

**NEMA Standards Publication No. ICS 1-2000 (R2005, R2008)**

*Industrial Control and Systems  
General Requirements*

Published by

National Electrical Manufacturers Association  
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## Foreword

This standards publication was prepared by a technical committee of the NEMA Industrial Automation Control Products and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes the indicated NEMA Standards Publication. This standards publication supersedes ICS 1-1993.

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

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

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

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

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

- a. Environmental conditions
- b. System design
- c. Equipment selection and application
- d. Installation
- e. Operating practices
- f. Maintenance

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

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

To continue to serve the best interests of users of Industrial Control and Systems equipment, the Industrial Control and Systems Section is actively cooperating with other standardization organizations in

the development of simple and more universal metrology practices. In this publication, the U.S. customary units are gradually being supplemented by those of the modernized metric system known as the International Systems of Units (SI). This transition involves no changes in standard dimensions, tolerances, or performance specifications.

NEMA standards publications are subject to periodic review. They are revised frequently to reflect user input and to meet changing conditions and technical progress.

Proposed revisions to this standards publication should be submitted to:

Vice President, Technical Services  
National Electrical Manufacturers Association  
1300 North 17<sup>th</sup> Street, Suite 1752  
Rosslyn, VA 22209

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

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Alstom Drives and Controls, Inc. – Pittsburgh, PA  
Automatic Switch Company – Florham Park, NJ  
Balluff, Inc. – Florence, KY  
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CMC Torque Systems – Billerica, MA  
Control Concepts Corporation – Beaver, PA  
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Omron Electronics, LLC – Schaumburg, IL  
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Post Glover Resistors, Inc. – Erlanger, KY  
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Regal-Beloit Corporation – Bradenton, FL  
Reliance Controls Corporation – Racine, WI  
Robert Bosch Corporation – Avon, CT  
Rockwell Automation – Milwaukee, WI  
R Stahl, Inc. – Salem, NH  
Russelectric, Inc. – Hingham, MA  
Schneider Automation, Inc. – North Andover, MA  
SEW-Eurodrive, Inc. – Lyman, SC  
Siemens Energy & Automation – Alpharetta, GA  
Square D – Lexington, KY  
Texas Instruments, Inc. – Attleboro, MA  
Torna Tech., Inc. – St. Laurent, Quebec, Canada  
Toshiba International Corporation – Houston, TX  
Total Control Products Inc. – Milford, OH  
Turck, Inc. – Plymouth, MN  
Tyco Electronics/AMP – Harrisburg, PA  
WAGO Corp. – Germantown, WI  
Weidmuller, Inc. – Richmond, VA  
Yaskawa Electric America – Waukegan, IL

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The standards or guidelines presented in a NEMA standards publication are considered technically sound at the time they are approved for publication. They are not a substitute for a product seller's or user's own judgment with respect to the particular product referenced in the standard or guideline, and NEMA does not undertake to guarantee the performance of any individual manufacturer's products by virtue of this standard or guide. Thus, NEMA expressly disclaims any responsibility for damages arising from the use, application, or reliance by others on the information contained in these standards or guidelines.

## INTRODUCTION

The standards pertaining to general requirements in NEMA Standards Publication ICS 1 are subdivided into the following clauses:

- 1 General
  - Referenced Standards
  - Scope
  - Normative References
- 2 Definitions
  - Terms which supplement the IEC International Electrical Vocabulary (IEV 441) or assist in clarifying the product standard.
- 3 Classification
  - Product classifications where they have been established.
- 4 Characteristics and Ratings
  - Descriptions of the kinds of ratings applicable to the product and tables of standard ratings for the product where they have been established.
- 5 Product Marking, Installation and Maintenance Information
  - Product information to be provided to assist the user in the installation, use and maintenance of the devices.
- 6 Service and Storage Conditions
  - A description of service and storage conditions for which the devices are intended.
- 7 Construction
  - Marking, color coding and similar production requirements to be incorporated into the product as manufactured, as well as production test requirements where they have been established, i.e., the rules that the manufacturer follows in producing the product.
- 8 Performance Requirements and Tests
  - The performance required to pass each design test specified for the product.

This standards publication contains general requirements that are applicable to the majority of products with the scope of the Industrial Automation Control Products and Systems Section. The product standards that make reference to these general requirements include:

NEMA Standards Title Publication No.

