to make final adjustments.

Authorized Engineering Information 1-5-1977.

1-109.41 PERFORMANCE TESTING

Manufacturers of industrial control equipment establish performance criteria for each of their products and conduct the checking they consider necessary to provide assurance that products shipped meet these performance criteria. This checking may include adjustments, settings, visual inspection, dielectric, operating and similar tests. Performance testing may be on a 100 percent or on a sample basis, depending upon the product involved, and the control of parts which make up the product.

Authorized Engineering Information 1-5-1977.

APPLICATION TESTS

1-109.50 APPLICATION TESTS

Application tests are those tests performed by a manufacturer to determine those operating characteristics which are not necessarily established by standards but which are of interest in the application of devices.

NEMA Standard 1-5-1977.

1-109.51 DETERMINATION OF OPERATING CHARACTERISTICS OF CONTACTORS AND RELAYS

The operating characteristics of electromagnetic contactors and relays should be determined at both extremes (high and low) of the standard operating voltage range.

1-109.51.1 Operate Time

Operate time is the elapsed time measured from initial control circuit energization to the initial touch of normally open contacts or initial break of normally closed contacts.

1-109.51.2 Effective Actuation Time

Effective actuation time is the elapsed time measured from initial control circuit energization to the time the contacts of a normally open device close and remain closed or the contacts of a normally closed device open and remain open. Effective actuation time includes any contact bounce or chatter time occuring due to the operation of the device being tested.

1-109.51.3 Release Time

Release time is the elapsed time measured from initial control circuit deenergization to the initial opening of a normally open contact or the initial closing of a normally closed contact.

1-109.51.4 Instrumentation

Operating characteristics are measured with equipment having adequate response time such as oscillographs, storage oscilloscopes, or digital electronic counters.

Authorized Engineering Information 1-5-1977.

1-109.52 BOUNCE TIME FOR CONTROL CIRCUIT DEVICES

When the contacts of a control circuit device control the input to an extremely fast relay or solid state logic system it is important to know maximum contact bounce or chatter time so that appropriate action can be taken to preclude false operation of the fast acting devices. Thus it is maximum contact bounce time that is of interest in control circuit devices. This maximum should include secondary bounce if it is present.

Contact bounce time is the period of time between the initial closing of a circuit by a set of contacts and the start of continuous current conduction by the contacts. This bounce time is sometimes referred to as distributed bounce time. The contact bounce of electromagnetic devices should be determined throughout the operating

voltage range. That bounce which occurs as contacts first close and rebound is called primary contact bounce. That bounce which occurs as a result of the actuation means seating or rebounding in electromechanical devices is called secondary bounce. In some cases, secondary bounce will occur before primary bounce has subsided. In other cases, contacts will be at rest when secondary bounce occurs.

Because contact bounce is the result of so many variables, each apt to be operating in a different manner at different times, a single device is likely to show a different contact bounce time from operation to operation, and from pole to pole with normally open poles performing differently from normally closed poles.

1-109.52.1 Test Load

A test load of 100 milliamperes maximum at 24 Vdc maximum measured under closed circuit conditions should be used to measure contact bounce time.

1-109.52.2 Test Apparatus

The contacts being evaluated should be connected as shown in Figure 1-109-4. A filter consisting of R2 and C1 as shown may be added to negate the inductance of the power supply and slow the rise and fall times of the test signal.

The instrument used to measure contact bounce duration should permanently record or retain the bounce signal trace until manually removed or reset, have a frequency response of at least 10 kHz and be capable of detecting a series of bounces each 25 microseconds or longer in duration.

No other test equipment such as motion transducers, accelerometers, and so forth, should be attached to the test device while contact bounce time is being measured.

The instrument should be triggered by the leading edge of the bounce signal, not by the voltage applied to the coil. (See Figure 1-109-5.) To prevent false triggering at the oscilloscope, an external circuit may be required to:

(a) Prevent arming of the oscilloscope trigger circuit until just before contact touch, or

(b) Blank the trace (i.e., reduce the intensity below visible level) at all times except during the anticipated contact bounce time interval.

1-109.52.3 Test Conditions

The test device should be mounted as intended for use in service with all parts of the device at room temperature. An electrically operated device should be supplied with coil voltage varied throughout the standard range of the operating voltage. The rate of operation should be slow enough to assure that the contacts have stopped moving before starting the next operation.

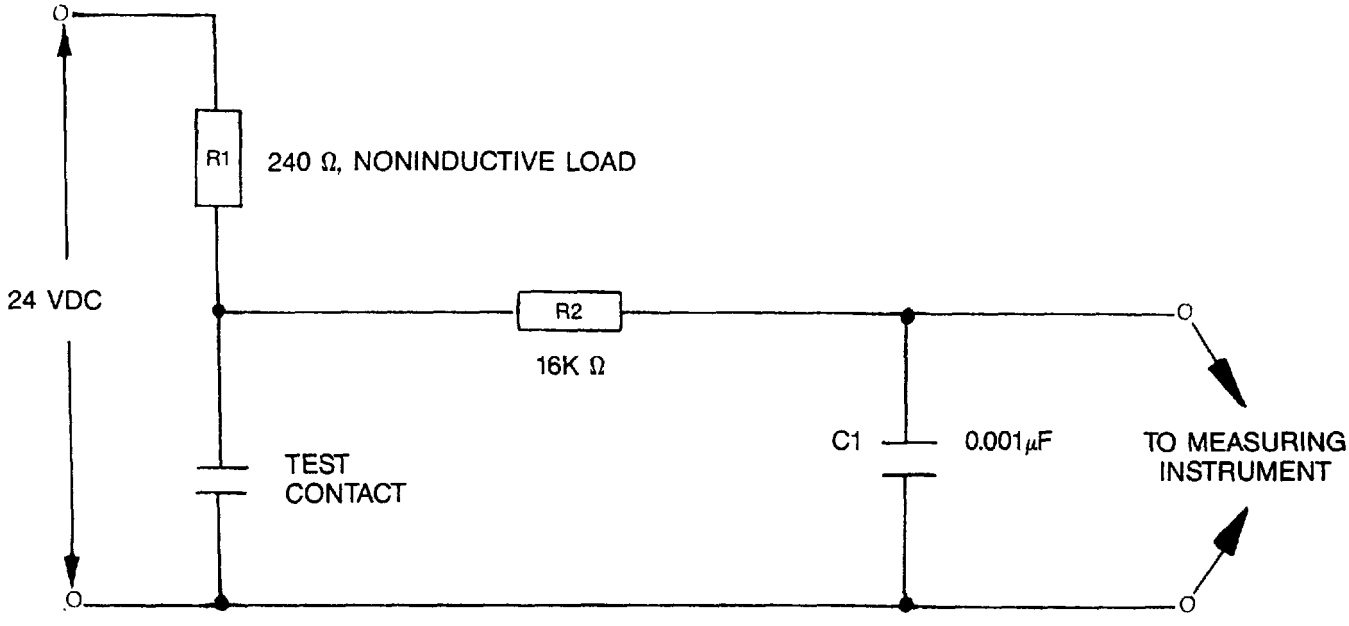


Figure 1-109-4
CONTACT BOUNCE TEST CIRCUIT

1-109.52.4 Number of Operations

The test device should be randomly energized to obtain the full range of contact bounce time. For electrically operated devices, 300 operations per pole with operating voltage being varied through the range is considered adequate. A storage oscilloscope connected to record the contact bounce time of each operation without erasing previous traces is recommended as the most efficient manner in which to record these data. The storage oscilloscope should be one which has a high contrast between background and trace, a suitable grid, and a bistable storage mode, as opposed to a variable persistence mode. New devices should be operated at least 50 times without recording data to mechanically seat the contacts in order to obtain more consistent readings.

1-109.52.5 Test Results

Contact bounce time measurements are expressed as representative maximum values in whole milliseconds for the poles tested. Test equipment and variable characteristics between similar devices preclude a high degree of accuracy.

Authorized Engineering Information 1-5-1977.

ELECTRICAL NOISE TESTS ●

1-109.60 PURPOSE

Exposing solid-state devices to electrical noise may damage the devices or cause malfunction of the equipment which they control.

The electrical noise tests described in 1-109.61 and 1-109.62 are designed to test solid-state logic input and output modules and power supplies that interface with control power sources. The wiring associated with these devices is frequently subjected to the showering-arc type of electrical noise that the test specifies. The tests are intended to demonstrate that the equipment is immune to electrical noise when subjected to the specified noise signals under the specified test conditions.

The tests are not intended to be used with logic level signal wiring. Solid-state logic wiring that carries logic level signals must be kept physically separated from control wiring which carries the showering-arc type of electrical noise. Logic level signal wires to panel-mounted thumbwheel switches, potentiometers for remote adjustment of timers and photocells, or proximity input signal wiring and similar wiring should not be subjected to the test specified in 1-109.61 and 1-109.62.

The circuits formed by the connection to the logic elements shown is Figures 1-109-6, 1-109-7, and 1-109-8 are intended to detect if noise signals injected into the power supply and input and output wiring have penetrated the isolating means afforded by these devices to a degree that would cause malfunction of logic gates. Additional detection circuits may be formed by interconnecting other logic elements, such as flip-flops, counters, and so forth, to further evaluate the noise rejection of power supplies and input and output devices; however, these other logic elements are not included in the scope of the electrical noise test.

Authorized Engineering Information 1-11-1984.

1-109.61 VERIFICATION TEST FOR ELECTRICAL NOISE

The modules which are combined to create a solid-state logic system shall be significantly immune to electrical noise. Logic system components, including a power supply, OR logic element, AND logic element, input signal converter, and 115-volt alternating current output amplifier, shall be mounted and interwired as shown in Figures 1-109-6, 1-109-7, and 1-109-8 using the manufacturer's standard assembly practices. While the logic system is operating, the output of a noise generator and coupling cable assembly constructed in accordance with 1-109.63 and 1-109.64 and calibrated in accordance with 1-109.65 shall be applied to the system terminals for external wiring, using the test procedure described in 1-109.62.

Suggested Standard for Future Design 1-11-1984.

1-109.62 NOISE TEST PROCEDURE

Wired connections between the noise generator, coupling cable assembly, logic system and control relay load (CR) shall be in accordance with Figure 1-109-6. For the initial test condition, use the connection diagram shown in Figure 1-109-6 where the coupling cable assembly is connected to input contact 1 CR.

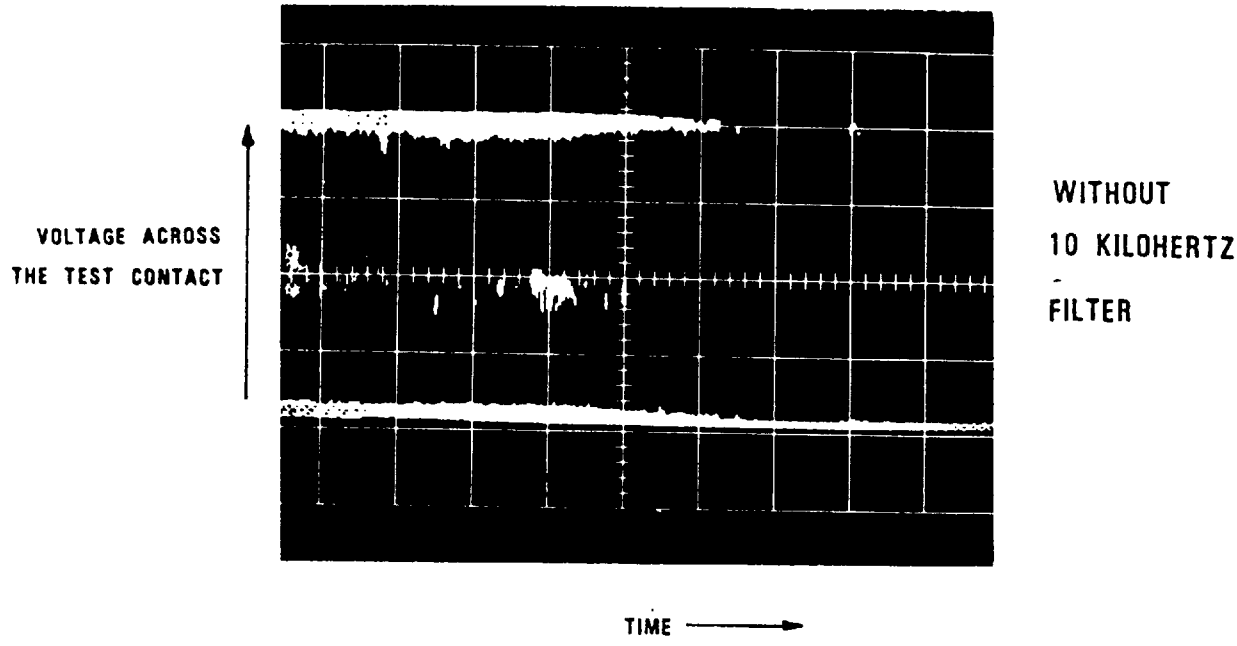
1-109.62.1 Noise Injected on Input Wiring

Connections shall be made in accordance with Figure 1-109-6 and the test sequences shall be in accordance with the following:

(a) *Case I*—OR logic element:
  (1) Close line switch SW1 to energize the logic power supply.
  (2) Preset the output of the OR logic element to a logic zero. Relay CR will not pick up.
  (3) Close line switch SW2 to energize the noise generator.

● Added 1-11-1984. Formerly a part of ICS 2-230.

Figure 1-109-5
OSCILLOSCOPE PHOTOGRAPHS SHOWING EFFECT OF 10 KILOHERTZ FILTER (300 RANDOM OPERATIONS DISPLAYED ON STORAGE TYPE OSCILLOSCOPE)



(4) Relay CR should not pick up or chatter during a 1-minute noise test.
(5) Open all line switches to terminate the test.

(b) *Case II*—AND logic element:
(1) Close line switch SW1 to energize the logic power supply.
(2) Preset the output of the AND logic element. Relay CR will pick up and remain in the picked-up position.
(3) Close line switch SW 2 to energize the noise generator.
(4) Relay CR should not drop out or chatter during a 1-minute noise test. A drop out of relay CR indicates a failure.
(5) Open all line switches to terminate the test.

1-109.62.2 Noise Injection on Output Wiring

Connections shall be made in accordance with Figure 1-109-7, and the steps described in (a) or (b) of 109.62.1 shall be repeated.

1-109.62.3 Noise Injected on Power Supply Line Wiring

Connections shall be made in accordance with Figure 1-109-8, and the steps described in (a) or (b) of 1-109.62.1 shall be repeated.

Suggested Standard for Future Design 1-11-1984.

1-109.63 NOISE GENERATOR

The characteristics of the electrical noise which is commonly produced by electrical contacts interrupting inductive loads are reproduced with controlled voltage amplitude by the test circuits shown in Figure 1-109-9 and Figure 1-109-9A.

The circuit in the Figure 1-109-9 produces continuous single polarity transients.

The circuit in Figure 1-109-9A is an alternate circuit to produce an output that oscillates between positive showering arc transients and negative showering arc transients. This circuit may be more appropriate for equipment sensitive to continuous single polarity transients, and may produce a slightly more severe test than the circuit of Figure 1-109-9.

Adjustments of the sparkgap, G, from 0 to 1.25 millimeters will produce showering arc transients from a minimum of 350 volts to more than 2000 volts. The voltage is measured by observing the oscilloscope display. Typical oscilloscope displays are shown in Figure 1-109-10 and Figure 1-109-10A.

CAUTION — THE VOLTAGES AND POWER AVAILABLE MAY BE DANGEROUS TO HUMAN LIFE. THE EQUIPMENT MUST BE HANDLED WITH CARE. THE RED PILOT LIGHT WARNS OF THE DANGER. THE NORMALLY-CLOSED RELAY CONTACTS PROVIDE A RAPID DISCHARGE PATH FOR THE CAPACITOR WHEN THE SWITCH IS OPENED.

Authorized Engineering Information 11-14-1985.

1-109.64 COUPLING CABLE ASSEMBLY

Electrical signals produced by the noise generator shall be coupled into logic system circuits by simulating actual wiring conditions where multiple wires lie side by side in a common conduit or wire duct. The coupling cable assembly shall be the means of providing repeatable conditions for injecting noise signals into logic system wiring. The assembly shall be constructed in accordance with Figure 1-109-11. The conductors in the cable shall be arranged in accordance with Figure 1-109-12. Connections between the noise generator and spark gap shall be made with cable wires No. 1 and 6, which are diametrically opposite. Two other wires shall be used to make the connections shown in Figures 1-109-6, 1-109-7, and 1-109-8. These two wires shall be selected using the calibration procedure described in 1-109.65.

Suggested Standard for Future Design 1-11-1984.

1-109.65 CALIBRATION PROCEDURE FOR NOISE GENERATOR AND COUPLING CABLE ASSEMBLY

In order to have a reproducible test, it is necessary to calibrate the output of the coupling cable assembly. This is done by selecting the proper pairs of wires to be used as the input and output of the cable assembly in accordance with the following:

(a) Connect the test circuit to the terminals as shown in Figure 1-109-13.

(b) Adjust the noise generator by means of the sparkgap, C, to produce 1500 volt transients similar to the display shown in Figure 1-109-10 or Figure 1-109-10A.

(c) After setting the noise generator, make an oscilloscope measurement of the output of the cable assembly as shown in Figure 1-109-14. This provides a measure of the peak current and the slope of the current in the leading edge of the first current pulse of the oscillation caused by each showering arc transient.

(d) If the measurements are not within the tolerances shown in Figure 1-109-14, select a pair of wires other than 2-2A and 7-7A (for example, 10-10A and 5-5A, or 2-2A and 5-5A, or 10-10A

9009279 0000388 005

and 7-7A). If none of these combinations produces the desired result, it is recommended that a pair of wires other than 1-1A and 6-6A be used for the input and that the above test procedure be repeated with other pairs of wires being used for the output to determine which pairs of wires give an output within the calibration shown in Figure 1-109-14.

The test apparatus is then ready for use in the test specified in 1-109.62.

The output of the cable assembly is connected to the device under test with a twisted pair of wires not more than 3 meters long.

Authorized Engineering Information 11-14-1985.

1-109.66 NOISE SUPPRESSION

Logic system components should be wired, enclosed and isolated from sources of potential noise so that any noise received by the logic components is less than that produced by the noise generator described in 1-109.63 and 1-109.64. This may require filters or surge suppressors applied to electromagnetic devices operating with logic system components to limit the magnitude and duration of transient voltages conducted or radiated into the logic system.

Authorized Engineering Information 3-17-1976.