- |       |                                                                                                                                  |
|-------|----------------------------------------------------------------------------------------------------------------------------------|
| ICS 1 | Industrial Control and Systems - General Requirements                                                                            |
| ICS 2 | Industrial Control and Systems - Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC |
| ICS 3 | Industrial Control and Systems - Factory-built Assemblies                                                                        |
| ICS 4 | Industrial Control and Systems - Terminal Blocks                                                                                 |
| ICS 5 | Industrial Control and Systems - Control Circuit and Pilot Devices                                                               |
| ICS 6 | Industrial Control and Systems - Enclosures                                                                                      |

ICS 7 Industrial Control and Systems - Adjustable Speed Drives

ICS 8 Industrial Control and Systems - Crane and Hoist Controllers

ICS 10 Industrial Control and Systems - AC Transfer Switch Equipment

## Industrial Control and Systems

### General Requirements

#### 1 General

##### 1.1 Referenced standards

The following standards contain provision which, through reference in this text, constitute provisions of this NEMA Standard Publication. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

##### **American National Standards Institute**

11 West 42nd Street  
New York, NY 10036

|             |                                                                         |
|-------------|-------------------------------------------------------------------------|
| C84.1-1995  | <i>Voltage Ratings for Electric Power Systems and Equipment (60 Hz)</i> |
| Z535.4-1998 | Standard for Product Safety Labels                                      |

##### **American Society for Testing and Materials**

1916 Race Street  
Philadelphia, PA 19103

|             |                                                                                       |
|-------------|---------------------------------------------------------------------------------------|
| D-3638-1993 | <i>Test Methods for Comparative Tracking Index of Electrical Insulating Materials</i> |
|-------------|---------------------------------------------------------------------------------------|

##### **Institute of Electrical and Electronics Engineers**

345 East 47<sup>th</sup> Street  
New York, NY 10017

|               |                                                                               |
|---------------|-------------------------------------------------------------------------------|
| IEEE 100-2000 | <i>Standard Dictionary of Electrical and Electronics Terms (ANSI C42-100)</i> |
|---------------|-------------------------------------------------------------------------------|

##### **International Electrotechnical Commission**

1, Rue de Varembe  
Geneva, Switzerland

|                |                                                                                                                              |
|----------------|------------------------------------------------------------------------------------------------------------------------------|
| IEC 112-1979   | <i>Methods for Determining the Comparative and the Tracking Indices of Solid Insulating Materials Under Moist Conditions</i> |
| IEC 664-1-1992 | <i>Insulation Coordination for Equipment Within Low-Voltage Systems, Part 1: Principles, Requirements and Tests</i>          |

##### **National Fire Protection Association**

1 Batterymarch Park  
Quincy, MA 02269

|                    |                                                               |
|--------------------|---------------------------------------------------------------|
| ANSI/NFPA 70-1999  | <i>National Electrical Code</i>                               |
| ANSI/NFPA 70E-2000 | <i>Electrical Safety Requirements for Employee Workplaces</i> |

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

UL 508 - 1999      *Industrial Control Equipment (17th Ed)*

## **1.2 Scope**

The scope of this publication is the scope of the Industrial Automation Control Products and Systems Section. The purpose of this publication is to consolidate all standards of a general nature in order to obtain uniform application of requirements throughout the range of industrial control and systems equipment.

## **1.3 Relation to Product Standards**

The requirements in this publication shall apply to all other NEMA Standards Publications for industrial control and systems equipment unless otherwise specified.

For each type of product, only two main documents are normally necessary to determine all requirements:

This general standard, referred to as ICS 1

The specific standard applying to the type of product, hereafter referred to as the "relevant product standard" or "product standard."

## 2 Definitions

(\* indicates definition from ANSI/IEEE Standard 100.)

For the purposes of this publication the following definitions apply:

The terms have been arranged in an alphabetical order that reflects common usage. Specialized definitions applying to specific products appear in the standards publications for those products.

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

**adaptive control systems\*:** 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.

**alternating current (AC) contactor:** A contactor for the specific purpose of establishing and interrupting an AC power circuit.

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

### NOTES—

- a. For self-ventilated equipment, the ambient temperature is the average† temperature of the air in the immediate vicinity of the equipment.

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.

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 vicinity of the equipment.

(These notes are not a part of ANSI/IEEE Std 100 definition.)

†The average of temperature readings at several locations.

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

**application test:** A test 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.

**automatic reset\*:** A function that operates to automatically re-establish specific conditions.

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

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

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

**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.

**bus:**

- a. A set of power supply leads
- b. A conductor that provides multiple connections

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

**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.

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).

**combination controller (600 volts or less)\*:** A full magnetic or semi-magnetic controller with additional externally operable disconnecting means contained in a common enclosure. The disconnecting means shall be permitted to be a circuit breaker or a disconnect switch. Combination starters are specific forms of combination controllers.

**conducting parts\*; live parts:** Those parts that are designed to carry current or that are conductively connected therewith.

**connection diagram:** See wiring diagram.

**construction diagram\*:** A diagram that shows the physical arrangement of parts, such as wiring, buses, resistor units, etc.

Example: A diagram showing the arrangement of grids and terminals in a grid-type resistor.

**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.

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

**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.

**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.

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

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

**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.

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

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

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

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

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

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

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

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

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

**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.

**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.

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).

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

**current relay\*:** A relay that functions at a predetermined value of current. It may be an overcurrent, undercurrent, or reverse-current relay.

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

**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.

**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.

**design test:** See type test.

**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.

The purpose of the tests is to determine the adequacy against breakdown of insulating materials and spacings under normal or transient conditions.

**dimension drawing; outline drawing:** A drawing (base plan, floor plan, etc.) 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.

**direct current (DC) contactor:** A contactor for the specific purpose of establishing and interrupting a DC power circuit.

**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.

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

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

**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.

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

**drum controller\*:** An electric controller that utilizes a drum switch as the main switching element. A drum controller usually consists of a drum switch and a resistor.

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

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

**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.

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

**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.

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

NOTE—For example, an electric motor controller may be a contactor or a starter rated in horsepower, kilowatts, or locked-rotor and full-load amperes. (The preceding sentence is not a part of the ANSI/IEEE Std 100 definition.)

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

**electronic direct current (DC) motor controller:** 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 DC motor, to provide adjustable-speed, adjustable- and compensated-speed, or adjustable- and regulated-speed characteristics.

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

**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.

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

**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.

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

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

NOTE—"Basic functions" usually refers to acceleration, retardation, line closing, reversing, etc. (This note is not a part of the ANSI/IEEE Std 100 definition.)

**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.

**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.

**graphic symbol:** Symbols 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.

**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.

**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.

**inch:** See jog.

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

**insulation class:** The classification of insulation materials for the purpose of establishing temperature limits for the use of the material. (See 8.3.2.1.)

**interconnection diagram:** A diagram which shows only the external connections between controllers and associated machinery and equipment.

**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 are either electrical or mechanical.

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

For example, when applied to apparatus such as combination controllers or control centers 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.

**intermittent periodic duty; 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.

**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.

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

**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.

For example:

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

**isolating switch (means):** A switch, or other mechanism, intended for isolating an electric circuit from the source of power.

NOTE—It has no interrupting rating, and it is intended to be operated only after the circuit has been opened by some other means.

**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.

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

NOTE—It may be expressed either as an absolute magnitude of speed or a percentage of maximum rated speed.

**live parts:** See conducting parts.

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

**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.

**magnetic brake\*:** A friction brake that is controlled by electromagnetic means.

**magnetic contactor\*:** A contactor actuated by electromagnetic means.

**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.

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

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

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

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

**motor-circuit switch:** A switch rated in horsepower and capable of interrupting the maximum operating overload current of a motor of the same horsepower rating at the rated voltage. Such a switch is intended for use in a motor branch circuit.

**multipole (electrical switching device):** A term 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.

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

**nonoverlapping contacts\*:** 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.

**off delay:** The intentional time period introduced between the initiation of an OFF signal and the change in output of the timing device.

For example: In a pneumatic timer, the period of time between the de-energization of the coil and the operation of its timed contacts.

**oiltight control-circuit [pilot] devices\*:** Devices such as push-button 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.

**on delay:** The intentional time period introduced between the initiation of an ON signal and the change in output of the timing device.

For example: In a pneumatic timer, the period of time between the energization of the coil and the operation of its timed contacts.

**one-line diagram; single-line diagram:** A diagram that 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.

**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.

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

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 4.4.

**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\*:** 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.

**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.

**part-winding starter\*:** A starter that applies to voltage successively to the partial sections of the primary winding of an AC motor.

**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.

**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.

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

**pilot duty rating:** A generic term formerly used to indicate the ability of a control device to control the coils of other devices.