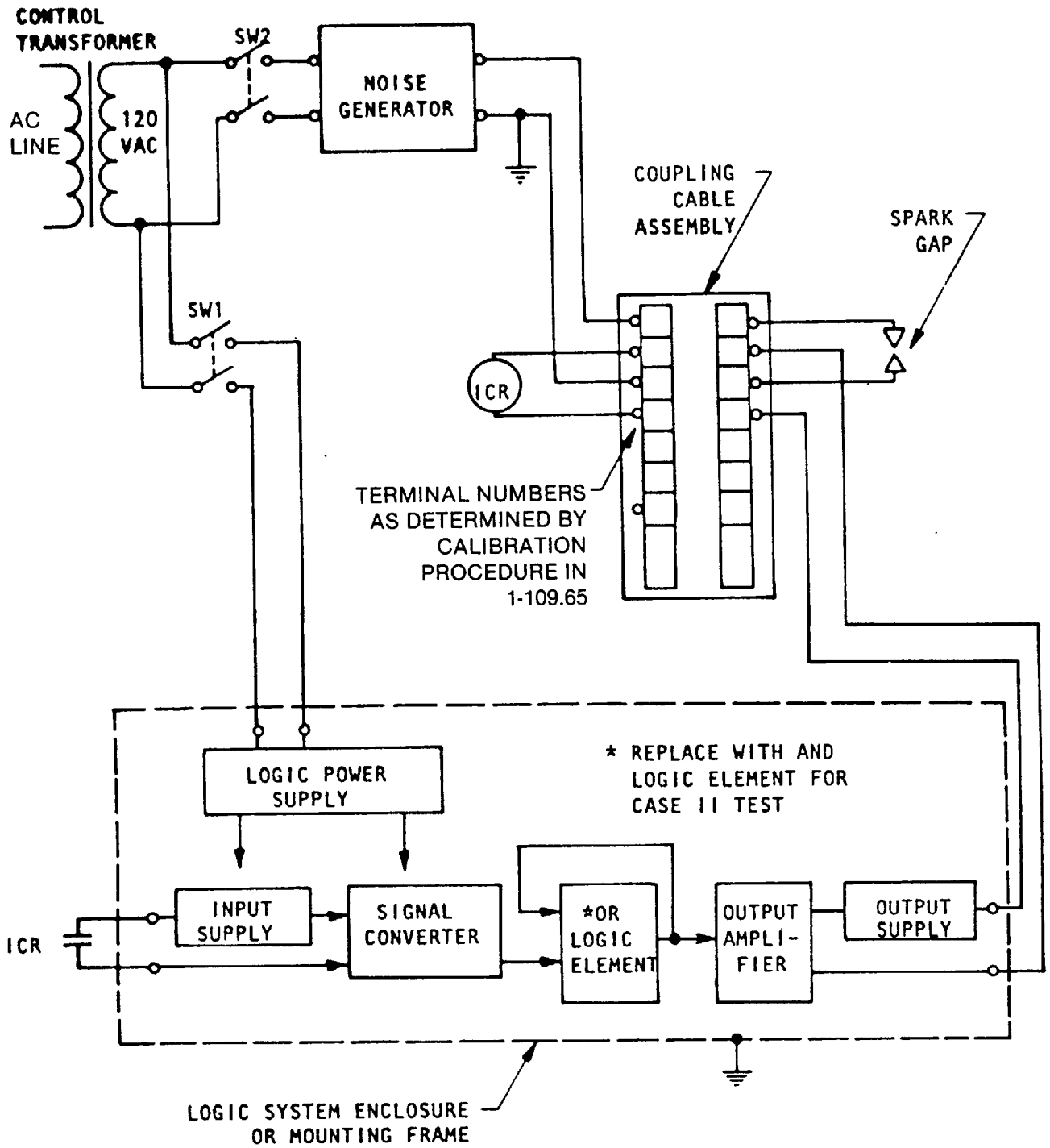


Figure 1-109-6
CONNECTION DIAGRAM FOR NOISE TEST OF OUTPUT CIRCUIT

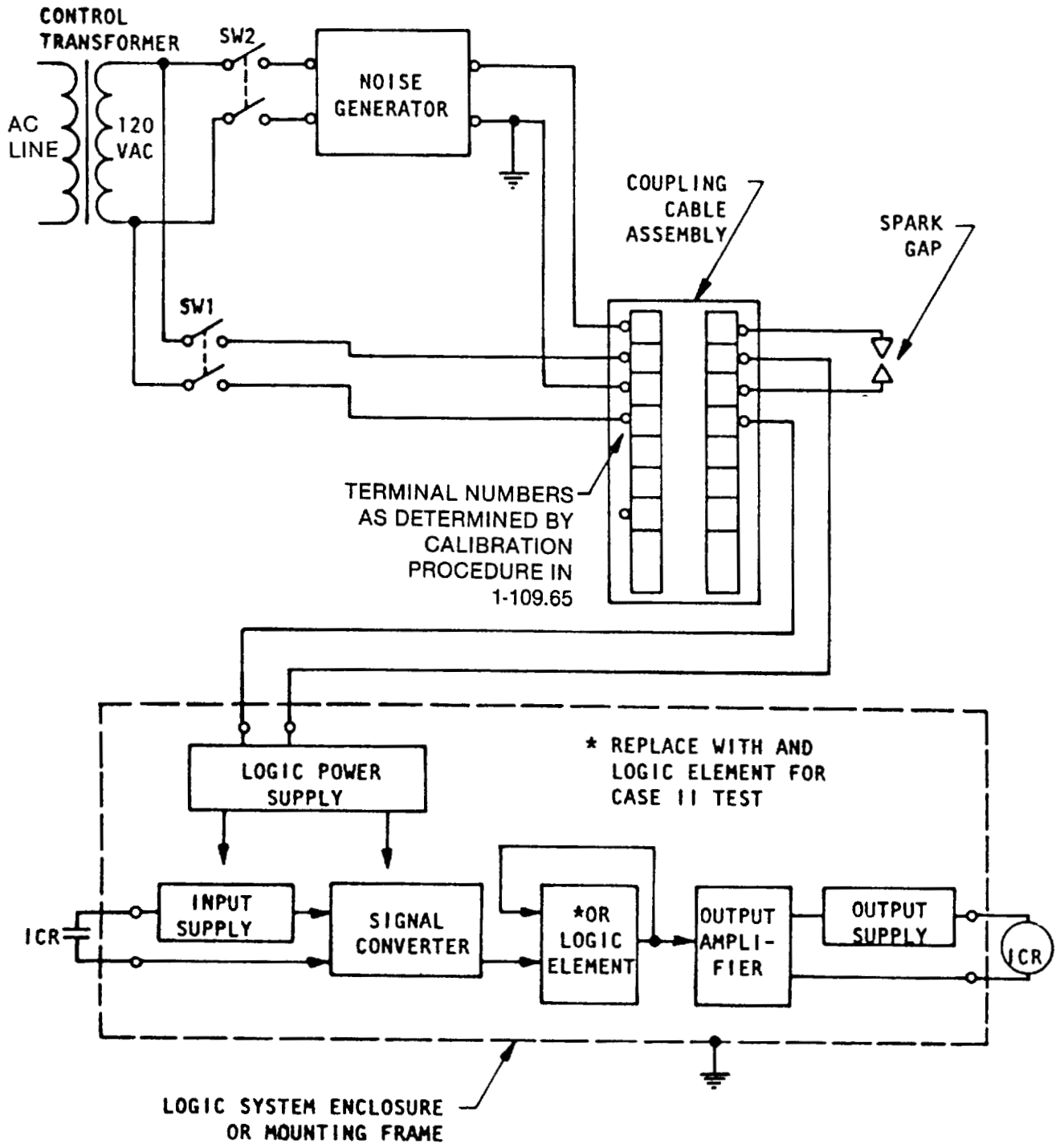


Figure 1-109-7
CONNECTION DIAGRAM FOR NOISE TEST OF LOGIC POWER SUPPLY CIRCUIT

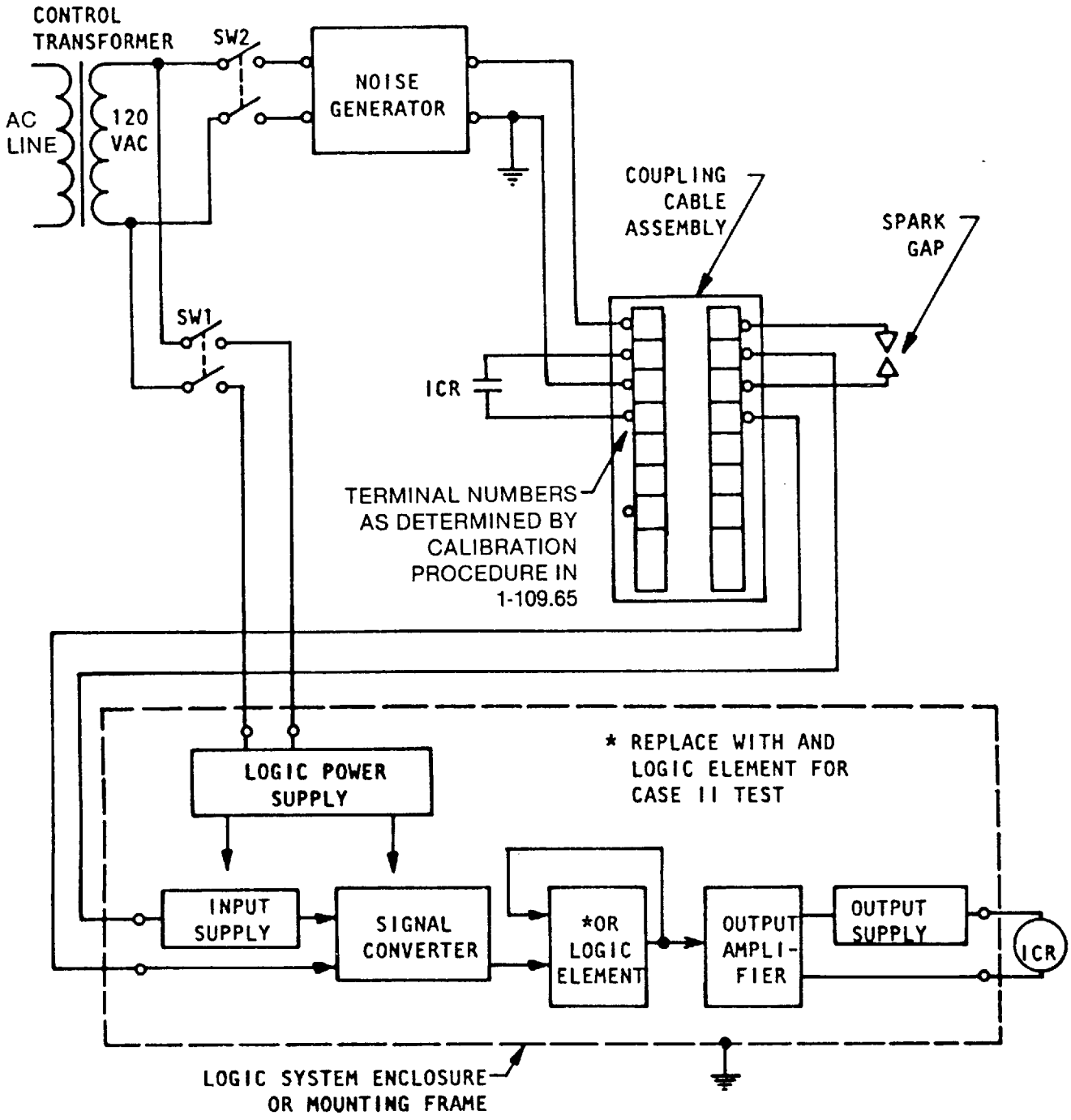
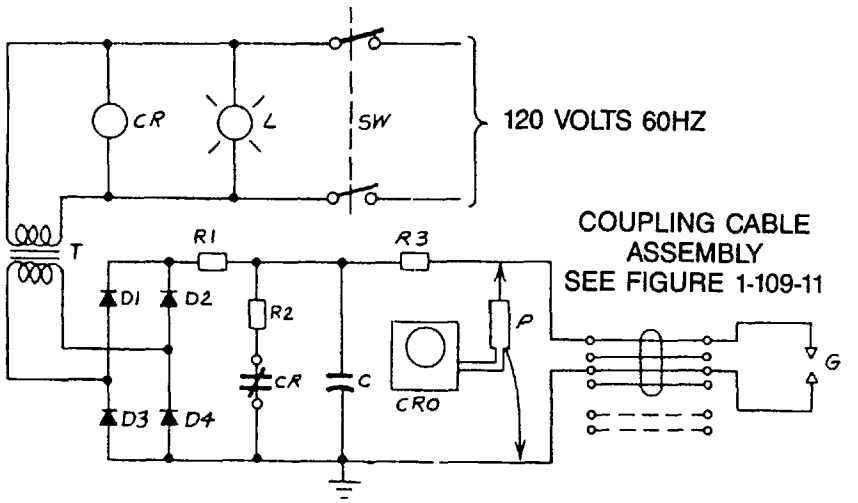


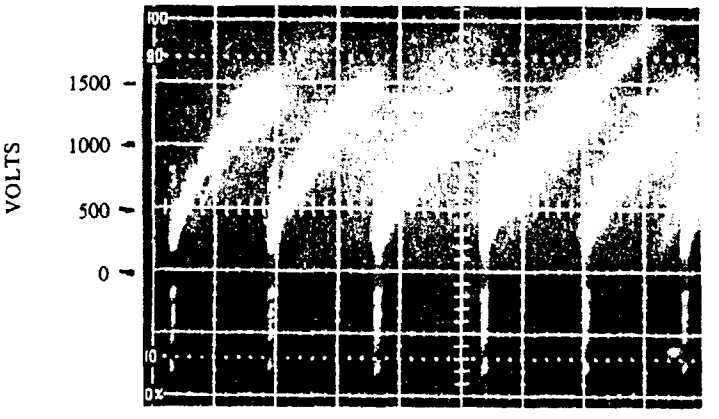
Figure 1-109-8
CONNECTION DIAGRAM FOR NOISE TEST OF INPUT CIRCUIT



CR .....120 V 60 Hz relay with normally closed contacts
T .....luminous sign transformer 100 VA 120 V primary, 3kV secondary
R_1, R_2 .....50 k Ω 20 W wire-wound resistor
R_3 .....300 k Ω 30 W resistor
SW .....“ON”-“OFF” switch
L .....red warning lamp
D1, D2, D3, D4 ...10 kV 25 mA silicon diodes
C .....1.0 μF, 5 kV capacitor
CRO .....cathode ray oscilloscope (100 kHz or greater upper bandwidth limit)
P .....2 kV oscilloscope probe
G .....tungsten contacts (automobile ignition breaker point set with insulated lever attached. Lever provides 2:1 motion reduction so that 2.5 mm motion provided by micrometer screw results in gap adjustment from 0 to 1.25 mm.)

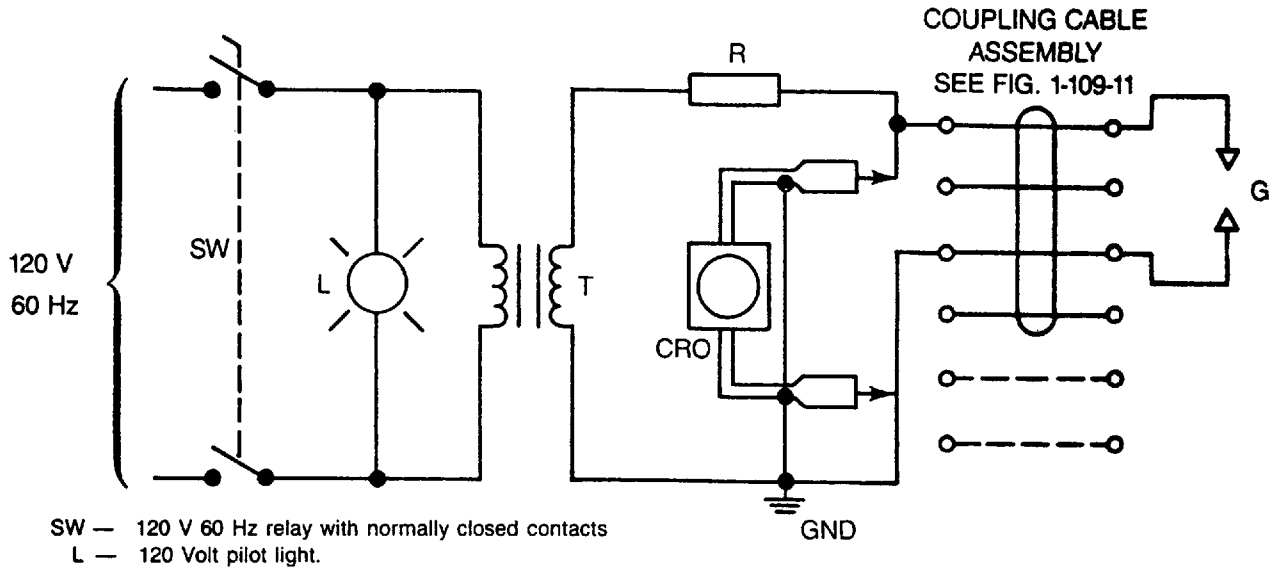
CAUTION—THE VOLTAGES AND POWER AVAILABLE MAY BE DANGEROUS TO HUMAN LIFE. THE EQUIPMENT MUST BE HANDLED WITH CARE. THE RED PILOT LIGHT WARNS OF THE DANGER. THE NORMALLY-CLOSED RELAY CONTACTS PROVIDE A RAPID DISCHARGE PATH FOR THE CAPACITOR WHEN THE SWITCH IS OPENED.

Figure 1-109-9
TEST EQUIPMENT, SINGLE POLARITY



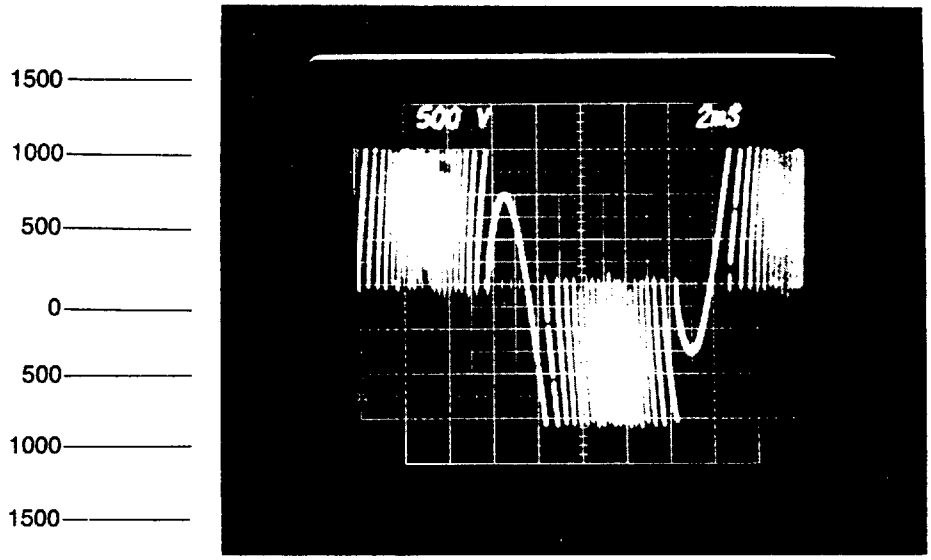
TIME → 0.2 ms/MAJOR DIVISION

Figure 1-109-10
TYPICAL OSCILLOGRAM OF CONTINUOUS SINGLE POLARITY TRANSIENT PRODUCED BY SHOWERING ARC ELECTRICAL NOISE GENERATOR



SW — 120 V 60 Hz relay with normally closed contacts
L — 120 Volt pilot light.
T — Luminous sign transformer
110 VA, 120 volt primary, 3 kV secondary
R — 300k Ω, 30 watt resistor
CRO — cathode ray oscilloscope (100 kHz or greater upper band width) with differential input amplifier.
G — tungsten contacts (automobile ignition breaker point set with insulated lever attached. Lever provides 2:1 motion reduction so that 2.5 mm motion provided micrometer screw results in gap adjustment from 9 to 1.25 mm.)

Figure 1-109-9A
TEST EQUIPMENT, OSCILLATING POLARITY



TIME 2ms/MAJOR DIVISION

Figure 1-109-10A
TYPICAL OSCILLOGRAM OF CONTINUOUS OSCILLATING POLARITY TRANSIENT PRODUCED BY SHOWERING ARC ELECTRICAL NOISE GENERATOR

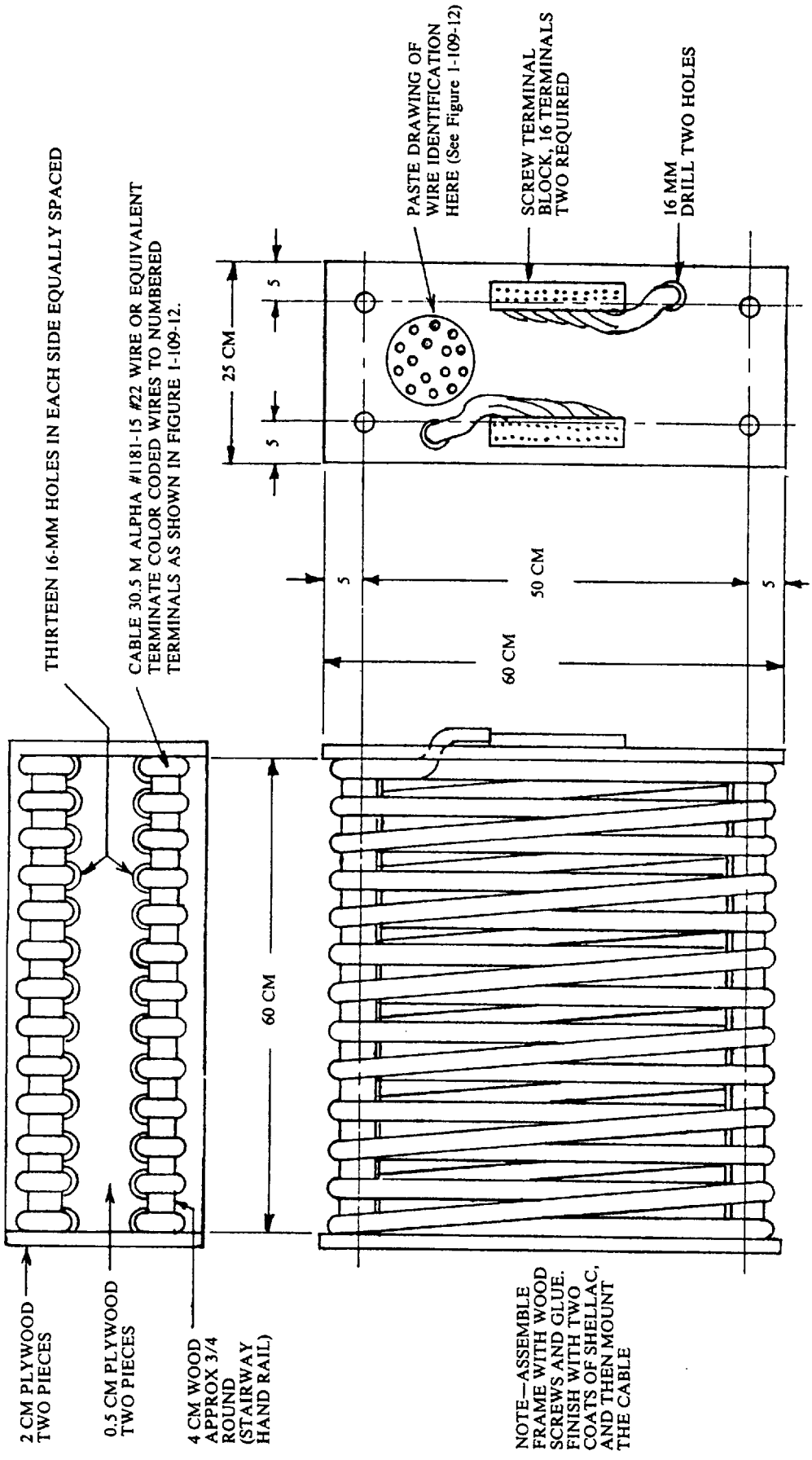


Figure 1-109-11
CABLE ASSEMBLY FOR COUPLING NOISE INTO SIGNAL AND POWER LINES

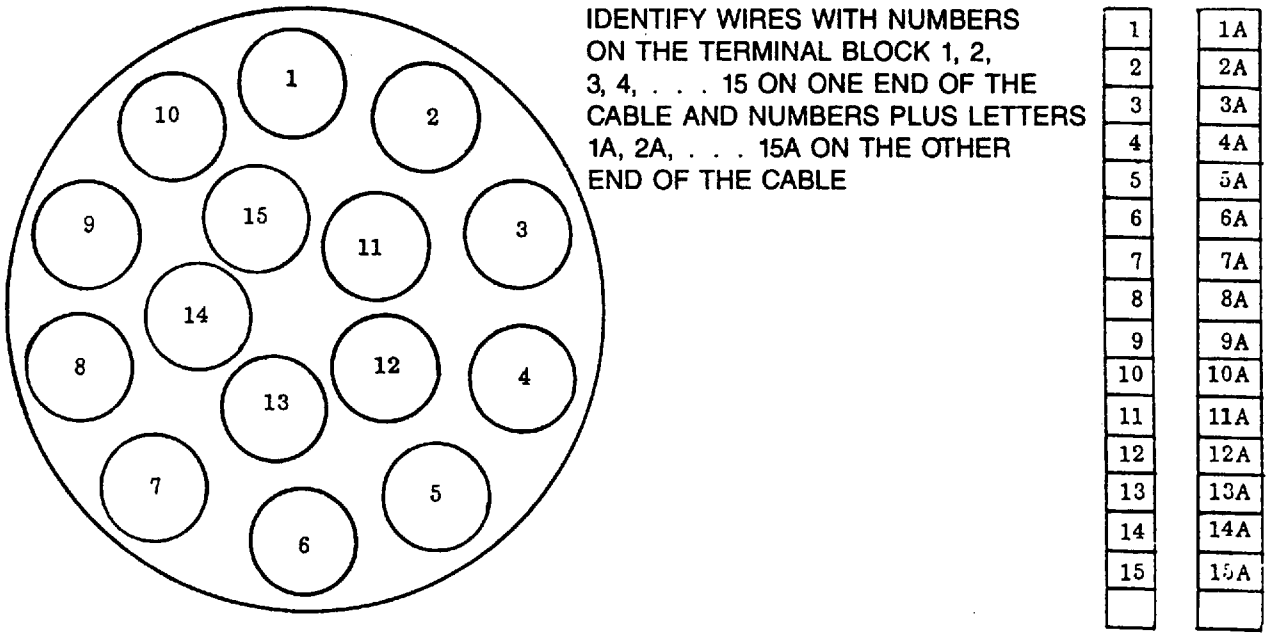
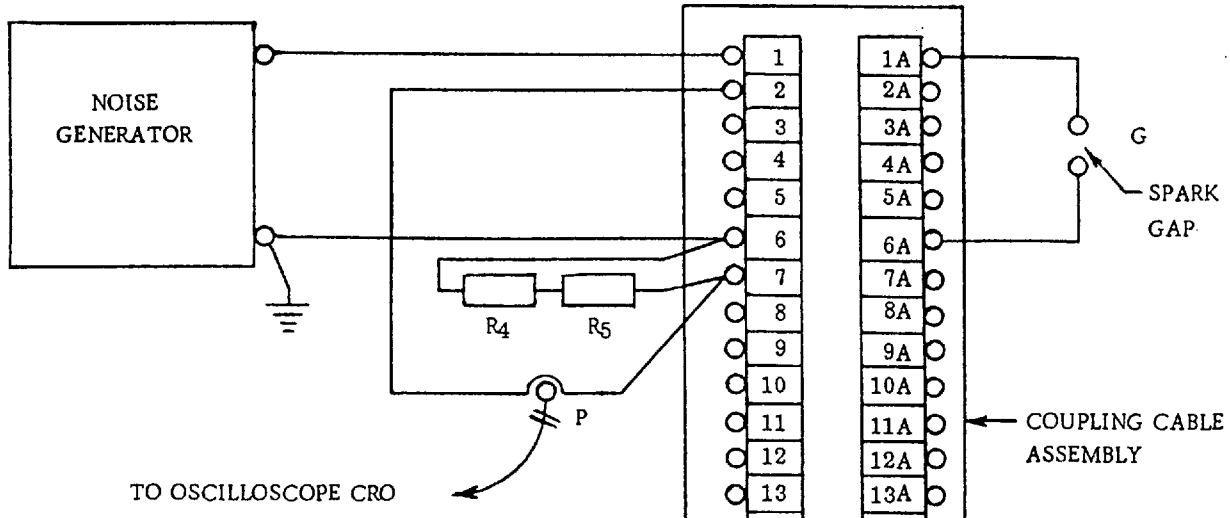
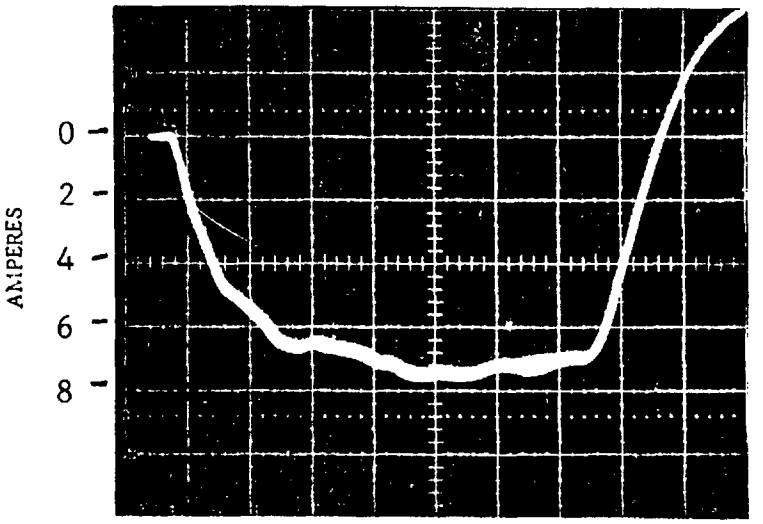


Figure 1-109-12
CONDUCTOR ARRANGEMENT



R_4, R_5—270 k Ω ± 10% 1 W CARBON COMPOSITION
P —CURRENT PROBE FOR OSCILLOSCOPE, 50 MHz OR GREATER UPPER BANDWIDTH LIMIT. USE TEKTRONIX CT-2 CURRENT PROBE OR ONE OF EQUIVALENT CHARACTERISTICS.
CRO —OSCILLOSCOPE, 50 MHz OR GREATER UPPER BANDWIDTH LIMIT.

Figure 1-109-13
CONNECTION DIAGRAM AND PARTS LIST FOR COUPLING CABLE ASSEMBLY STANDARDIZATION



Peak current = 6.0 amperes minimum
Leading edge rise time from 1 to 3 amperes = 25×10^{-9} seconds maximum

Figure 1-109-14
CURRENT PULSE OSCILLOGRAM FOR STANDARDIZING COUPLING CABLE ASSEMBLY

Part 1-111

SPACINGS

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified.

The definitions contained in Part 1-100 of this Standards Publication also apply to this part.

Part ICS 1-111 covers design (type) and performance test procedures. For specific design, performance and application requirements, see appropriate product standards.

For an alternate procedure for determining spacing and for tests to verify the performances, see Part ICS 1-111A.

GENERAL

1-111.1 INSULATION REQUIREMENTS

Industrial control and systems apparatus shall be designed to provide insulation between live parts under operating and service conditions considered normal for such equipment. This insulation shall be achieved by designs which have air or other insulating material between live parts and ground, and between live parts of opposite polarity. The shortest distance measured through air between two conducting parts is called clearance. The shortest distance along the surface of an insulating material between two conducting parts is called creepage distance. For joints and inserted barriers, the creepage distances are measured through the joint, unless the parts are so cemented or heat-sealed or tightly secured mechanically together that ingress of moisture or dirt into the joint is not likely to occur.

NEMA Standard 1-5-1977.

The clearances and creepage distances specified in Part 1-111 are those considered necessary to provide insulation under conditions of overvoltages resulting from faults, lightning, switching, and other transient phenomena which are likely to occur in installations where industrial control and systems equipment is utilized. These minimum distances also take into consideration: (1) the probability of some form of pollution reducing their effectiveness, and (2) a safety factor which considers the consequences of power follow-through in the event of a fault (available let-through energy) and the need to provide continuity of service.

Authorized Engineering Information 1-5-1977.

1-111.2 SPACINGS

1-111.2.1 General Requirements

The clearance and creepage distances between nonarcing uninsulated live parts and:

(a) Nonarcing uninsulated parts of different potential,

(b) Metal parts (other than enclosure walls) which may be grounded when the equipment is installed,

(c) Exposed ungrounded metal parts, and

(d) The walls of a metal enclosure (including fittings for conduit or armored cable)

shall be not less than those shown in Tables 1-111-1 or 1-111-2, as applicable.

Table 1-111-1 applies for general use on all power systems where the transient voltages are not controlled or known.

NEMA Standard 9-20-1978.

Table 1-112-2 applies where provision is made to limit random surge and transient peak voltages to a total of not more than 300 percent of the instantaneous peak working voltage or 300 volts, whichever is greater. This limitation on surge and transient peak voltages applies between uninsulated live parts and ground when the apparatus is subjected to the 1.2/50 impulse test specified in 1-11A.

NEMA Standard 5-25-1988.

1-111.2.2 Exceptions

(a) Table 1-111-2 spacings are not required when surge suppression means are used to limit random surge and transient peak voltgages to not more than 300 volts peak and meet the test requirements of 1-111A. However, provision shall be made to preserve the integrity of the spacings throughout the service life of the equipment through the use of means of protection from pollution and mechanical forces that could bridge clearances or cause leakage currents across creepage distances and the use of materials that will not deteriorate with age, moisture or leakage current. In addition, external connections shall comply with the minimum spacing requirements of Table 1-111-2.

NEMA Standard 5-25-1988.

(b) The clearances and creepage distances given in Tables 1-111-1 and 1-111-2 do not apply to internal parts of hermetically sealed or encapsulated components; however, the external connections on such components shall have the clearance and creepage distances specified in this publication, unless the components are in accordance with the NEMA standards for these components and those standards cover industrial applications.

(c) The clearance and creepage distances given in Tables 1-111-1 and 1-111-2 do not apply to snap switches, lampholders, and similar wiring devices used as part of industrial control equipment, provided such devices are not employed in motor circuits.

(d) This standard does not apply to the internal spacings of rotating electric machines, or to motor control center bus spacings, or to the open gaps of contacts.

NEMA Standard 9-20-1978.

1-111.3 MEASUREMENT OF SPACINGS

Figures 1-111-1 through 1-111-12 show how clearance and creepage distance shall be measured for various situations involving ridges or grooves between conductive parts.

NEMA Standard 5-25-1988.

DESIGN TESTS AND PERFORMANCE

1-111.4 IMPULSE TEST

Industrial control and systems apparatus designed in accordance with Table 1-111-2 shall be capable of withstanding the impulse withstand voltage test of ICS 1-111A.

NEMA Standard 5-25-1988.

Table 1-111-1
CLEARANCE AND CREEPAGE DISTANCES FOR GENERAL USE WHERE TRANSIENT VOLTAGES ARE NOT CONTROLLED OR KNOWN

Group	Voltage Rating, Volts[1] (Rms or Direct Current)	Minimum Clearance and Creepage Distance, Inches					
		To Other Than Enclosure Walls				To Walls of Metal Enclosure[3]	
		Clearance[2] Through		Creepage Along Surface		Clearance Through	Creepage Along
		Air	Oil	Air	Oil	Air or Oil	Surface
A. General industrial control	0-50	0.125	0.125	0.125	0.125	0.500	0.500
	51-150	0.125	0.125	0.250	0.250	0.500	0.500
	151-300	0.250	0.250	0.375	0.375	0.500	0.500
	301-600	0.375	0.375	0.500	0.500	0.500	0.500
	601-1000	0.550	0.450	0.850	0.625	0.800	1.000
	1001-1500	0.700	0.600	1.200	0.700	1.200	1.650
	1501-2000	1.000	0.750	2.000	1.000	2.000	3.000
	2001-2500[6]	1.000	0.750	2.000	1.000	2.000	3.000
	2501-5000[6]	2.000	1.500	3.500	2.000	3.000	4.000
	5001-7200[6,7]	2.000	1.500	3.500	2.000	3.000	4.000
B. Industrial control with per pole and total load restrictions[4]	51-300	0.063	0.063	0.125	0.125	0.250	0.250
	301-600	0.188	0.188	0.375	0.375	0.500	0.500
C. Industrial control with per pole restrictions[5]	51-150	0.125	0.125	0.250	0.250	0.250	0.250
	151-300	0.250	0.250	0.250	0.250	0.250	0.250

(Deleted 9-20-1978.)

Where the repetive peak voltage on which the device is used is more than 1.5 times the rms volts, the peak voltage shall be divided by $\sqrt{2}$ to obtain an equivalent rms rating in volts.

For grounded power systems, such as three-phase four-wire systems, the clearance and creepage distances to ground shall be governed by the voltage to ground.

[2]The spacings between screw-type wiring terminals of opposite polarity shall be not less than 0.250 inch if the terminals are in the same plane.

[3]For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce clearance and creepage distances between the metal piece and uninsulated live parts.

For subassembly enclosures where clearance and creepage distances are rigidly maintained and when mounted inside another enclosure, the distances for "to other than enclosure walls" shall be permitted to be used instead of "to walls of metal enclosure" but in no case shall they be less than 0.100 inch.

[4]The maximum per pole ratings are limited to 1 HP or less; 720 VA or less: 15 A at 51-150 V; 10 A at 151-300 V; 5 A at 301-600 V. For multipole devices, intended to control more than one load, the total load controlled at one time is limited to two times these values.

[5]The maximum per pole rating is limited to 1 HP or less; 2000 VA or less; 15 A at 51-150 V; 10 A at 151-300 V.

[6]Because of the effect of configurations of metal parts, spacings in excess of those listed for these ratings may be required to meet the requirements of the impulse voltage tests described in Part 2-324 of NEMA Standards Publication No. ICS 2. (This footnote is approved as Authorized Engineering Information.)

[7]These spacings approved as Suggested Standard for Future Design 11-20-1986.

Table 1-111-2
CLEARANCE AND CREEPAGE DISTANCES FOR USE WHERE TRANSIENT VOLTAGES ARE CONTROLLED AND KNOWN

Group	Instantaneous Peak Working Voltage,[1] Volts	Minimum Clearance and Creepage Distance, Inches: To Other Than Enclosure Walls[2] — Clearance[3] Through Air	To Other Than Enclosure Walls[2] — Creepage Along Surface In Air	To Walls of Metal Enclosure[4] — Clearance Through Air	To Walls of Metal Enclosure[4] — Creepage Along Surface
E. For general use where transient voltages are known and controlled by the apparatus or by specified external means.	0-50	0.030	0.030	0.500[8]	0.250
	51-225	0.075	0.100	0.500	0.500
	226-450	0.150	0.200	0.500	0.500
	451-900	0.300	0.400	0.500	0.500
	901-1400	0.438	0.625	0.750	1.0
	1401-2100	0.625	1.0	1.0	1.5
	2101-3500	1.0	1.6	2.0	3.0
	3501-7000	2.0	3.5	3.0	4.0
F. For use where transient voltages are known and controlled by the apparatus or by specified external means and the power supplying the circuit under consideration is limited to a short circuit of 10 kilovolt-amperes or less.[5]	0-30	0.030	0.030[6]	0.500[8]	0.250
	31-50	0.030	0.030	0.500[8]	0.250
	51-225	0.060	0.060	0.500	0.500
	226-450	0.100	0.100	0.500	0.500
	451-900	0.200	0.200	0.500	0.500
	901-1400	0.300	0.300	0.500	0.750
	1401-2100	0.450	0.450	0.500	1.0
G. For use where transient voltages are known and controlled by the apparatus or by specified external means and the power supplying the circuit under consideration is limited to a short circuit of 500 volt-amperes or less.[5]	0-36	0.012	0.012[7]	0.500[8]	0.250
	37-72	0.016	0.016[7]	0.500[8]	0.250
	73-100	0.030	0.030[7]	0.500[8]	0.250
	101-225	0.045	0.045	0.500	0.500
	226-450	0.060	0.060	0.500	0.500
	451-900	0.100	0.100	0.500	0.500

[1]For grounded power systems, such as three-phase four-wire systems, the clearance and creepage distances to ground shall be governed by the voltage to ground.

[2]The clearance and creepage distances of 0.100 inch and less are particularly intended for use on printed circuit boards or small devices where the distances are precision controlled. They shall not be used on main power circuits, such as bus or contactors. See Part 1-113 for material.

[3]The spacings between screw-type wiring terminals of opposite polarity shall be not less than 0.250 inch if the terminals are in the same plane.

[4]For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce clearance and creepage distances between the metal piece and uninsulated live parts.

For subassembly enclosures where clearance and creepage distances are rigidly maintained and when mounted inside another enclosure, the distances for "to other than enclosure walls" shall be permitted to be used instead of "to walls of metal enclosure," but in no case shall they be less than 0.100 inch.