**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.

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

**pollution degree:** The classification of pollution in terms of type, severity, combinations of pollutants, and frequency of occurrence. Pollution degrees are designated by a conventional number. See Annex A.

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

**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.

**process diagram; flow diagram:** A conceptual diagram of the functional interrelationship of subsystems in block or pictorial form that shows process equipment such as machinery for proper understanding.

**pulse:** A signal of relatively short duration.

**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.

**rated insulation voltage,  $U_i$ :** The voltage to which rated impulse withstand voltage, clearances, and creepage distances are referred.

**rated operational current,  $I_o$ :** A value of current, stated by the manufacturer, which takes into account the rated operational voltage, the rated frequency, the rated duty, the overvoltage category, and the type of a protective enclosure.

**rated operational voltage,  $U_o$ :** 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.

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

**rating (device)\*:** The designated limit(s) of the rated operating characteristic(s). Such operating characteristics as current, voltage, frequency, etc., may be given in the rating.

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

**relay:**

- a. 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.
- b. 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.
- c. A device in which a portion of one or more sets of electrical contacts is moved by an armature and its associated operating coil.

Inputs are usually electric, but may be mechanical, thermal, or other quantities. Limit switches and similar simple devices are not relays.

A relay may consist of several units, each responsive to specified inputs, the combination providing the desired performance characteristics.

**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.

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

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

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

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

**schematic diagram; elementary diagram:** A diagram that 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.

**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.

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

**service\* (controller):** The specific application in which the controller is to be used.

Example:

- a. General purpose
- b. Definite purpose
  - 1. Crane and hoist
  - 2. Elevator
  - 3. Machine tool

**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.

**short-time rating\*:** A rating that 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.

**single-line diagram:** See one-line diagram.

**single pole (electrical switching device):** A contact arrangement in which all contacts connect in one position or another to a common contact.

**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.

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

**starter (electric motor):** A form of electric motor controller that includes the switching means necessary to start and stop a motor in combination with suitable overload protection.

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

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

A switch is understood to be manually operated, unless otherwise stated.

**system voltage (nominal):** The root-mean-square, phase-to-phase voltage by which the electrical distribution system is designated and to which certain operational characteristics of the system are related (ANSI C84.1).

The nominal system voltage is near the voltage level at which the system normally operates. To allow for operating contingencies, systems generally operate at voltage levels about five percent to ten percent below the maximum system voltage for which system components are designed (ANSI C84.1). See: utilization voltage.

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

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

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

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

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

**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.

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.

**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.

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

**utilization voltage:** The root-mean-square, phase-to-phase or phase-to-neutral voltage at the line terminals of utilization equipment (ANSI C84.1). See: system voltage and rated operational voltage.

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

For outdoor applications, ventilating openings or louvers are usually filtered, screened, or restricted to limit the entrance of dust, dirt, or other foreign objects.

**voltage relay\*:** A relay that functions at a predetermined value of voltage. It may be an overvoltage relay, an undervoltage relay, or a combination of both.

**wiring diagram; connection diagram:** A diagram which locates and identifies electrical devices, terminals, and interconnecting wiring in an assembly.

A wiring 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 either:

- a. The elementary diagram;
- b. A wiring table;
- c. A computer wiring chart;
- 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.

**wireless connection diagram:** A diagram that 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 may be included in the connection diagram.

### 3 Classification

Products covered by this publication are classified as components, assemblies or systems. Components are general-purpose mechanical, electromechanical, and solid-state devices used in industrial control applications. Assemblies consist of two or more interconnected components, usually in an enclosure. Systems are assemblies arranged to include one or more feedback loops.

## 4 Characteristics and ratings

### 4.1 General

#### 4.1.1 Basis of rating

The ratings of industrial control apparatus are based on an ambient temperature of 40°C.

#### 4.1.2 Rating of control apparatus

In general the rating of control apparatus shall be expressed in volts, amperes, horsepower, kilowatts, or other appropriate units.

#### 4.1.3 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.

#### 4.2 Rated operational or utilization voltages ( $U_e$ )

Rated operational voltages or utilization voltages ( $U_e$ ) for industrial control apparatus shall be as follows:

- a. AC, 60 hertz, Multiphase — 115, 200, 230, 460, 575, 800, 1,000, 2,300, 4,000, 4,600, and 6,600 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 — 115, 230 and 550 volts.