[5]Maximum short-circuit voltamperes is determined as the product of the open-circuit voltage and the short-circuit amperes available at the supply terminals when protective devices are by-passed.

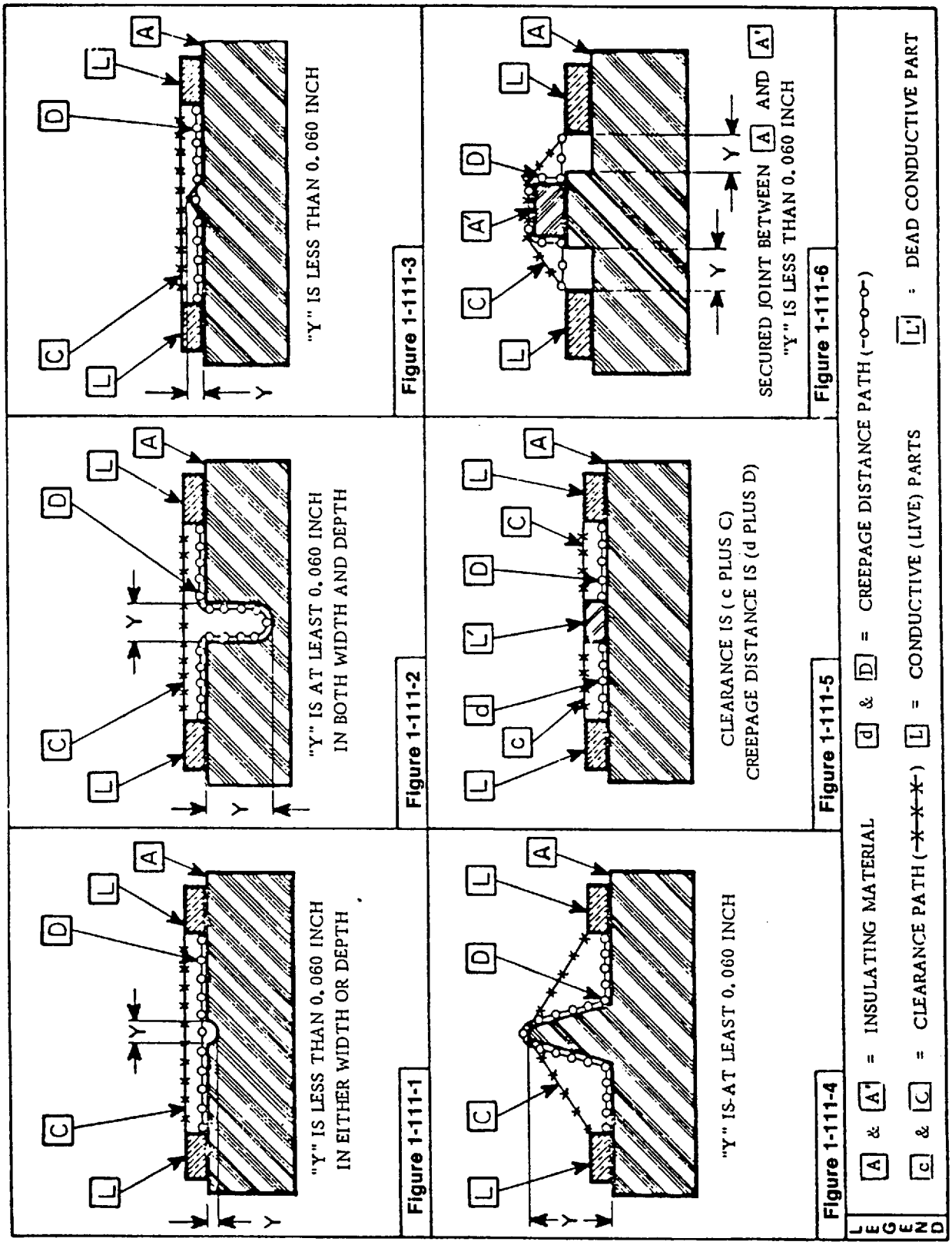
Spacings in signal or control circuits originating from main power circuits shall be in accordance with Group A or E up to the point where circuit conditions permit the use of spacings in accordance with Group F or G. Products designed in accordance with Groups F and G spacings include a supply which limits the short-circuit VA to values shown.

[6]Smaller creepage distances are permissible for this voltage range if the live parts of different potential are rigidly attached to an insulating surface and provided suitable precautions are applied for environmental protection.

[7]Pollution shall be taken into account through the use of larger dimensions, protective coating or enclosures, mounting orientation, protective maintenance, or by other acceptable means. Pollution is any material or condition which supplies conductive particles or ions, or both, to an electric field, changing the normal condition of the electric field at rated temperature, atmospheric pressure, and relative humidity.

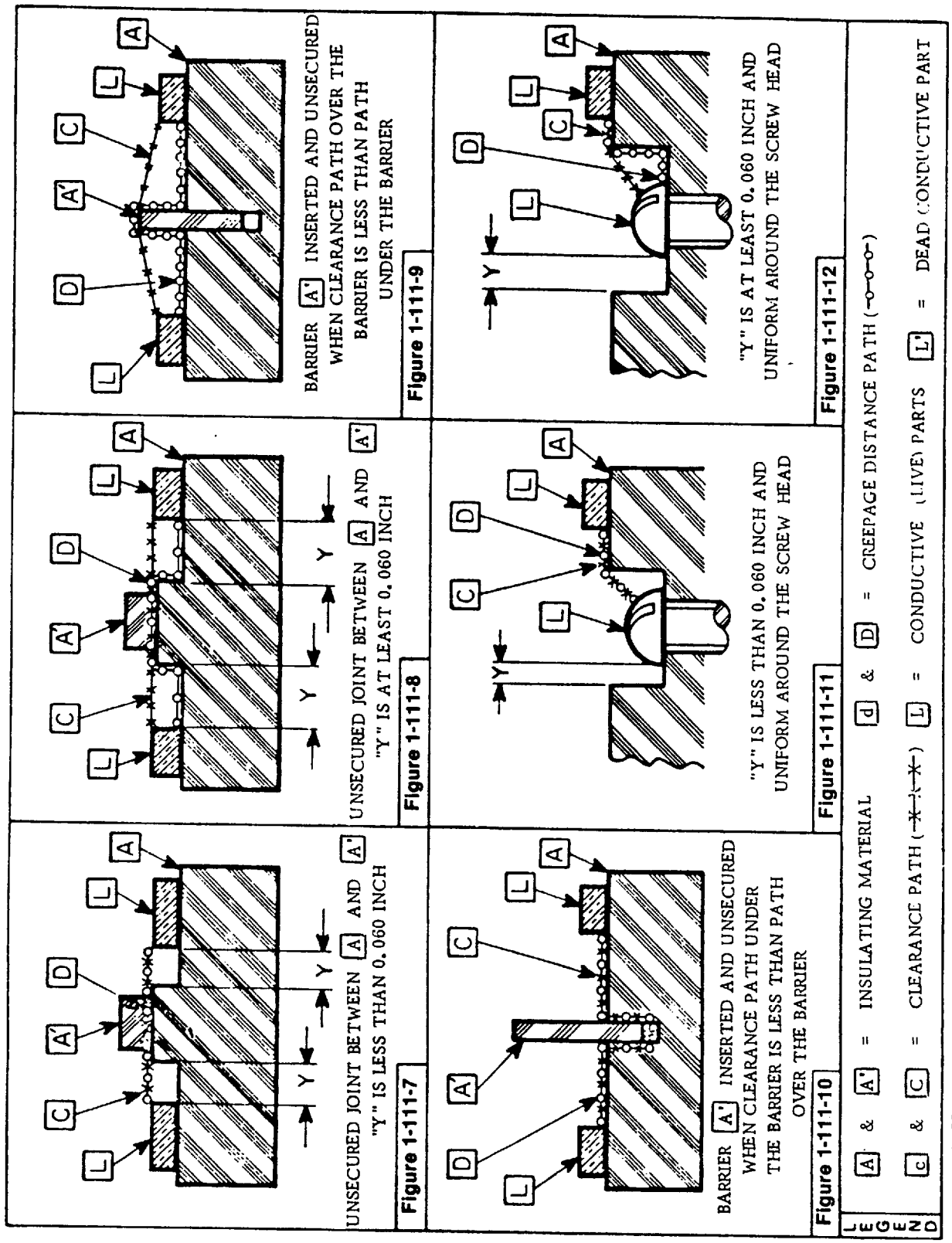
[8]Where deflection of the enclosure wall cannot reduce the through-air spacing to the enclosure wall, the spacing through air shall be permitted to be 0.250 inch.

Figures 1-111-1 through 1-111-12
MEASUREMENT OF SPACINGS



(Continued)

Figures 1-111-1 through 1-111-12 (Cont.)
MEASUREMENT OF SPACINGS



Part 1-111A

SPACINGS

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified.

Part ICS 1-111A covers design (type) and performance test procedures. For specific design, performance and application requirements, see appropriate product standards.

The definitions contained in Part ICS 1-100 of this Standards Publication also apply to this part.

For an alternate procedure and tests for determining spacings, see Part ICS 1-111.

GENERAL

1-111A.1.1 SCOPE

This document is concerned with spacings (clearance and creepage distances) of industrial control equipment for installation in low-voltage distribution systems including services, feeders and branch circuits. The concept of insulation coordination is introduced in this standard. It is a concept under which the insulation characteristics of the components of a system are designed or selected to minimize undesired incidents due to voltage stresses. Voltage stresses are caused by transient overvoltages which can exist in the network system to which the installation is connected. These overvoltages are caused by external events such as lightning and network switching. Transient overvoltages may also be generated within the installation itself, mainly from operation of the equipment.

Authorized Engineering Information 11-14-1985.

1-111A.1.2 INSULATION SYSTEMS

1-111A.1.2.1 Uncoordinated Insulation System

An uncoordinated insulation system implies the selection of the electrical insulation characteristics of equipment whose levels of sparkover voltage of clearances and the breakdown voltage of solid insulation are unknown. This occurs because most existing product standards, based primarily on experience, specify dimensional requirements for equipment design, but do not specify tests to measure the ability of the equipment to withstand conditions of transient overvoltages. Such standards are considered to be "Design Standards." Furthermore, the various products in an installation may have their design based on different Design Standards, each reflecting different experience. In an uncoordinated system, it is therefore possible for a clearance to have a voltage breakdown level that is higher than the voltage breakdown level of its associated solid insulation, or the solid insulation of another component. Consequently, the sparkover of clearances or the breakdown of solid insulation can occur at random locations and at unknown transient overvoltage levels.

Authorized Engineering Information 11-14-1985.

1-111A.1.2.2 Coordinated Insulation System

A coordinated insulation system implies the design or selection of the electrical insulation characteristics of equipment with regard to its application and in relation to its surroundings. Consideration must be given to the continuity of service desired, to the safety of persons and property, to the overvoltages which can appear within the system, and to the location and characteristics of the transient overvoltage protective devices. An insulation system is considered to be coordinated when it passes the impulse withstand test voltage requirements of tables 1-111A.2.2-1 and 1-111A.2.2-2.

Authorized Engineering Information 11-14-1985.

When an insulation system is coordinated, the solid insulation materials involved should have a voltage breakdown level that is higher than the breakdown voltage level of either the associated overvoltage protective device or the clearance on which the coordination is based (see Table 1-111A.2.2-2). Thus the overvoltage protective devices or clearances in air, (a renewable insulation), provide a degree of protection for the non-renewable solid insulation. The design basis for a coordinated insulation is a Performance Standard.

Authorized Engineering Information 11-14-1985.

1-111A.1.3 PERFORMANCE STANDARDS

1-111A.1.3.1 Performance Standards, uniformly based on fundamental research data, permit the designing of coordinated insulation systems that significantly minimize the random sparkover of clearances or breakdown of solid insulation. Performance Standards specify requirements for equipment design to meet specific transient voltage withstand levels, and they also specify tests that measure the ability of the equipment insulation to withstand the voltage stresses caused by those transient voltage levels.

Authorized Engineering Information 11-14-1985.

1-111A.1.3.2 In addition to their common data base and performance tests, Performance Standards incorporate new concepts of interrelated influencing factors including insulation material groups, transient overvoltage protective devices, installation (overvoltage) categories and pollution degrees. Knowledge of and suitable application of these factors can also improve insulation performance. Thus, in order to use insulation to its full advantage, it will be advisable for persons using Performance Standards to acquire in-depth knowledge of principles of insulation coordination and influencing factors. A study of IEC Reports 664 and 664A is recommended for this purpose.

Authorized Engineering Information 11-14-1985.

1-111A.1.4 DEFINITIONS

1-111A.1.4.1 Coordination of Insulation

The correlation of insulating characteristics of electrical equipment on the one hand with the expected overvoltages and with the characteristics of overvoltage protective devices, and on the other hand with the expected micro-environment and the pollution protective means.

NEMA Standard 11-14-1985.

1-111A.1.4.2 Current, Rated Operational

A rated operational current (I_e) of an equipment is stated by the manufacturer and takes into account the rated operational voltage, the rated frequency, the rated duty, the utilization (overvoltage) category and the type of protective enclosure.

NEMA Standard 11-14-1985.

1-111A.1.4.3 Electric Fields

Homogeneous (Uniform) Field

An electric field that has an essentially constant voltage gradient between electrodes, such as that between two spheres where the radius of each sphere is greater than the distance between them.

NEMA Standard 11-14-1985.

Inhomogeneous (Non-Uniform) Field

An electric field that does not have an essentially constant voltage gradient between electrodes.

NEMA Standard 11-14-1985.

1-111A.1.4.4 Installation (Overvoltage) Category (of a Device or Equipment)

Installation (overvoltage) category is a classification of a device or equipment according to its intended location in a distribution system.

NEMA Standard 11-14-1985.

The value of an impulse withstand voltage to earth of the device or equipment relative to the rated insulation voltage to earth for which the device or equipment is intended.

Authorized Engineering Information 11-14-1985.

1-111A.1.4.5 Insulation Measurement

Clearance

The shortest distance in air between two conductive parts.

NEMA Standard 11-14-1985.

Creepage Distance

The shortest distance along a surface of an insulating material between two conductive parts.

NEMA Standard 11-14-1985.

Creepage distance is sometimes referred to as creepage.

Authorized Engineering Information 11-14-1985.

1-111A.1.4.6 Micro-Environment

The ambient conditions that surround the clearance or creepage under consideration.

NEMA Standard 11-14-1985.

The micro-environment of the creepage or clearance and not the general environment of the equipment determines the effect on the insulation. The micro-environment may be better or worse than the general environment of the equipment. It includes all factors influencing the insulation, such as climatic, electromagnetic, generation of pollution, etc.

Authorized Engineering Information 11-14-1985.

1-111A.1.4.7 Pollution

Any addition of a foreign matter, solid, liquid, or gaseous (ionized gases), that may produce a reduction of dielectric strength or surface resistivity..

NEMA Standard 11-14-1985.

1-111A.1.4.8 Pollution Degree (of Environmental Conditions)

The amount of conductive or hygroscopic dust, ionized gas or salt and the relative humidity and its frequency of occurrence resulting in hygroscopic absorption or condensation of moisture leading to reduction in surface resistivity.

NEMA Standard 11-14-1985.

The pollution degree to which a device or equipment is exposed may be different from that of the general environmental conditions due to the protection afforded by an enclosure or by internal heating to prevent absorption or condensation of moisture at the micro-environment.

Authorized Engineering Information 11-14-1985.

1-111A.1.4.9 Tests

Routine Tests

A test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria.

NEMA Standard 11-14-1985.

Sampling Tests

A test of a number of devices taken at random from a batch.

NEMA Standard 11-14-1985.

Type Tests

A test of one or more devices made to a certain design to show that the design meets certain specifications.

NEMA Standard 11-14-1985.

1-111A.1.4.10 Voltages

Rated Impulse Withstand Voltage

The peak value of an impulse voltage, of prescribed form and polarity, that the equipment is capable of withstanding without breakdown under specified conditions of test and to which the value of the clearances is referred.

NEMA Standard 11-14-1985.

Rated Insulation Voltage

The rated insulation voltage (U_i) of an equipment is the value of voltage to which dielectric voltage tests, clearances and creepage distances are referred.

In no case shall the maximum value of the rated operational voltage exceed that of the rated insulation voltage.

NEMA Standard 11-14-1985.

Rated Operational Voltage

A rated operational voltage (U_e) of an equipment is a value of voltage that, combined with a rated operational current, determines the application of the equipment and to which the various tests and the utilization (overvoltage) categories are referred. For polyphase circuits, it is stated as the voltage between phases.

NEMA Standard 11-14-1985.

Recurring Peak Voltage

Voltages generated within an equipment as a result of its operation or within associated equipment. For example, these peak voltages may be required for the operation of the equipment or they may occur as a consequence of its operation. These voltages are likely to be repetitive as compared to lightning related transient voltages, which occur infrequently.

NEMA Standard 11-14-1985.

1-111A.1.5 INTERRELATED INFLUENCING FACTORS

1-111A.1.5.1 Interface Requirements

In a system, the insulation levels of the various installation (overvoltage) categories normally follow each other in descending order of magnitude of the impulse withstand voltage as the equipment is located further away from the source of energy. The transition from one installation (overvoltage) category to the next lower category (from one impulse level to a lower impulse level) is justified by the effect of transient limiting elements that perform an interface function.

Authorized Engineering Information 11-14-1985.

Typical elements that influence the interface are:

1. An overvoltage protective device.
2. A transformer with isolated windings and secondary load (capable of diverting, dissipating, or absorbing energy of surges).
3. A busbar system with a multiplicity of branches (capable of diverting energy of surges).
4. A capacitance, for example a cable or a capacitor (capable of absorbing energy of surges).

   While capacitance may be used to absorb the energy of an impulse, the effects of subsequent release of the stored energy back into the circuit should be considered.
5. A resistance or similar damping device (capable of dissipating energy of surges).

Authorized Engineering Information 11-14-1985.

1-111A.1.5.2 Installation (Overvoltage) Category (of a Device or Equipment)

Low voltage industrial control equipment shall be assigned one or more of the following installation (overvoltage) categories:

Category IV—*Primary Supply Level*. Overhead lines and cable systems including distribution and its associated overcurrent protective equipment (equipment installed at the service entrance).

Category III—*Distribution Level*. Fixed installations of equipment connected to the primary supply level, Category IV.

Category II—*Load Level*. Appliances and portable equipment etc., connected to the distribution level, Category III.

Category I—*Signal Level*. Special equipment or parts of equipment such as low-voltage electronic logic systems, remote control, signalling and power limited (per NEC Article 725) circuits connected to the load level, Category II.

NEMA Standard 11-14-1985.

1-111A.1.5.3 Material Groups

Material groups are classified according to their Comparative Tracking Index (CTI) Values in Table 1-111A.1.5-1. The CTI ratings refer to the values obtained, in accordance with ASTM D-3638 and IEC 112 (Method A). The CTI may be obtained using the insulating parts of the device or separate samples of the material used.

Authorized Engineering Information 11-14-1985.

Table 1-111A.1.5-1

CTI VALUES	MATERIAL GROUP			
	I	II	IIIa	IIIb
Equal or Greater Than	600	400	175	100
Less Than	–	600	400	175

NEMA Standard 11-14-1985

1-111A.1.5.4 Pollution Degree

The pollution degree refers to the general environmental conditions for which the equipment is intended. Industrial control equipment shall be suitable for normal service conditions corresponding to Pollution Degree 3. However, for the purpose of evaluating clearances and creepage the following three degrees of pollution in the micro-environment are established:

Pollution Degree 1—No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.

Pollution Degree 2—Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation must be expected.

Pollution Degree 3— Conductive pollution occurs or dry, non-conductive pollution occurs, which becomes conductive due to condensation that is expected.

NEMA Standard 11-14-1985.

DESIGN

1-111A.2.1 INSULATION REQUIREMENTS

1-111A.2.1.1 Insulation Requirements for Equipment for Use in General Purpose Applications Where Transient Voltages are Not Controlled by a Transient Limiting Means

The requirements for insulation are as follows:

1. Clearances between earth and live parts, between poles, and between circuits, shall withstand a value of impulse voltage corresponding to the voltage from phase-to-earth derived from the rated system voltage and the assigned installation (overvoltage) category or categories in Table 1-111A.2.2-1.

   NEMA Standard 11-14-1985.

   Equipment may be assigned several installation (overvoltage) categories either at the same rated operational voltage or at different rated operational voltages.

   Authorized Engineering Information 11-14-1985.

2. Solid insulation of equipment shall withstand the impulse withstand voltage of the associated clearances of requirement 1 of 1-111A.2.1.1.

   NEMA Standard 11-14-1985.

3. Equipment shall have creepage distances or spacings not less than those corresponding to the rated insulation voltage according to Table 1-111A.2.3-1.

4. Creepage distances less than those of Table 1-111A.2.3-1 may be used when properly designed ribs are used as part of the creepage path. See 1-111A.2.4.4.

   Authorized Engineering Information 11-14-1985.

1-111A.2.1.2 Insulation Requirement for Equipment for Use in a System Where Transient Voltages are Controlled by Transient Limiting Means

The requirements for insulation are as follows:

1. Clearances between earth and live parts, between poles, and between circuits, shall withstand a value of impulse withstand voltage corresponding to the voltage from phase-to-earth derived from the rated system voltage and the assigned installation (overvoltage) category or categories in Table 1-111A.2.2-2, 1-111A.2.5-1, or 1-111A.2.5-2.

NEMA Standard 11-14-1985.

Equipment may be assigned several installation (overvoltage) categories either at the same rated operational voltage or at different rated operational voltages.

Authorized Engineering Information 11-14-1985.

2. Solid insulation of equipment shall withstand the impulse withstand voltage of the associated clearances of requirement 1 of 1-111A.2.1.2.

NEMA Standard 11-14-1985.

3. Equipment shall not generate voltages higher than the value corresponding to the lowest impulse withstand voltage rating according to the installation (overvoltage) category per requirement 1 of 1-111A.2.1.1.

NEMA Standard 11-14-1985.

However, because of the probability that they may be highly repetitive, recurring peak voltages, in conjunction with the properties of the insulation material and pollution degree, may accelerate the degradation of the insulation material.

Authorized Engineering Information 11-14-1985.

4. For an equipment or a device incorporating a transient overvoltage protective device, the impulse sparkover and the discharge voltage shall not exceed the value of the impulse withstand voltage to earth corresponding to the stated installation (overvoltage) category.

NEMA Standard 11-14-1985.

5. Equipment shall have creepage distances not less than those corresponding to the rated insulation voltage according to Table 1-111A.2.3-1.

NEMA Standard 11-14-1985.

6. Creepage less than that of Table 1-111A.2.2-1 may be used when properly designed ribs are used as part of the creepage path.

Authorized Engineering Information 11-14-1985.

Table 1-111A.2.2-1
CLEARANCES OF EQUIPMENT FOR GENERAL PURPOSE APPLICATIONS WHERE TEST VOLTAGE VALUES ARE FUNCTIONALLY EQUIVALENT TO MEASURED MINIMUM CLEARANCES SPECIFIED IN ICS 1-111-1

(2000 Meter Altitude, Pollution Degree 3)

Voltage from Phase-to-Earth Derived from Rated System Voltage[5,6] ac rms or dc max.	Installation (Overvoltage) Category								
	II			III			IV		
	Rated Impulse Withstand[2,3]	Clearance[1]		Rated Impulse Withstand[2,3]	Clearance[1]		Rated Impulse Withstand[2,3]	Clearance[1]	
	kV	mm	(in)	kV	mm	(in)	kV	mm	(in)
50	2.7	1.6	(.063)	4.3	3.2	(.125)	–	–	
100	2.7	1.6	(.063)	4.3	3.2	(.125)	11.0	12.7	(.493)
150	2.7	1.6	(.063)	4.3	3.2	(.125)	–	–	
300	2.7	1.6	(.063)	6.8	6.4	(.250)	16.0	19.0	(.741)
600	5.6	4.8	(.188)	8.8	9.5	(.375)	20.0	25.4	(1.000)
1000	–	–		12.0	14.0	(.546)	–	–	

[1]Clearances are given for inhomogeneous field (Case A) conditions, and were derived from Table ICS 1-111-1; however, smaller clearances shall be permitted as stated in 1-111A.2.2.1.

[2]See 1-111A.3.1.3 for altitude correction factors.

[3]The values of impulse withstand voltage are from IEC Report 664 Table A1.

[4]For industrial control equipment used at the service entrance (transition from installation (overvoltage) Category IV to III), installation (overvoltage) category IV is required only for the main terminals of service entrance equipment.

[5]For unearthed (ungrounded) systems or systems with one phase earthed (grounded phase) the phase-to-earth voltage shall be considered as the phase-to-phase voltage.

NEMA Standard 11-14-1985.

[6]Phase-to-earth insulation level for unearthed or impedanced earthed systems equals that for phase-to-phase because the operating voltage to earth or any phase may, in practice, approach full phase voltage. This is because the actual voltage to earth is determined by the insulation resistance and capacitative reactance of each phase-to-earth; thus, low (but acceptable) insulation resistance on one phase may in effect earth it and raise the other two to full phase volts above earth.

Authorized Engineering Information 11-14-1985.

Table 1-111A.2.2-2
CLEARANCES OF EQUIPMENT FOR APPLICATIONS WHERE TRAINSIENT VOLTAGES ARE CONTROLLED BY TRANSIENT LIMITING MEANS

(2000 Meter Altitude, Pollution Degree 3)

Voltage from Phase-to-Earth Derived from Rated System[6,7] Voltage ac rms or dc max.	Installation (Overvoltage) Category											
	I			II			III			IV		
	Rated Impulse Withstand Voltage [2,3]	Clearance[1]		Rated Impulse Withstand Voltage[2,3]	Clearance[1]		Rated Impulse Withstand Voltage[2,3]	Clearance[1]		Rated Impulse Withstand Voltage[2,3]	Clearance[1]	
	kV	mm	(in)	kV	mm	(in)	kV	mm	(in)	kV	mm	(in)
50	0.33	0.8	(.031)	0.5	0.8	(.031)	0.8	0.8	(.031)	1.5	0.8	(.031)
100	0.5	0.8	(.031)	0.8	0.8	(.031)	1.5	0.8	(.031)	2.5	1.5	(.059)
150	0.8	0.8	(.031)	1.5	0.8	(.031)	2.5	1.5	(.059)	4.0	3.0	(.117)
300	1.5	0.8	(.031)	2.5	1.5	(.059)	4.0	3.0	(.117)	6.0	5.5	(.215)
600	2.5	1.5	(.059)	4.0	3.0	(.117)	6.0	5.5	(.215)	8.0	8.0	(.312)
1000	4.0	3.0	(.117)	6.0	5.5	(.215)	8.0	8.0	(.312)	12.0	14.0	(.546)

[1]Clearances are given for inhomogeneous field (Case A) conditions from IEC Report 664; however, smaller clearances shall be permitted as stated in 1-111A.2.2.1.

[2]See Clause 1-111A.3.1.3 for altitude correction factors.

[3]Transients shall be controlled to values that do not exceed the rated impulse withstand voltage of the associated clearance for each installation (overvoltage) category.

NEMA Standard 11-14-1985.

[4]For industrial control equipment used at the service entrance (transition from installation (overvoltage) category IV to III), installation (overvoltage) category IV is required only for the main terminals of service entrance equipment.

Authorized Engineering Information 11-14-1985.

[5]Clearances to the walls of a metal enclosure shall be in accordance with this table except to those portions of the walls that can be deflected and thereby reduce a clearance. Clearance to deflectable portions of enclosure walls shall be in accordance with Table 1-111A.2.2-3.

[6]For unearthed (ungrounded) systems or systems with one phase earthed (grounded phase) the phase-to-earth voltage shall be considered as the phase-to-phase voltage.

NEMA Standard 11-14-1985.

[7]Phase-to-earth insulation level for unearthed or impedanced earthed systems equals that for phase-to-phase because the operating voltage to earth or any phase may, in practice, approach full phase voltage. This is because the actual voltage to earth is determined by the insulation resistance and the capacitative reactance of each phase to earth; thus, low (but acceptable) insulation resistance on one phase may in effect earth it and raise the other two to full phase volts above earth.

Authorized Engineering Information 11-14-1985.

1-111A.2.2 CLEARANCES

1-111A.2.2.1 General

Clearances shall be verified by measurement or test in accordance with Table 1-111A.2.2-1 or Table 1-111A.2.2-2. Clearances smaller than the values in these tables, except as permitted in Section 1-111A.2.5, shall be verified by testing at the applicable rated impulse withstand voltage. The method of measuring clearances is given in 1-111A.2.4.

NEMA Standard 11-14-1985.

1-111A.2.2.2 Clearances to Enclosure Walls

Clearances to the walls of a metal enclosure shall be in accordance with Tables 1-111A.2.2-1 and 1-111A.2.2-2 except for those portions of the walls that can be deflected and, thereby, reduce a clearance. Attached metal parts shall be considered to be part of a wall.

Table 1-111A.2.2-3
CLEARANCES TO DEFLECTABLE ENCLOSURE WALLS

Voltage from Phase-to-Earth Derived from System Volts ac rms or dc max.[2]	Installation (Overvoltage) Category			
	I		II, III, IV	
	mm[1]	(in)	mm[1]	(in)
50	12.7	(.495)	12.7	(.495)
100	12.7	(.495)	12.7	(.495)
150	12.7	(.495)	12.7	(.495)
300	12.7	(.495)	12.7	(.495)
600	12.7	(.495)	12.7	(.495)
1000	–		19.0	(.741)

[1]Clearances from Table ICS 1-111-1.

[2]For unearthed (ungrounded) systems or systems with one phase earthed (grounded phase) the phase-to-earth voltage shall be considered as the phase-to-phase voltage.

NEMA Standard 11-14-1985.

1-111A.2.3 CREEPAGE

The minimum values of creepage for Pollution Degree 3 are given in Table 1-111A.2.3-1.

Table 1-111A.2.3-1
CREEPAGE FOR EQUIPMENT SUBJECT TO LONG TERM STRESS

(Pollution Degree 3)

Rated Insulation Voltage[4] ac rms or dc max.	CREEPAGE[3]											
	Installation (Overvoltage) Categories I, II, III Material Groups[2]						Installation (Overvoltage) Category IV[1,2] Material Groups					
	I		II		IIIa & IIIb		I		II		IIIa & IIIb	
	mm	(in)	mm	(in)	mm	(in)	mm	(in)	mm	(in)	mm	(in)
50	1.5	(.059)	1.7	(.066)	1.9	(.074)	1.7	(.066)	1.9	(.082)	2.1	(.082)
100	1.8	(.070)	2.0	(.078)	2.2	(.086)	2.0	(.078)	2.2	(.086)	2.5	(.098)
150	2.0	(.078)	2.2	(.086)	2.5	(.098)	3.2	(.125)	3.6	(.140)	4.0	(.156)
300	4.0	(.156)	4.5	(.176)	5.0	(.195)	6.3	(.246)	7.1	(.277)	8.0	(.312)
600	8.0	(.312)	9.0	(.351)	10.0	(.390)	12.5	(.488)	14.0	(.546)	16.0	(.624)
1000	12.5	(.488)	14.0	(.546)	16.0	(.624)	20.0	(.780)	22.0	(.858)	25.4	(1.000)

[1]For industrial control equipment used at the service entrance (transition from installation (overvoltage) category IV to III) installation (overvoltage) category IV is required only for the line terminals.

[2]For inorganic insulating materials (which do not track) for example, glass or ceramics, creepages need not be greater than their associated inhomogeneous field (Case A) clearance, except for equipment in installation (overvoltage) category IV.

[3]Creepage values shown in this table have been determined for insulation intended to be under stress for a long time (or continuously).

[4]For insulation coordination within an equipment, creepage distances for printed wiring boards from IEC 664A Table IV, Pollution Degree 1, corresponding to the working voltage values within the equipment shall be permitted to be used. In this case, the limiting impulse withstand voltage can be found in IEC Publication 664 Table A1 under Case A impulse values corresponding to the creepage distance (clearance) value under consideration.

NEMA Standard 11-14-1985.

1-111A.2.4 MEASUREMENT OF CREEPAGE AND CLEARANCE

1-111A.2.4.1 Function of Grooves and Ribs

Grooves and ribs may be used to achieve required creepage between conductor parts without affecting the clearance between those parts.

Authorized Engineering Information 11-14-1985.

1-111A.2.4.2 Measurement Examples

Examples of the measurement for creepage and clearance are indicated in 1-111A.4.1. These examples do not differentiate between gaps and grooves or between types of insulation. Furthermore:

1. Any corner is assumed to be bridged with an insulating link of X mm width moved into the most unfavorable position (see example 3).
2. Where the distance across the top of a groove is X mm or more, creepage is measured along the contours of the grooves (see example 2).
3. Creepage and clearance measured between parts moving in relation to each other are measured when these parts are in their most unfavorable positions.

NEMA Standard 11-14-1985.

1-111A.2.4.3 Use of Grooves

The widths of grooves (X mm in examples of 1-111A.4.1) as a function of Pollution Degree shall be as follows:

Table 1-111A.2.4-1

MINIMUM VALUES OF WIDTH OF GROOVES BY POLLUTION DEGREE

Pollution Degree	Minimum Values of Width of Grooves	
	mm	(in)
1	0.25	(.010)
2	1.0	(.039)
3	1.5	(.059)
4	2.5	(.100)

[1] If the associated clearance is less than 3 mm, the minimum groove width shall be permitted to be reduced to 1/3 of this clearance.

NEMA Standard 11-14-1985.

1-111A.2.4.4 Use of Ribs

Because they diminish the effects of contamination and decrease drying-out time, ribs considerably decrease the formation of leakage current. Creepage distances can therefore be reduced to 80 percent of the values in Table 1-111A.2.3-1 provided the minimum height is 2 mm. However, creepage (including the use of ribs) cannot be less than the associated clearance. The minimum width of the base of a rib is determined by mechanical requirements.

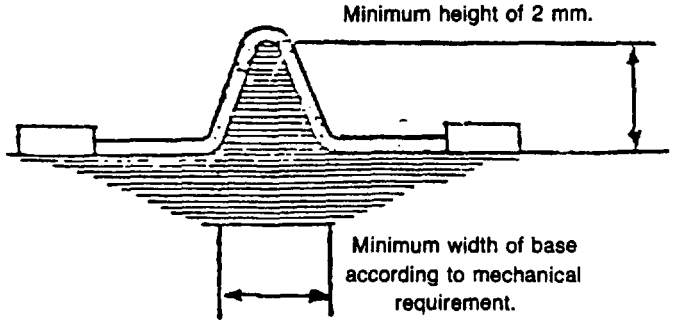


Figure 1-111A-1
MEASUREMENT OF RIBS

NEMA Standard 11-14-1985.

1-111A.2.5 Printed Wiring Boards

Electrical spacings for printed wiring boards are given in Tables 1-111A.2.5-1 and 1-111A.2.5-3.

Table 1-111A.2.5-1
UNCOATED PRINTED WIRING BOARDS
SPACINGS (CLEARANCE AND CREEPAGE DISTANCES) FOR EQUIPMENT WHERE TRANSIENT VOLTAGES ARE INTENTIONALLY CONTROLLED BY A TRANSIENT LIMITING MEANS[8]
(2000 Meters Altitude)

Rated Insulation Voltage[6] ac rms or dc volts	Installation (Overvoltage) Category													
	I					II					III			
	Impulse Withstand Voltage[2,3] Volts	Spacings for Pollution Degree				Impulse Withstand Voltage[2,3] Volts	Spacings for Pollution Degree				Impulse Withstand Voltage[2,3] Volts	Spacings for Pollution Degree			
		1[7]		2[1,4,5,7]			1[7]		2[1,4,5,7]			1[7]		2[1,4,5,7]	
		mm	(in)	mm	(in)		mm	(in)	mm	(in)		mm	(in)	mm	(in)
50	330	0.025	(.001)	0.2	(.008)	500	0.04	(.002)	0.2	(.008)	800	0.1	(.004)	0.2	(.008)
100	500	0.1	(.004)	0.2	(.008)	800	0.1	(.004)	0.2	(.008)	1500	0.5	(.020)	0.5	(.020)
150	800	0.25	(.010)	0.4	(.016)	1500	0.5	(.020)	0.5	(.020)	2500	1.5	(.059)	1.5	(.059)
300	1500	0.75	(.029)	1.6	(.062)	2500	1.5	(.059)	1.6	(.062)	4000	3.0	(.117)	3.0	(.117)
600	2500	1.8	(.070)	3.2	(.125)	4000	3.0	(.117)	3.2	(.125)	6000	5.5	(.215)	5.5	(.215)
1000	4000	3.2	(.125)	5.0	(.195)	6000	5.5	(.215)	5.5	(.215)	8000	8.0	(.312)	8.0	(.312)

[1]For Pollution Degree 3, creepage from Table 1-111A.2.3-1 must be used.

NEMA Standard 11-14-1985.

[2]Transients shall be controlled to values that do not exceed the rated impulse withstand voltage of the associated clearance for each installation (overvoltage) category. In addition, maximum recurring peak voltages shall be limited to the values in Table 1-111A.2.5-2 to prevent the degradation on insulation caused by partial discharges (corona).

NEMA Standard 11-14-1985.

[3]Pollution Degree 1 Spacings for Installation Categories II and III shall be permitted to be smaller than those shown, providing they can withstand their associated impulse withstand voltages; however, they shall not be smaller than the Pollution Degree 1 Spacings for Installation Category I.

NEMA Standard 11-14-1985.

[3]Because of "environmental/chemical" effects, it is not recommended that spacings less than 0.2 mm be used in industrial control equipment.

Authorized Engineering Information 11-14-1985.

[5]Clearances to the walls of a metal enclosure shall be in accordance with this table except for those portions of the walls that can be deflected and thereby reduce a clearance. Clearances to deflectable portions of an enclosure wall shall be in accordance with 1-111A.2.2-2.

NEMA Standard 11-14-1985.

[6]For insulation coordination within an equipment, creepage distances for printed wiring boards for IEC 664A Table IV, Pollution Degree 1, corresponding to the working voltage values within the equipment shall be permitted to be used. In this case, the limiting impluse withstand voltage can be found in IEC Publication 664 Table A1 Under Case A impulse values corresponding to the creepage distance (clearance) value under consideration.

NEMA Standard 11-14-1985.

[7]The Comparative Tracking Index (CTI) shall be:
Pollution Degree 1, CTI $\geq$ 100.
Pollution Degree 2, CTI $\geq$ 175.

NEMA Standard 11-14-1985.

[8]The spacings given were derived from IEC Publication 664A Table IV, however, some values of spacings were increased so that no creepage can be smaller than its associated clearance necessary to withstand the required impulse withstand voltage.

Authorized Engineering Information 11-14-1985.

Table 1-111A.2.5-2
MAXIMUM RECURRING PEAK VOLTAGE RELATED TO SPACINGS ON UNCOATED PRINTED WIRING BOARDS

(2000 Meter Altitude)

Spacings		Max. Recurring Peak Voltage[1]	Spacings		Max. Recurring Peak Voltage[1]
mm	in		mm	in	
0.025	(.001)	330	1.5	(.059)	1140
0.04	(.002)	330	1.6	(.062)	1150
0.1	(.004)	330	1.8	(.070)	1250
0.2	(.008)	400	3.0	(.117)	1650
0.25	(.010)	450	3.2	(.125)	1700
0.4	(.016)	600	5.0	(.195)	2200
0.5	(.020)	640	5.5	(.215)	2300
0.75	(.029)	800	8.0	(.312)	2800

[1]Recurring peak voltage values are based on statistical evaluation of partial discharge data.

NEMA Standard 11-14-1985.