AC voltages are based on Publication C84.1 of the American National Standards Institute with the exception of 800 volts and 1,000 volts. The 800 volt utilization voltage applies to equipment installed in 830Y/480 volt electrical distribution systems typically used for irrigation and oil field pumping. The 1,000 volt utilization voltage applies to equipment installed in 1,040Y/600 volt electrical distribution systems typically used in mines. Voltages shown 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.

#### 4.3 Frequency ratings

The reference to "50 and 60 hertz" for AC controllers in this publication should not be construed to mean that the same 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.

#### 4.4 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.

These overloads are currents that may persist for a very short time only, usually a matter of seconds.

#### 4.5 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.

#### **4.6 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.

#### **4.7 Overload devices**

Overload devices that deenergize magnetically operated devices shall open the circuit of such devices.

### **5 Product marking, installation, and maintenance information**

#### **5.1 Installation and maintenance**

Installation should be performed by a qualified person and in accordance with NFPA 70 (NEC) and properly operated and maintained in accordance with the safety practices of NFPA 70E.

#### **5.2 Apparatus handling guidelines**

##### **5.2.1 General**

This subclause provides guidelines to help avoid personal injury and equipment damage during installation when handling and moving industrial control equipment.

##### **5.2.2 Guidelines**

The manufacturer's instructions, and the instructions listed below, should be followed:

- a. Follow the manufacturer's handling instructions for specific equipment.
- b. Handle industrial control equipment with care to avoid damage to components and 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 5-1 and 5-2) consisting of integral lifting angles, lifting plates, or eye bolts.
  1. Use spreaders (Figure 5-1) 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 5-1 and 5-2.)
  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 environment including the possibility of condensation of moisture inside the enclosure. For specific instructions, consult the manufacturer.

### 5.3 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. Where industrial control apparatus is field-wired with aluminum wire, care must be taken to use suitable terminations and wiring techniques.

### 5.4 Preventive maintenance of industrial control and systems equipment

See NEMA Publication ICS 1.3.

## 6 Service and storage conditions

### 6.1 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:

#### 6.1.1 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 incoming air.

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.

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°C to 25°C. The permissible internal air temperature limit depends upon the temperature rating of the components used.

#### 6.1.2 Altitude

Altitude Class 1 Km designates equipment for installation where the altitude does not exceed 1,000 meters (3,300 feet). Altitude Class 2 Km designates equipment for installation where the altitude does not exceed 2,000 meters (6,600 feet).

Systems using power semiconductors are usually Class 1 Km. Electromagnetic and manual devices are Class 2 Km.

### 6.1.3 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.

### 6.1.4 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 6.1 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. AC 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.

### 6.1.5 Environmental protection

Industrial control devices and systems are designed for use in a wide range of environments provided the apparatus is suitably enclosed. (See 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.

## 6.2 Storage temperature

When equipment is stored, the ambient temperature should be above  $-30^{\circ}\text{C}$  but should not exceed  $65^{\circ}\text{C}$ . Where the storage temperature is below the freezing point of the cooling liquid, the coolant should be removed. Where 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.

# 7 Construction

## 7.1 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.

The clearances and creepage distances specified 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:

- a. The probability of some form of pollution reducing their effectiveness;
- b. 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.

## 7.2 Spacings

NOTE—For an alternate concept for determining spacing and for tests to verify the performance, see Annex A.

### 7.2.1 General requirements

The clearance and creepage distances between non-arcing uninsulated live parts and:

- a. Nonarcing uninsulated parts of different voltage
- b. Metal parts (other than enclosure walls) which may be grounded when the equipment is installed
- c. Exposed ungrounded metal parts
- d. The walls of a metal enclosure (including fittings for conduit or armored cable) shall be not less than those shown in Tables 7-1 or 7-2, as applicable.

Table 7-1 applies for general use on all power systems where the transient voltages are not controlled or known.

Table 7-2 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 microsecond impulse test specified in Annex A. See Annex B for typical impulse generator circuit.

### 7.2.2 Exceptions

- a. Table 7-2 spacings are not required where surge suppression means are used to limit random surge and transient peak voltages to not more than 300 volts peak and meet the test requirements of Annex A. 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 7-2.
- b. The clearances and creepage distances given in Tables 7-1 and 7-2 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 7-1 and 7-2 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 motors, or to motor control center bus spacings, or to the open gaps of contacts.