Table 1-111A.2.5-3
COATED PRINTED WIRING BOARDS[1] SPACINGS (CLEARANCES AND CREEPAGE DISTANCES) FOR EQUIPMENT WHERE TRANSIENT VOLTAGES ARE INTENTIONALLY CONTROLLED BY A TRANSIENT LIMITING MEANS

Rated Insulation Voltage[4] ac rms or dc volts	Installation (Overvoltage) Category								
	I			II			III		
	Impulse Withstand Voltage volts	Spacings for Pollution Degree 1[2,3,5]		Impulse Withstand Voltage volts	Spacings for Pollution Degree 1[2,3,5]		Impulse Withstand Voltage volts	Spacings for Pollution Degree 1[2,3,5]	
		mm	in		mm	in		mm	in
50	330	0.025	(.001)	500	0.025	(.001)	800	0.025	(.001)
100	500	0.1	(.004)	800	0.1	(.004)	1500	0.1	(.004)
150	800	0.25	(.010)	1500	0.25	(.010)	2500	0.25	(.010)
300	1500	0.75	(.029)	2500	0.75	(.029)	4000	0.75	(.029)
600	2500	1.8	(.070)	4000	1.8	(.070)	6000	1.8	(.070)
1000	4000	3.2	(.125)	6000	3.2	(.125)	8000	3.2	(.125)

[1]Spacings are for Pollution Degree 1. The use of suitable coatings permit application in other degrees of pollution and installation (overvoltage) categories. Coating performance requirements are under consideration.

[2]These spacings apply to the coated portions of the board. Uncoated areas such as solder pads or components shall have the larger spacings from Table 1-111A.2.5-1.

Prior to coating, printed wiring boards must meet the impulse withstand voltage requirments of installation (overvoltage) category I in Table 1-111A.2.5-1 under clean and dry conditions. A test board, coated but without components, shall meet the impulse withstand voltage requirements of the intended installation (overvoltage) category as given in this table.

[3]Clearances to walls of enclosures shall be in accordance with Table 1-111A.2.5-1, Footnote 5.

[4]For insulation coordination within an equipment, creepage distances for printed wiring boards from IEC 664A Table IV, pollution degree 1, corresponding to the working voltage values within the equipment shall be permitted to be used. In this case, the limiting impulse withstand voltage can be found in IEC Publication 664 Table A1 under Case A impulse values corresponding to the creepage distance (clearance) value under consideration.

[5]Comparative Tracking Index (CTI) ≥ 100.

NEMA Standard 11-14-1985.

TEST

1-111A.3.1 VERIFICATION OF ELECTRICAL PROPERTIES OF INSULATION

1-111A.3.1.1 Kind of Tests

Tests for Insulation Coordination

A type test and a routine or sampling test for insulation coordination are required if clearance values, except as permitted in Section 1-111A.2.5, are less than those shown in Tables 1-111A.2.2-1 and 1-111A.2.2-2. The equipment shall be tested with the test voltages according to the impulse withstand voltage requirements of the selected installation (overvoltage) category as given in Table 1-111A.2.2-1 and 1-111A.2.2-2.

NEMA Standard 11-14-1985.

General Type Tests

An impulse test voltage specified for purposes other than verifying clearances must not exceed the value of the test voltage that is required for the verification of insulation coordination as given in Tables 1-111A.2.2-1 and 1-111A.2.2-2. These values shall only be exceeded if special testing provisions are to be made, e.g. when testing reinforced insulation.

NEMA Standard 11-14-1985.

Sampling and Routine Tests

(Under consideration.)

NEMA Standard 11-14-1985.

1-111A.3.1.2 Test of Solid Insulation

Requirements

Products designed with clearances equal to or larger than those in Tables 1-111A.2.2-1 and 1-111A.2.2-2 do not need a type test or routine test for insulation coordination purposes. However solid insulation of equipment associated with clearances shall withstand the impulse withstand voltages specified for the associated clearances.

NEMA Standard 11-14-1985.

Pre-Test Conditioning

Prior to the application of the test voltage, the device or equipment shall be conditioned for 96 hours in an atmosphere of 85 ± 5 percent relative humidity at a temperature of 25 ± 2°C. Subsequent dielectric tests, such as after endurance or performance tests, are to be performed without a humidity soak.

NEMA Standard 11-14-1985.

Test Selection Factors

The voltage withstand characteristic of solid insulation is dependent upon many factors that should be considered for the selection of methods and values for testing.

One of these factors is the voltage-time characteristic of the insulation. The one-minute dielectric test does not prove its ability to withstand an impulse withstand voltage associated with a clearance. Likewise, a one-minute power frequency test at the rated impulse withstand voltage of the clearance would be too severe. Therefore, the test to be used for this purpose is an impulse voltage corresponding to that required for the clearance.

Authorized Engineering Information 11-14-1985.

Partial Discharge

Another factor influencing solid insulation is its ability to withstand partial discharges at voltage withstand values associated with its application. In the most severe case, this would be the voltage associated with its clearance. In other instances, it may depend on exposure to periodically recurring peak voltages generated within the equipment itself.

Authorized Engineering Information 11-14-1985.

1-111A.3.1.3 Conditions of Test

Altitude

Breakdown voltage of a clearance in air, for a homogenous field (withstand voltage Case B) is, according to Paschen's Law, proportional to the product of the distance between electrodes and the atmospheric pressure. Therefore, testing at an altitude other than 2000 meters requires the use of the altitude correction factors given in Table 1-111A.3.1-1. These factors also apply for an inhomogenous field (withstand voltage Case A).

Table 1-111A.3.1-1
CORRECTION FACTORS FOR TEST VOLTAGES CORRESPONDING TO BAROMETRIC PRESSURE OR ALTITUDE

Altitude In		Barometric Pressure kPa	Correction (Multiplication) Factor for Test Voltage[1]
Meters	(Feet)		
0	(0)	101.3	1.27
500	(1641)	95.0	1.19
1000	(3281)	90.0	1.13
2000	(6562)	80.0	1.00
3000	(9843)	70.0	0.88
4000	(13124)	62.0	0.78
5000	(16405)	54.0	0.68
6000	(19686)	47.0	0.59
7000	(22967)	41.0	0.51
8000	(26248)	35.5	0.44

[1]At a given altitude, corrections for normal variation in barometric pressure are disregarded.

NEMA Standard 11-14-1985.

Enclosure

If the equipment or the device is to be used in an enclosure, it shall be mounted in the smallest enclosure in which it is likely to be used. If the equipment or the device is to be used without an enclosure, it shall be mounted on a metal plate and all metal parts (frame, etc.) which are earthed in normal service shall be connected to the metal plate.

NEMA Standard 11-14-1985.

Actuator Handle

An actuator (handle) of insulating material, and the integral non-metallic enclosure of the device that is intended to be used without additional enclosure, shall be covered by a metal foil and connected to the frame or the mounting plate.

NEMA Standard 11-14-1985.

1-111A.3.1.4 Points of Application of Test Voltages and Conditions of Test

The test voltages of 1-111A.3.1.6 shall be applied as follows:

1. Between the poles of the main circuit of the equipment and the metal parts that are earthed in normal service, including the enclosure, with the contacts in all normal positions.
2. Between each pole of the main circuit and with the other poles connected to the frame, and with the contacts in all normal positions.
3. Between each control and auxiliary circuit that is not normally connected to the main circuit in service and each of the main and other control and auxiliary circuits that have been connected to the frame for the purpose of the test.
4. For solid state equipment being tested per 1) or 2) of 1-111A.3.1.4, the test voltage shall be applied between the poles of the main circuit with the solid state devices in their blocking condition, and also with a shorting wire across the devices simulating the closed condition.
5. For equipment intended for use in other than motor branch circuits, the test voltage shall be applied between poles rated for opposite polarity and between all poles and the metal parts that are earthed in normal service with contacts in all normal positions.

NEMA Standard 11-14-1985.

1-111A.3.1.5 Results to be Obtained

There shall be no flashover or breakdown (disruptive discharge) during the test. The operation of a specific overvoltage protective function incorporated in the equipment for that purpose shall be permitted.

NEMA Standard 11-14-1985.

1-111A.3.1.6 Dielectric Tests

Dielectric Test Voltages

Dielectric test voltages shall be an alternating current power frequency voltage, a direct current voltage or an impulse voltage. The values of dielectric test voltage are given in Table 1-111A.3.1-2.

NEMA Standard 11-14-1985.

Impulse Dielectric Test

An impulse dielectric test voltage of 1.2/50 microsecond wave shape is used to simulate overvoltage due to lightning or switching operations.

NEMA Standard 11-14-1985.

Power Frequency Dielectric Test

A power frequency dielectric test voltage is expressed in rms or peak values.

NEMA Standard 11-14-1985.

Since the dielectric test voltage is greater than the rated voltage, care must be taken to not apply the test voltage in a manner that energizes a circuit.

Authorized Engineering Information 11-14-1985.

DC Dielectric Test

A dc dielectric test voltage shall be considered to be equivalent to the peak value of the power frequency dielectric test voltage.

NEMA Standard 11-14-1985.

The dc test voltage may be used in place of an ac test voltage in those cases where an ac test voltage would result in undesirable ac current which might be sufficient to damage (overheat and/or overvoltage) components or which may appear to be a high leakage current. Care should be taken to discharge any stored energy left in the circuit after test.

Authorized Engineering Information 11-14-1985.

Other Dielectric Test Techniques

Other techniques that limit the test energy, e.g. a half sine wave pulse, may be used. The test voltage values are shown in Table 1-111A.3.1-2.

Authorized Engineering Information 11-14-1985.

Table 1-111A.3.1-2
DIELECTRIC TEST VOLTAGES
(2000 Meters Altitude)

Type of Test	Impulse	AC RMS	AC Peak or DC	AC Peak ½ Sine Wave	AC Peak Ramp
Rate of Rise	1.2/50 us	–	–	–	6000 V/sec.
Hertz	–	50/60	50/60	50/60	50/60
Duration of Test	3 Pos. & 3 Neg.[1]	3 Pos. & 3 Neg.[3]	3 Pos. & 3 Neg.[3] DC, Min 10 ms	3 Pos. & 3 Neg.[1,3]	4-5 ma[2] detection
	330	230	330	330	330
	500	350	500	500	500
	800	570	800	800	800
	1500	1060	1500	1500	1500
	2500	1770	2500	2500	2500
	4000	2830	4000	4000	4000
	6000	4240	6000	6000	6000
	8000	5660	8000	8000	8000
	12000	8480	12000	12000	12000

[1]The minimum interval between pulses is 1 second.

[2]The voltage is to be increased until the ramp value is exceeded without detection of a leakage current of 4-5 milliamperes.

NEMA Standard 11-14-1985.

[3]Available current should be limited to 4-5 milliamperes. The test equipment can be power limited or designed to shut off by the detection of 4-5 milliampere leakage current.

Authorized Engineering Information 11-14-1985.

NOTE:

The test voltage values are given in Table A1 of IEC Publication 664.

The 3 Positive and 3 Negative pulses, without disruptive discharge, have been used in medium and high voltage dielectric testing, as for example in UL 347, paragraph 30.2.

The one-second power frequency and dc test duration has been used in NEMA Standard ICS 1 Part 1-109.21.06 at test voltage values 20 percent higher than the 60-second test voltage. The power frequency and dc voltage values given in Table 1-111A.3.1-2 are related to the impulse withstand voltage values from IEC Publication 664, Table A1.

The ½ sine wave pulse and ac voltages are slightly more severe than the impulse voltage values in time duration and have been found to be satisfactory in laboratory tests. These two test methods are relatively easy to achieve with less sophisticated test apparatus than the impulse test method.

Authorized Engineering Information 11-14-1985.

1-111A.3.2 VERIFICATION OF CREEPAGE DISTANCES

Creepage distances or spacings shall be in accordance with Table 1-111A.2.3-1 corresponding to the rated insulation voltage of the equipment.

NEMA Standard 11-14-1985.

1-111A.3.3 VERIFICATION OF OVERVOLTAGES GENERATED BY THE EQUIPMENT OR DEVICE (TYPE TEST)

1-111A.3.3.1 Procedure

All line and load terminals of the component, device or equipment shall be monitored for overvoltages during operation at rated operational voltage under load and no-load conditions.

NEMA Standard 11-14-1985.

1-111A.3.3.2 Performance

No voltages shall be generated greater than the lowest impulse withstand voltage rating corresponding to the assigned installation (overvoltage) category or categories.

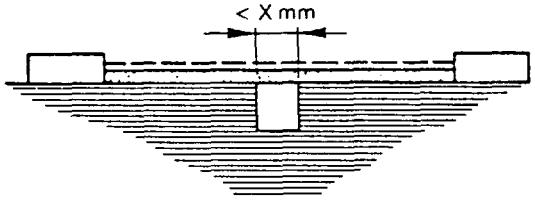
NEMA Standard 11-14-1985.

DETERMINATION OF CLEARANCE AND CREEPAGE MEASUREMENT

1-111A.4.1 EXAMPLES OF CLEARANCE AND CREEPAGE MEASUREMENT

For values of X, see Table 1-111A.2.4-1.

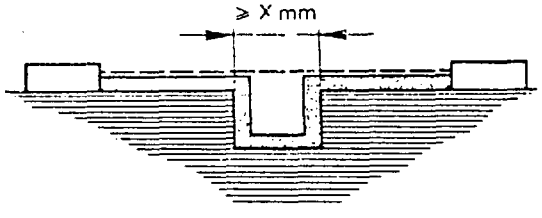
EXAMPLE 1



Condition: Path under consideration includes a parallel or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

EXAMPLE 2



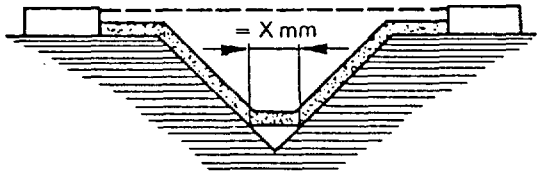
Condition: Path under consideration includes a parallel-sided groove of any depth and equal to or more than X mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove.



Clearance Creepage

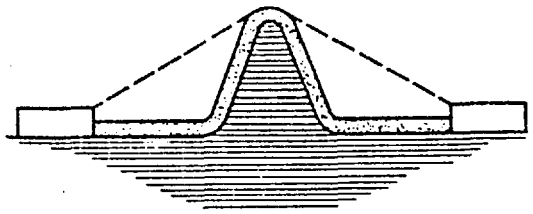
EXAMPLE 3



Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

EXAMPLE 4

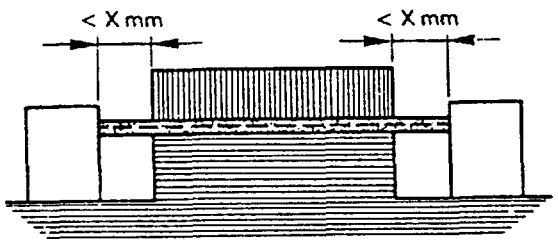


Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib.

Clearance Creepage

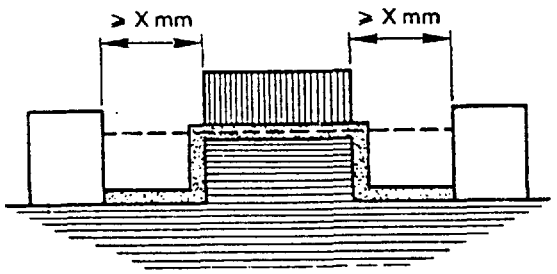
EXAMPLE 5



Condition: Path under consideration includes an uncemented joint with grooves less than X mm wide on each side.

Rule: Creepage and clearance path is the "line of sight" distance shown.

EXAMPLE 6

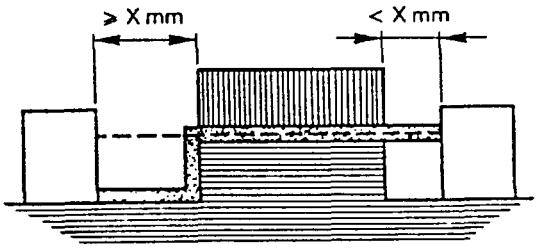


Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm wide on each side.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the grooves.

Clearance Creepage

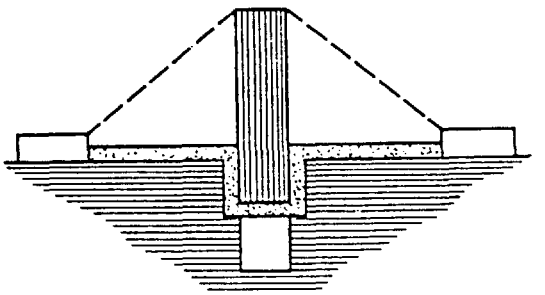
EXAMPLE 7



Condition: Path under consideration includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage paths are as shown.

EXAMPLE 8

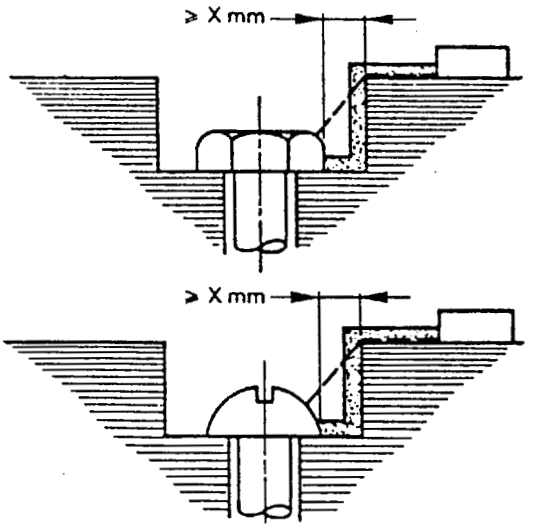


Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

Rule: Clearance is the shortest direct air path over the top of the barrier.

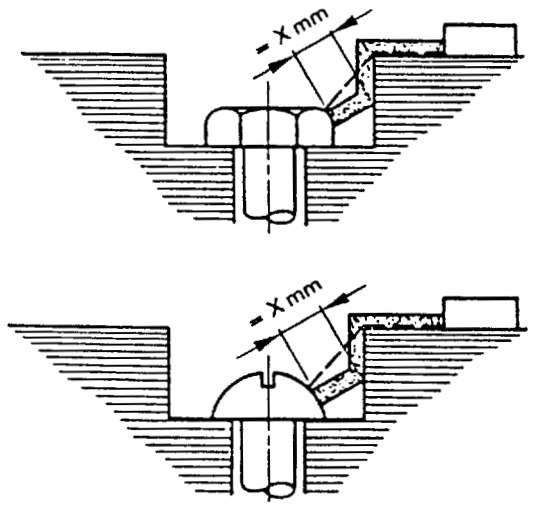
Clearance Creepage

EXAMPLE 9



Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

EXAMPLE 10

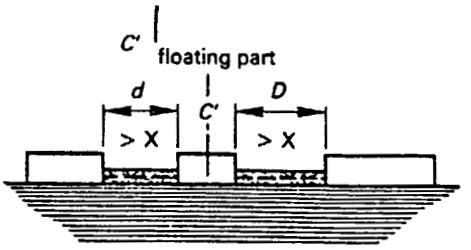


Condition: Gap between head of screw and wall of recess too narrow to be taken into account.

Rule: Measurement of creepage distance is from screw to wall when the distance is equal to X mm.

Clearance Creepage

EXAMPLE 11



Clearance is the distance of d + D

Creepage distance is also d + D

Authorized Engineering Information 11-14-1985.

Clearance Creepage

1-111A.4.2 WORKSHEET FOR DETERMINING CLEARANCE AND CREEPAGE DISTANCES

The equipment parameters which must be considered for the determination of clearance and creepage are given in Table 1-111A.4.2-1:

Table 1-111A.4.2-1
EQUIPMENT PARAMETERS

Equipment Parameters		
Voltages from Phase-to-Earth Derived from Rated System Voltages.[1,2] ac rms or dc max.		____ v rms or dc
Installation (Overvoltage) Category		I, II, III, IV
Material Group		I, II, IIIa, IIIb
Pollution Degree		1, 2, 3
Transient Voltage	Controlled Controlled Level	Yes, No ____ v peak ac
	Uncontrolled	Yes, No

[1]For conversion of Phase-to-Earth voltages to Rated System Voltage, see IEC 664A Table IIIa and IIIb.

[2]For unearthed (ungrounded) systems or systems with one phase (earthed (grounded phase)) the phase-to-earth voltage shall be considered as the phase-to-phase voltage.

1-111A.4.2.1 Using the parameters selected from Table 1-111A.4.2-1, determine creepage and clearances as follows:

Step 1— From Table 1-111A.2.2-1 (General Purpose Applications) or Table 1-111A.2.2-2 (Transient Voltage Controlled), determine the clearance and impulse withstand voltage.

Clearance ____

Rated Impulse Withstand Voltage ____

Equipment should not generate a transient that exceeds the rated impulse withstand voltage.

Step 2—From Table 1-111A.2.3-1, determine the creepage.

Step 3— Compare the creepage distance from Step 2 with clearance distance from Step 1. Creepage (including the use of ribs) cannot be less than the associated clearance.

Step 4—The dielectric test voltage is equal to the rated impulse withstand voltage per Step 1, adjusted for altitude per 1-111A.3.1.3.

Authorized Engineering Information 11-14-1985.

9009279 0000420 220

Part 1-112

RATING, PERFORMANCE, MANUFACTURING, AND APPLICATION

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified.

The definitions contained in Part 1-100 of this Standards Publication also apply to this part.

RATINGS

1-112.20 RATING OF CONTROL APPARATUS

In general, the rating of control apparatus shall be expressed in volts, amperes, horsepower, kilowatts, or other appropriate units.

NEMA Standard 3-7-1946.

1-112.21 RATING OF A CONTROLLER

For the purpose of these standards, the rating of a controller is based upon power governed and the duty service required. Unless specifically stated otherwise, standard ratings do not provide overload capacity (see Part 2-321 of NEMA Standards Publication No. ICS 2).

NEMA Standard 2-9-1940.

1-112.22 RATED OPERATIONAL VOLTAGES (U_e)

Rated operational voltages, U_e, for industrial control apparatus shall be as follows:

a. *AC, 60 Hertz, Multiphase*—115, 200, 230, 460, 575, 796, 920, 2300, 3300, 4000, 4600, and 6600 volts.
b. *AC, 50 Hertz, Multiphase*—380 volts.
c. *AC, 60 Hertz, Single Phase*—115 and 230 volts.
d. *AC, 50 Hertz, Single Phase*—220 volts.
e. *DC*—125 and 230 volts.

Voltages for resistance welding control higher than 230 volts shall be 460 and 575 volts.

NEMA Standard 5-25-1988.

AC voltages are based on Publication No. C84.1 of the American National Standards Institute, where applicable, and reflect the fact that industrial control is normally applied at the point of power utilization. Individual manufacturers may choose to mark coils or control-circuit transformers at the utilization voltage (listed above) or at the corresponding nominal system voltage (120, 208, 240, 480, or 600 volts, 60 Hertz). Coils marked with voltage ratings in multiples of 120 volts or in multiples of 115 volts are considered adequate for use on nominal system voltage ratings in multiples of 120 volts.

Authorized Engineering Information 11-21-1968.

1-112.23 FREQUENCY RATINGS

The reference to "50 and 60 Hertz" for ac controllers in this publication should not be construed to mean that the same shunt operating coil can be used on 50 or 60 Hertz at the same voltage rating. For example, some 460-volt 60-Hertz coils can be used on 380 volts at 50 Hertz but not on 440 volts 50 Hertz.

Authorized Engineering Information 8-19-1964.

1-112.24 BASIS OF RATINGS

The ratings of industrial control apparatus are based on an ambient temperature of 40°C.

NEMA Standard 10-21-1987.

PERFORMANCE

1-112.40 OPERATING OVERLOAD

For the purpose of this standard, the maximum operating overload of industrial motors and their control apparatus shall be considered to be:

a. *For AC Apparatus*—6 times normal full-load current.
b. *For DC Apparatus for Full-Voltage Starting*—10 times normal full-load current.
c. *For DC Apparatus for Reduced-Voltage Starting*—4 times normal full-load current.
d. *For Apparatus Where the Operating Overload is Automatically Limited*—100 percent of the limited value.

NEMA Standard 11-16-1972.

These overloads are currents that may persist for a very short time only, usually a matter of seconds.

Authorized Engineering Information 11-16-1972.

1-112.41 UNDERVOLTAGE RELEASE DEVICES (LOW-VOLTAGE RELEASE DEVICES)

Undervoltage or low-voltage releases are generally not designed to become effective at any specific degree of voltage reduction.

Authorized Engineering Information 5-17-1971.

1-112.42 UNDERVOLTAGE PROTECTION DEVICES (LOW-VOLTAGE PROTECTION DEVICES)

The principal objective of these devices is to prevent automatic restarting of the equipment. Undervoltage or low-voltage protection devices generally are not designed to become effective at any specific degree of voltage reduction.

Authorized Engineering Information 5-17-1971.

1-112.43 OVERLOAD DEVICES

Overload devices that deenergize magnetically operated devices shall open the circuit of such devices in order to provide fail-safe operation.

NEMA Standard 5-15-1932.

MANUFACTURING

1-112.60 PROTECTION OF SEMICONDUCTORS IN CIRCUITS

Semiconductors may be used to control circuit current in the power circuits of industrial control equipment. Such equipment after installation should have a disconnect means and overcurrent protection required by the *National Electrical Code.*

Authorized Engineering Information 5-25-1988.

When the rating of the power circuit supply exceeds 2.5 kW, the following standards shall apply:

NEMA Standard 5-25-1988.

1-112.60.1 Disconnect Means

Disconnect means, when provided as part of the industrial control equipment, shall be capable of interrupting operating overloads.

1-112.60.2 Overcurrent Protection

When overcurrent protection for semiconductors in power circuits is provided as part of the equipment, it shall conform to the following:

a. Fault overcurrent protection means, when provided, shall be capable of limiting the half-cycle peak currents and let-through energy under fault conditions to not more than the half-cycle surge current (electrical withstandablility) rating or the rupture rating of the semiconductors. When overcurrent protection is provided only to limit let-through current and energy up to the rupture rating, the equipment shall be so marked.
b. Running overload protection means, when provided, shall sense current that is greater than rated and respond in such a way as to eliminate the overload within the time-current rating of the semiconductors.
c. The overcurrent protective means, when provided, shall isolate the faulted circuit or component to prevent additional subsequent damage.

When overcurrent protection is not provided for semiconductors as part of the equipment in power circuits, information shall be provided that specifies the maxiumum peak current and maximum let-through energy that the semiconductors can withstand without damage and that suggests a means of obtaining the appropriate overcurrent protection.

NEMA Standard 5-25-1988.

Surge current rating is that value of half-cycle peak current that a device can withstand and have its characteristics remain the same. This half-cycle load is not repeatable. The device should be allowed to cool before it is subjected to the overloaded system. The rupture rating of a semiconductor is that value of current or let-through energy, or both, that the device can withstand without rupturing due to electromagnetic force or heat but not necessarily without altering the electrical characteristics of the device.

Authorized Engineering Information 1-5-1977.

1-112.60.3 Transient Voltage Protection

The peak reverse voltage of semiconductors shall be more than 2.5 times the nominal rms voltage of the circuit in which the semiconductors are used and means shall be provided to limit transient overvoltages to the voltage ratings of the semiconductors. Information shall be provided that expresses the design capability of the transient voltage protection means in terms of maximum energy (joules), maximum transient voltage magnitude, or maximum rate of change of current, or both, in addition to the maximum allowable rate of change of voltage.

NEMA Standard 5-25-1988.

Experience has shown that semiconductors with peak reverse voltage ratings of approximately 2.5 to 3.0 times their nominal application voltage can be protected against damage by transients by reasonable and economical means. The appropriate design capability of the transient voltage protection means is a function of the energy available to the circuit and the manner in which transients will be generated.

Authorized Engineering Information 1-5-1977.

1-112.60.4 Protection Against Loss of Forced Cooling

When forced cooling medium is used, control means shall be provided to protect the semiconductor against loss of such cooling.

NEMA Standard 5-25-1988.

1-112.61 MOTOR CONTROL CIRCUIT OVERCURRENT PROTECTION

The following are general requirements for control circuit conductor overcurrent protection. For specific requirements, see individual product standards.

These requirements apply to controllers rated 600 volts or less. For controllers rated above 2000V, see Part 2-324 of NEMA Standards Publication ICS 2.

1-112.61.1 Integral Control Source Without Control-Circuit Transformer

When the control-circuit power is supplied from the load side of the motor branch circuit short circuit protective device, the control-circuit conductors shall be protected as follows:

1-112.61.1.1 CONTROL-CIRCUIT CONDUCTORS THAT DO NOT EXTEND BEYOND THE MOTOR CONTROLLER ENCLOSURE

The control-circuit conductors are considered to be protected if the branch circuit short circuit protective device rating or trip setting does not exceed the values shown in Table 1-112-1.

Table 1-112-1
BRANCH CIRCUIT
SHORT CIRCUIT PROTECTION

Control Circuit Wire Size, AWG	Maximum Size of Branch Circuit Protective Device, Amperes
22	12
20	20
18	25
16	40
14	100
12	120

When the rating or trip setting of the Short Circuit Protective Device (SCPD) exceeds the values in Table 1-112-1, the control-circuit conductors shall be protected by an overcurrent protective device of the maximum rating given in Table 1-112-2.

Table 1-112-2
OVERCURRENT PROTECTION

Control Circuit Wire Size, AWG	Maximum Protective Device, Amperes
22	3
20	5
18	7
16	10
14	20
12	25

1-112.61.1.2 The overcurrent protection required for conductors by ICS 1-112.61.1.1 shall be permitted to be omitted for short direct leads, generally not exceeding 12 inches in length, that do not extend beyond the motor controller enclosure.

1-112.61.1.3 CONTROL-CIRCUIT CONDUCTORS THAT EXTEND BEYOND THE MOTOR CONTROLLER ENCLOSURE

The control-circuit conductors shall be considered to be protected if the branch circuit SCPD rating or trip-setting does not exceed the values shown in Table 1-112-3.

Table 1-112-3
BRANCH CIRCUIT
SHORT CIRCUIT PROTECTION

Control Circuit Wire Size, AWG	Maximum Size of Branch Circuit Protective Device, Amperes
22	3
20	5
18	7
16	10
14	45
12	60

When the rating or trip-setting of the SCPD exceeds the values shown in Table 1-112-3, the control-circuit conductors shall be protected by an overcurrent protective device of the maximum rating given in Table 1-112-2. The overcurrent device shall be located within the enclosure.

NEMA Standard 10-21-1987.

1-112.61.2 Integral Control Source With Motor Control-Circuit Transformer

When a motor control-circuit transformer is provided, its primary shall be connected on the load side of the branch circuit short circuit protective device.

If the control circuit is to be grounded, the ground connection shall be made at a transformer secondary lead or terminal.

1-112.61.2.1 PRIMARY-CIRCUIT CONDUCTOR PROTECTION

1-112.61.2.1.1 Requirements for overcurrent protection of primary-circuit conductors shall be the same as specified in ICS 1-112.61.1.1 for control-circuit conductors when a control-circuit transformer is not used.

1-112.61.2.1.2 The above paragraph does not negate the need for control-circuit transformer overcurrent protection where required by ICS 1-112.61.2.2. However, the same overcurrent protective device shall be permitted to be used for both control-circuit transformer protection and primary-circuit conductor protection if its rating satisfies each requirement.

1-112.61.2.2 MOTOR CONTROL-CIRCUIT TRANSFORMER PROTECTION

1-112.61.2.2.1 Where the rated primary current is less than 2 amperes, the primary shall be protected by

an overcurrent protective device in each ungrounded leg rated at not more than 500 percent of the rated primary current.

1-112.61.2.2.2 Where the rated primary current is equal to or greater than 2 amperes and less than 9 amperes, the primary shall be protected by an overcurrent protective device rated at not more than 167 percent of the rated primary current.

1-112.61.2.2.3 Where the rated primary current is 9 amperes or more, the primary shall be protected by an overcurrent protective device rated at not more than 125 percent of the rated primary current. However, if 125 percent of the rated primary current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, the next higher standard rating of the protective device shall be permitted to be used.

1-112.61.2.2.4 An overcurrent protective device shall not be required if the transformer is protected by other means, such as an integral thermal protector, which meets the requirements of UL 508; or,

The transformer supplies a Class 1 power limited, Class 2 or Class 3 remote control-circuit conforming with the requirements of Article 725 of the *National Electrical Code*; or,

The transformer rated less than 50 VA, is protected by an impedance limiting means, is an integral part of controller, and is located within the controller enclosure.

NEMA Standard 10-21-1987.

Transformers that are protected by an impedance and rated less than 50 VA are special purpose components typically used for low voltage power supplies and such in electronic circuits.

Authorized Engineering Information 10-21-1987.

1-112.61.3 Secondary-Circuit Conductor Protection

1-112.61.3.1 Where the control-circuit transformer has a two-wire, single-voltage secondary, the ungrounded secondary-circuit conductors are considered to be protected if the primary-circuit overcurrent protective device rating or the control-circuit transformer protection does not exceed the ratio of the secondary voltage to the primary voltage, multiplied by the maximum protective device rating shown in Table 1-112-2 for the secondary conductor size.

1-112.61.3.2 Protection of ungrounded secondary conductors is required per Table 1-112-2 where the control-circuit transformer has a tapped or multiple-winding secondary or where protection is not provided on the primary side as permitted by other paragraphs of this standard, unless secondary conductors meet the requirements of ICS 1-112.61.1.2.

1-112.61.4 Special Applications

The requirements of ICS 1-112.61 do not apply for applications identified in the *National Electrical Code* where a hazard would be created by the opening of the control circuit.

NEMA Standard 10-21-1987.

1-112.61.5 External Control Source

1-112.61.5.1 Control circuits of two or more motor controllers may be supplied from a common source and the conductors may be protected by common overcurrent devices at the source, if all conductors are the same size.

NEMA Standard 10-21-1987.

1-112.61.5.2 Motor control circuits supplied from a source external to the motor controller may require overcurrent devices within the controller, for example, where the conductor size is reduced.

Authorized Engineering Information 10-21-1987.

1-112.61.5.3 If overcurrent protection is provided, conductors shall be protected in accordance with their ampacities, in accordance with Table 1-112-2.

1-112.61.6 Interrupting Ratings

Protective devices used in control circuits shall have interrupting ratings not less than the available short circuit current at the protective device location in the circuit.

1-112.61.7 Accessory Kits

When a protective device is not assembled as part of the controller, an accessory kit, intended for installation in the controller enclosure, shall be available and information shall be provided with the controller to identify the proper kit to be used.

NEMA Standard 10-21-1987.

1-112.62 CONNECTIONS

Control devices intended to be renewable shall be provided with convenient means for making conductor connections.

NEMA Standard 7-7-1965.

1-112.63 COLOR CODING OF WIRING

When wired with thermoplastic insulated wire and when NEMA standard color coding is specified, the color

code for industrial control wiring shall be:

a. Line and load circuits, ac and dc power and motor circuits..... black
b. Control circuits
   (1) ac ..... red
   (2) dc ..... blue
c. Connection to primaries of control transformers..... black

Color coding, if specified, applies to the wiring between devices that are interconnected to form a control equipment and not to the wiring, which is an integral part of the devices.

When solenoids, brakes, and similar devices are employed as a part of the controller system, the panel wiring shall be color coded in the same manner as the power circuits. However, the panel wiring shall be color coded in the same manner as the control circuit when solenoids, brakes, and similar devices are:

d. Operated at line voltage and fused by control-circuit fuses; or are,
e. Operated from a voltage lower than the line voltage.

NEMA Standard 9-20-1973.

The colors green and white have been recognized in equipment and distribution circuit work. Green usually indicates an equipment grounding conductor, and white indicates the grounded neutral conductor of the circuit.

Authorized Engineering Information 9-20-1973.

1-112.64 COIL TERMINALS

Terminals shall be provided on or adjacent to all operating coils for contactors and relays.

NEMA Standard 1-9-1947.

1-112.65 MARKINGS OF COILS

Coils that are applied at their continuous ratings on single coil devices shall contain the following minimum information:

a. Rated voltage;
b. Rated frequency (for ac coils); "Direct Current" (for dc coils);
c. Manufacturer's name or trademark; and,
d. Manufacturer's ordering number.

NEMA Standard 1-5-1977.

It is recommended that the coils be so mounted that the manufacturer's ordering number will be visible when the coil is in place on the device.

Authorized Engineering Information 1-5-1977.

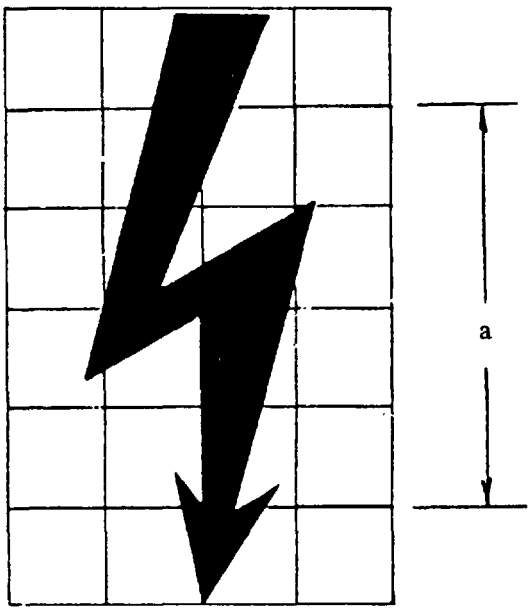
1-112.66 WARNING LABEL MARKING

1-112.66.1 Warning Symbol

When warning labels alerting the users to potential hazards of electrical shock or burn are furnished with enclosed industrial controls and systems, it is recommended they include a symbol for electrical hazards as shown and proportioned in Figure 1-112-1.

The warning labels of a size appropriate for the enclosure should be located on the front of the enclosure. When practicable, the label should be mounted where it remains visible after a door is opened or a cover removed. When space permits, a format similar to Figure 1-112-2 is recommended. For small devices, the warning symbol only (Figure 1-112-1) is recommended.

Suitable explanatory instruction on how to avoid the hazard should be shown on the warning label or in other instructions. For example, *Turn Off Power Before Working On This Equipment.*



Symbol proportion—height = 1.48 a
width = 0.58 a

Figure 1-112-1
SYMBOL DENOTING HAZARD OF ELECTRICAL SHOCK OR BURN

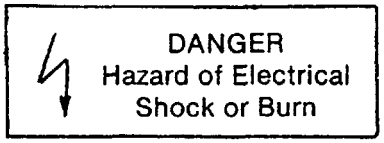


Figure 1-112-2
TYPICAL WARNING LABEL

1-112.66.2 Color Requirements

Vivid red* Munsell Notation 7.5R 4.0/14 should be the predominant visual color for either the signal word "DANGER" and the symbol or for the background. Black, white, or metallic may be used for contrast. These colors may be used either for the lettering or the background.

This requirement is not intended to rule out the use of other labels or markings that are required to comply with other nationally recognized standards or applicable law or regulations, such as radiation warnings, or that may be deemed necessary by the manufacturer.

* This vivid red is defined in Munsell Notation as follows:

Color	Red
Central	7.5R 4.0/14
Tolerances	
Hue	+8.5R, −6.5R
Value	+4.5/, −3.5/
Chroma†	+/16, −/12

† Colors may be stronger (more saturated) than the Chroma color as long as they comply with the hue and value tolerances.

NOTE—Vivid red is shown in the Hazardous Materials Label and Placard Color Tolerance Charts available from T.E.S. 231, Department of Transportation, Office of Hazardous Materials, 400 7th Street, S.W., DHM 51, Washington, D.C. 20590, telephone (202) 366-2301. These charts are also called the Combined Standard Safety Color Code Color Tolerance Charts (CSSCC).

1-112.66.3 Permanance and Legibility

The label should conform with 2.2 of NEMA Standards Publication No. ICS 6.

1-112.66.4 Other Labels or Markings

The use of this symbol on the front of enclosed electrical control equipment is not intended to rule out the use of other labels or markings, either internal or external, that are required to comply with other nationally recognized standards, laws, or regulations.

Authorized Engineering Information 1-5-1977.

Part 1-114●

APPARATUS HANDLING GUIDELINES

The standards in this part apply to all other parts in the NEMA Standards Publications for Industrial Controls and Systems unless otherwise specified.

1-114.1 GENERAL

Part 1-114 provides guidelines to help avoid personal injury and equipment damage during installation when handling and moving industrial control equipment.

Authorized Engineering Information 1-11-1984.

1-114.2 GUIDELINES

(a) Follow the manufacturer's handling instructions for specific equipment.

(b) Handle industrial control equipment with care to avoid damage to components and the enclosure.

(c) Extreme care must be exercised during any movement or placement of the equipment to prevent falling, tipping, or any other uncontrolled movement. Large equipment provided with a shipping skid should not be removed from the skid during handling or moving to minimize tipping and to protect the enclosure from distortion.

(d) Know the capabilities of the lifting and moving means available to handle the weight of the equipment.

(e) Large equipment may be supplied with lifting means (Figures 1-114-1 and 1-114-2) consisting of integral lifting angles, lifting plates, or eye bolts. The manufacturer's instructions, and the instructions listed below, should be followed:

(1) Use spreaders (Figure 1-114-1) to provide the vertical lift and eye bolts and lifting slings so as to avoid failure of the eye bolt or other damage to the equipment frame or its finish.

(2) Select or adjust the rigging lengths to compensate for any unequal weight distribution of load to maintain the equipment in an upright position.

(3) In order to reduce the tension on the rigging and the compressive load on the lifting or spanner bars and spreaders, do not allow the angle between the lifting cables and vertical to exceed 45 degrees. (See Figures 1-114-1 and 1-114-2.)

(4) Do not pass ropes or cables through the lift holes in bars, angles, or channels. Use slings with safety hooks or shackles.

(f) If industrial control equipment is to be stored for any length of time prior to installation, the equipment should be protected from the enviroment including the possibility of condensation of moisture inside the enclosure. For specific instructions, consult the manufacturer.

Authorized Engineering Information 1-11-1984.

● Added 1-11-1984.

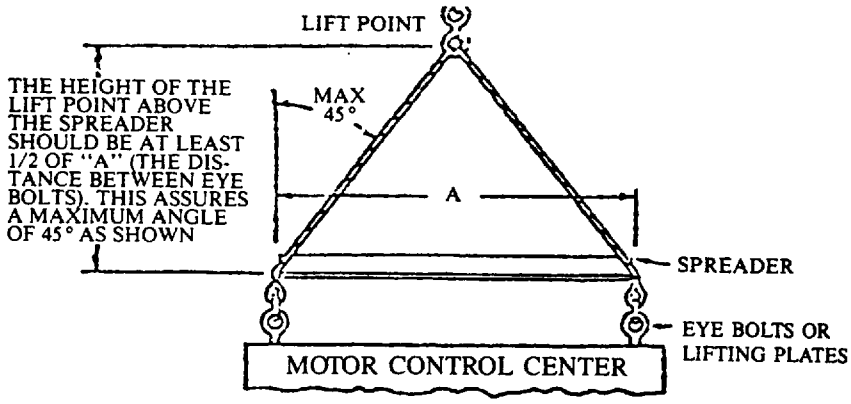


Figure 1-114-1
LIFTING WITH EYE BOLTS OR LIFTING PLATES

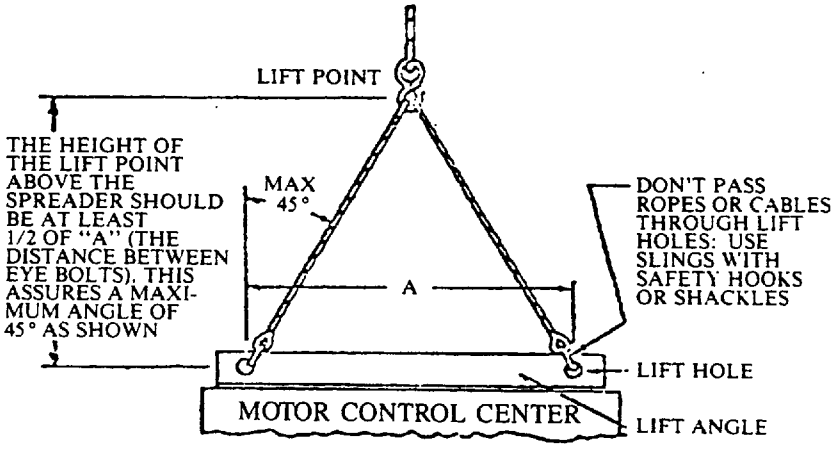


Figure 1-114-2
LIFTING WITH INTEGRAL LIFT ANGLE

Part 1-115

PREVENTIVE MAINTENANCE OF INDUSTRIAL CONTROL AND SYSTEMS EQUIPMENT

(This part is classified as Authorized Engineering Information.)

The purpose of Part 1-115 is to assist those responsible for maintenance and repair of Industrial Control and Systems Equipment. It covers maintenance practices that are common to most Industrial Control and Systems Equipment. It is intended to supplement more specific maintenance instructions that may be provided for particular product lines and specific products in other NEMA Standards and manufacturers' publications. It also covers general safety precautions for preventive maintenance activities.

More specifically, Part 1-115 covers fundamental principles, safety precautions, and common guidelines for preventive maintenance of equipment within the scope of the NEMA Industrial Control and Systems Section. The products of the Industrial Control and Systems Section are identified in NEMA Standards Publication Nos. ICS 2, ICS 3, ICS 4, and ICS 6.[1]

FUNDAMENTALS

1-115.1.1 Planning

A well-planned and executed preventive maintenance program is essential to the satisfactory operation of electrical and electronic equipment. A program should be established at the time the equipment is installed. At that time, any manufacturer's instructional literature should be reviewed and retained in a location readily accessible for reference during maintenance of the equipment.

1-115.1.2 Scheduling

A schedule should be established for routine preventive maintenance of the equipment at intervals selected on the basis of severity of duty and environment. The schedule should be adjusted if later experience indicates the need.

1-115.1.3 Documentation

A specific checklist of routine preventive maintenance requirements for each equipment item is recommended, as well as a logbook to record the maintenance history.

1-115.1.4 Renewal Parts

A supply of renewal parts recommended by the equipment manufacturer should be kept available.

[1]See 1-100.1, Referenced Standards for more detailed information.

SAFETY PRECAUTIONS

1-115.2.1 Work Practices

For the safety of maintenance personnel as well as others who might be exposed to hazards associated with maintenance activities, the safety related work practices of ANSI/NFPA 70E, Part II,[1] should always be followed when working on electrical equipment. Maintenance personnel should be trained in the safety practices, procedures, and requirements that pertain to their respective job assignments.

1-115.2.2 Deenergization

Circuit parts and equipment that can endanger personnel should be deenergized and locked out or tagged out in accordance with the requirements of ANSI/NFPA 70E, Part II. If more than one incoming power source exists (e.g., a separate control circuit), make sure that all sources are deenergized. Solid-state electronic equipment may contain elements that exhibit potentially hazardous leakage current in the "off" state. Such equipment should be isolated from the source of power by conventional disconnection means rather than by simply "turning off" the solid-state device.

1-115.2.3 Work on Energized Equipment

Persons should not be permitted to work on electric circuit parts or equipment that have not been deenergized and locked out or tagged out unless they are qualified and trained to use all appropriate safe work practices, procedures, and protective equipment in accordance with the requirements specified in ANSI/NFPA 70E, Part II. No work should be permitted on energized electrical equipment in any hazardous location as defined in the *National Electrical Code* (ANSI/NFPA 70).[1]

1-115.2.4 Hazards of Controlled Equipment

Maintenance activities, particularly shut-down and return to service of equipment or processes, must be coordinated with operations management to avoid hazardous conditions. Access to any machinery or process equipment that is controlled by the electrical equipment undergoing maintenance should be prohibited unless all means of activating the machinery or process have been locked out or blocked; including release or restraint of all stored energy, such as the electrical charge in capacitors, pressure in fluid or gas systems and stored mechanical energy in springs and elevated parts.

GENERAL GUIDELINES

1-115.3.1 Cleanliness

1-115.3.1.1 Opening Enclosures

Control equipment should be kept clean and dry. Before opening the door or cover of a cabinet or enclosure, comply with "SAFETY PRECAUTIONS." Foreign material, dirt, hardware, or debris should be removed from the outside top surfaces to avoid the risk of anything falling onto the equipment. Methods used in cleaning the outside of cabinets or enclosures should be chosen with consideration for the enclosure's type designations (see NEMA Standards Publication No. ICS 6),[1] to avoid risk of contaminating the enclosed equipment.

1-115.3.1.2 Inspection

Upon opening the cabinet or enclosure, control equipment should be inspected for any dust, dirt, moisture or evidence of moisture, or other contamination. If any is found, the cause must be eliminated. This could indicate an incorrectly selected, deteriorated, or damaged enclosure; unsealed enclosure openings; internal condensation; condensate from an unsealed conduit; or improper operating procedures (e.g., operating with enclosure door or cover open).

1-115.3.1.3 Operating Conditions

Enclosure doors, access plates, and covers are intended to remain closed during normal operation. Evidence that equipment has been operated with the enclosure door open or cover removed is usually an indication of a problem that should be diagnosed and corrected.

1-115.3.1.4 Cleaning

Corroded or damaged parts should be replaced. Dirty, wet, or contaminated parts of control equipment should also be replaced unless they can be cleaned effectively by vacuuming or wiping with dry cloth or soft brush. Use care to avoid damaging delicate parts. Compressed air is not recommended for cleaning because it may displace dirt, dust, or debris into other parts or equipment, or damage delicate parts. Liquid cleaners, including spray cleaners, are not recommended unless specified by the equipment manufacturer, because of the risk of residues causing damage or interfering with electrical or mechanical functions. The inside bottom of the cabinet or enclosure should also be cleaned, including removal of any hardware or debris, so that any new or unusual wear or loss of parts occurring after the inspection may be more readily detected during subsequent maintenance.

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[1]See 1-100.1, Referenced Standards, for more detailed information.

1-115.3.2 Mechanical Integrity

1-115.3.2.1 INSPECTION

A general inspection of mechanical integrity should be made, i.e., loose, broken, missing, or badly worn parts. The intended movement of mechanical parts, such as armature and contacts or electromechanical contactors, disconnector, or circuit breaker operator mechanism, and mechanical interlocks should be checked for freedom of motion and functional operation. For example, does a mechanical interlock actually provide the intended function?

1-115.3.2.2 SERVICING

Any broken, deformed, or badly worn parts or assemblies should be replaced with manufacturer-recommended renewal parts. Any loose fasteners should be retightened securely (to manufacturer-recommended torque if specified). Lubricate mechanisms only if recommended by the manufacturer, using only the recommended type and amount of lubricant. Remove any surplus lubricant to avoid risk of establishing a tracking path across insulating surfaces, and of excess lubricant migrating into areas that should not be lubricated.

1-115.3.3 Temperature Control

1-115.3.3.1 INSPECTION

Ventilation passages should be kept open. If equipment depends on auxiliary cooling or heating, the temperature control system should be checked and repaired if necessary to assure proper functioning. Filters should be cleaned or replaced if necessary, based on inspection or the time interval recommended by the manufacturer.

1-115.3.3.2 SERVICING

If dust or dirt has accumulated on heat sinks and/or components that generate heat, it should be removed carefully by vacuuming, wiping or brushing, since such accumulation can reduce heat dissipation capability and lead to premature failures (see 1-115.3.1.4).

1-115.3.4 Diagnosis

Maintenance should always aim to determine and correct the cause of any problems, not just the symptoms.

1-115.3.5 Repair

If the equipment condition indicates need for adjustment, repair, or replacement, the manufacturer's instruction manual should be followed carefully. Diagnostic information within such a manual should be used to identify the probable source of the problem and to formulate a repair plan. The level of field repair recommended by the manufacturer should be followed; if more extensive repair is needed, the item should be replaced and/or returned to the manufacturer.

1-115.3.6 Replacement Parts

Some apparently equivalent replacement parts from sources other than the original equipment manufacturer may not be suitable because the original equipment manufacturer may have required the original part to meet unique specifications, performance or test requirements (e.g., burn-in). Therefore, replacement parts meeting the specifications of the original equipment manufacturer should be used. Care should be taken to avoid the use of parts that are no longer compatible with changes in the equipment; revision levels should be verified. All parts contained in a replacement kit should be changed. Do not use parts that have deteriorated in storage.

1-115.3.7 Disposal of Parts

Government regulations and/or safe practice dictate that some types of parts that may be removed during maintenance require special handling and disposal. Examples are lithium storage batteries, and capacitors or transformers filled with polychlorinated biphenyl (PCB) electrolyte. Follow manufacturer's instructions and any applicable government regulations.

1-115.3.8 Fault Conditions

Fault conditions can cause extensive damage to control equipment. Opening of a short circuit protective device (such as a fuse or circuit breaker) indicates a fault condition in excess of operating overload. Where evidence of a fault is found, before restoring power any damaged item(s) should be repaired or replaced. Refer to NEMA Standards Publication No. ICS 2-302[1] for further information.

1-115.3.9 Functional Check

1-115.3.9.1 TESTS

After inspection, maintenance, or repair operations, the equipment should be tested for proper functioning before it is returned to service. During such tests, personnel should be protected against hazards in the event of a malfunction.

1-115.3.9.2 INDICATIONS

A change in magnitude or frequency of vibration or noise indicates a need for attention; for example, a noisy ac magnet solenoid (see 1-115.4.5).

1-115.3.10 Documentation

An entry should be made into the log each time preventive maintenance is performed. The entry should indicate the date maintenance was performed; observations; description of any repairs or modifications and reasons for them; and indentity of person(s) who performed the maintenance.

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[1]See 1-100.1, Referenced Standards, for more detailed information.

SPECIFIC GUIDELINES

Refer to individual product standards (NEMA Standards Publication Nos. ICS 2, ICS 3, ICS 4, and ICS 6)[1] for additional details.

1-115.4.1 Assembly/Reassembly

If partial disassembly of a mechanism is necessary, the manufacturer's instructions should be followed for disassembly, reassembly, and any required adjustment or lubrication. Upon reassembly the mechanism should be checked for freedom of motion and functional operation. Alignment should be checked by operating the mechanism (at a reduced speed if an operating means for this purpose has been supplied by the manufacturer).

1-115.4.2 Terminals and Connections

Loose electrical connections can cause overheating that can lead to equipment malfunction or failure. Loose bonding or grounding can compromise safety and/or function. Terminal screws, lugs, bus connections, bonding and grounding connections should be checked for tightness and retightened securely (to manufacturer's specifications) as required. Fuse clips should be checked for signs of overheating, looseness or inadequate spring pressure, and replaced if necessary. Any parts or wiring found to be damaged by overheating should be replaced, using parts supplied or recommended by the manufacturer. Evidence of overheating may include discolored conductors, terminals or parts; or melted, charred, or burned insulation.

CAUTION: Do not remove plating on aluminum parts in joints or terminations.

1-115.4.3 Conductors

Examine insulation on conductors for overheating or chafing against metal edges that could progress into an insulation failure. Any damaged conductors should be replaced. Replacement conductors should be rerouted, braced or shielded if needed to avoid similar damage in future operation. Temporary wiring should be removed or replaced by permanent wiring.

1-115.4.4 Contacts and Arc Chutes

1-115.4.4.1 INSPECTION

Contacts and arc chutes of electromechanical contactors should be checked for excessive burning, beads of molten material, and unusual erosion of the contact faces. Do not file or dress contacts unless recommended by the manufacturer.

1-115.4.4.2 SERVICING

Replace excessively worn or pitted contacts with manufacturer recommended renewal parts, or replace the contactor. All contacts of multi-pole devices should be replaced simultaneously to avoid misalignment and uneven contact pressure. Arc chutes and arc hoods should be replaced if they are broken or deeply eroded. Easily dislodged dust or granules should be removed by vacuuming, wiping, or light brushing. Insulating surfaces should not be scraped, sandpapered, or filed.

1-115.4.5 AC Magnet Solenoids

A noisy solenoid in a relay or contactor indicates failure to seat properly or a broken or loose shading coil. The cause should be determined and corrected to avoid overheating and coil damage. If a coil exhibits evidence of overheating (cracked, melted, or burned insulation), it must be replaced, after the cause of overheating has been detected and corrected. This could include the AC magnet symptoms described above, or any binding that keeps the magnet from seating properly when energized, or overvoltage or undervoltage conditions. If melted coil insulation has flowed onto other parts, they should be cleaned or replaced.

[1]See 1-100.1, Referenced Standards, for more detailed information.

1-115.4.6 Solid-State Devices

1-115.4.6.1 INSPECTION

Solid-state devices require periodic visual inspection. Printed circuit boards should be inspected to determine that they are fully inserted into the edge board connectors. Board locking tabs should also be engaged. Unplugging and replugging of connectors to verify seating is not recommended as this will shorten the useful life of most types of connectors used with solid-state devices.

1-115.4.6.2 CLEANING

Dust or dirt, if found, should be cleaned from boards and components as recommended in 1-115.3.1.4. Solvents should not be used on printed circuit boards.

1-115.4.6.3 SERVICING

Necessary replacements should be made only at the printed circuit board or plug-in component level unless otherwise recommended by the equipment manufacturer. Special care is needed to avoid damage when servicing equipment that contains electrostatic-sensitive components. Manufacturer's recommendations should be followed for removal, handling, packaging, shipping, and/or replacement of such components or modules.

1-115.4.6.4 TESTING

Use only test equipment and test instructions specified by the manufacturer of the solid-state equipment to avoid damage to the solid-state equipment or the test equipment, or unintended actuation of other equipment controlled by the solid-state equipment. Refer to NEMA Standards Publication No. ICS 1.1[1] for further information.

1-115.4.7 Protective Devices

The rating and setting of protective devices for each particular application, such as fuses, circuit breakers, and overload relays, should be checked to verify that they are proper. Adjustment, repair, or replacement should be performed as necessary, in accordance with any applicable instructions of the manufacturer. For replacement purposes, use only fuse types and ratings specified by the equipment manufacturer. Never attempt to defeat rejection mechanisms that are provided to guard against installation of the wrong type of fuses.

1-115.4.8 Indicating Devices

All indicating lamps, mechanical flags, and similar auxiliaries should be checked and repaired or replaced if required.

1-115.4.9 Labels and Nameplates

Labels and nameplates should be checked to verify that they are securely attached and legible. Clean or replace any that are damaged, loose, missing, or deteriorated to the extent that legibility is compromised.

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[1]See 1-100.1, Referenced Standards, for more detailed information.

NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status, are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below.

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard. *(Standardization Policies and Procedures, p. 1)*

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.
(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.
(Standardization Policies and Procedures, p. 9)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 8 & 17)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.
(Standardization Policies and Procedures, pp. 8 & 17)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment, and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon.
(Standardization Policies and Procedures, pp. 8 & 17)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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INDUSTRIAL CONTROL AND SYSTEMS SECTION OF THE NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

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Automatic Switch Company
Florham Park, NJ 07932

Balluff Inc.
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Cooper Industries, Inc.
Arrow-Hart Components Products
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Curtis Industries, Inc.
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Custom Switchgear & Controls
Santa Clara, CA 95051

Cutler-Hammer Products
Eaton Corporation
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Furnas Electric Company
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GE
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Kulka Smith, Inc.
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Syracuse, NY 13221

The Planum Technology Corporation
Hillside, NJ 07205

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Robicon Corporation
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Russelectric Inc.
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Siemens Energy & Automation, Inc.
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Sprecher & Schuh, Inc.
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