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NEMA STANDARDS PUBLICATION NO. ICS 6

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Industrial Control and Systems Enclosures

NEMA

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

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NEMA Standards Publication No. ICS 6-1993

INDUSTRIAL CONTROL AND SYSTEMS ENCLOSURES

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FOREWORD

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

Replacement: ICS 6-1993 supersedes ICS 6-1988, Enclosures for Industrial Control and Systems.

This revision of ICS 6 consists of reformatting in accordance with the ANSI directive dated July 27, 1990 with no changes of substance.

The standards of ICS 6-1993 apply to all other NEMA ICS Standards Publications except where noted.

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. Users should secure the latest edi-

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tions. See the postal return card attached to the front cover of the Standards Publication for the proper procedure to obtain revision service for your copy of the publication.

Proposed revisions to this Standards Publication should be submitted to:

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

INTRODUCTION

The standards pertaining to enclosures in NEMA Standards Publication ICS 6 are subdivided into the following parts:

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

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

NEMA Standards Title
Publication No.

ICS 1-1993 Industrial Control and Systems
General Requirements

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

Part 1: *General Standards for Manual and Magnetic Controllers*
Part 2: *AC Noncombination Magnetic Motor Controllers, Rated 600 Volts*
Part 3: *Nonmagnetic Motor Controllers*
Part 4: *Overload Relays*

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Part 5: *DC General-Purpose Constant-Voltage Controllers*
Part 6: *AC Combination Motor Controllers*
Part 7: *Magnetic Lighting Contactors*

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

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

ICS 4-1993 Industrial Control and Systems
Terminal Blocks

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

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

ICS 6-1993 Industrial Control and Systems
Enclosures

ICS 7-1993 Industrial Control and Systems
Adjustable Speed Drives

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

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

Part 1: *General Standards for Crane Controllers Rated 600 Volts or Less AC and DC*
Part 2: *Constant-Voltage DC Magnetic Controllers for Motors on Cranes*
Part 3: *Adjustable-Voltage DC Controllers for Motors on Cranes*
Part 4: *Magnetic Controllers for AC Wound-Rotor Motors on Cranes*
Part 5: *Static Controllers for AC Wound-Rotor Motors on Cranes*
Part 6: *Crane and Hoist Power-Circuit Limit Switches*
Part 7: *Heavy-Duty DC Magnetic Contactors Rated 600 Volts*

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

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

ICS 10-1993 Industrial Control and Systems
Transfer Switches

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1 General

1.1 Referenced Standards

The following standards contain provisions which, through reference in this text, constitute provision 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 St. 13th Floor
New York, NY 10036

ANSI C80.5-1983	*Fittings for Rigid Metal Conduit and Electrical Metallic Tubing*

American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017

ASME B1.20.1-1983	*Pipe Threads (General Purpose)*

Canadian Standards Association
178 Rexdale Blvd.
Rexdale, Ontario M9W 1R3 Canada

CSA C22.2-0-M-1991	*General Requirements for the Canadian Electrical Code*
CSA C22.2-0.5-1982	*Threaded Conduit Entries*

National Electrical Manufacturers Association
2101 L Street, N.W. Suite 300
Washington, DC 20037

NEMA ICS 1-1993	*General Standards for Industrial Control Systems*
NEMA ICS 1.3-1986 (R1991)	*Preventative Maintenance of Industrial Control and Systems Equipment*
NEMA 250-1991	*Enclosures for Electrical Equipment (1000 Volts Maximum)*

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269

NFPA 70-1993	*National Electrical Code*

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

UL 508-1991	*Industrial Control Equipment*
UL 698-1990	*Industrial Control Equipment for Use in Hazardous Locations*

1.2 Scope

The standards in this publication apply to enclosures used for all enclosed products within the scope of the Industrial Control and Systems Section.

1.3 Normative Standards

The definitions and standards of NEMA Standards Publications No. 250 and ICS 1 apply, except that the 1,000-volt maximum limitation does not apply to enclosures for industrial control and systems.

1.4 General Requirements

Enclosure types for products within the scope of the Industrial Control and Systems Section shall meet all the requirements of NEMA Standards Publication No. 250 and also the requirements contained herein except that the enclosure with its enclosed equipment for hazardous locations need only meet the requirements of UL 698.

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2 Definitions

See NEMA Standards Publication No. 250 for definitions applying to this standard.

3 Classification

3.1 Standard Enclosure Types

Enclosure types for products within the scope of the Industrial Controls and Systems Section shall be Types 1, 2, 3, 3R, 3S, 4, 4X, 5, 6, 6P, 7, 8, 9, 10, 12, 12K and 13 as defined by NEMA Standards Publication No. 250.

3.2 Multiple Type Designations

Enclosures shall be designated by the type number indicating the external conditions for which they are suitable. A single enclosure which meets the requirements for more than one type of enclosure shall be permitted to be designated by a series of type numbers, the lesser number being given first.

4 Characteristics and Ratings

This publication contains no ratings.

5 Product Marking, Installation and Maintenance Information

5.1 Marking

Enclosures shall be marked with their type designation(s).

5.2 Enclosure Grounding

Conductive material which encloses electric conductors or equipment or forms part of such equipment must be grounded.

Metal enclosures in fixed installations are normally grounded by connection via armored cable, metal conduit, or metal raceway.

5.3 Tapered Pipe Threads

Tapered pipe threads provided for installation of rigid conduit are intended to be made up wrench-tight with a sealant to prevent spiral leakage through the gaps at the crests and roots of the mating threads.

5.4 Maintenance

See ICS 1.3 for general maintenance instructions.

6 Service and Storage Conditions

The external environmental limits for the enclosure are established by the enclosure design test procedures of NEMA Standards Publication No. 250.

See ICS 1, Part 6, for storage conditions.

7 Construction

This part constitutes the Industrial Control and Systems Section manufacturing standards for enclosures as referenced in NEMA Standards Publication No. 250.

7.1 Strength of Enclosures

7.1.1 Sheet Metal Enclosures

The minimum thickness required for sheet metal enclosures varies with the size of the enclosure. Based on the use of solid sheet metal without any openings other than those required for operating handles or shafts or for ventilation, the thickness shall be not less than that given in Tables 7-1 and 7-2 and, at points where conduit or armored cable is connected, not less than 0.032 inch (0.81 mm) where made of steel and not less than 0.045 inch (1.14 mm) where made of nonferrous metal. For large enclosures, such as those used for complex multicomponent controllers, where the enclosure surface does not contribute to the structural integrity of the enclosure and deformation would not increase electrical hazards, Tables 7-1 and 7-2 do not apply.

7.1.2 Cast Metal Enclosures

Cast metal, other than die-cast metal, shall be at least 1/8 inch (3.2 mm) thick at every point and of greater thickness at reinforcing ribs and door edges and shall be at least 1/4 inch (6.4 mm) thick at threaded holes for conduit. Die-cast metal shall be not less than 3/32 inch (2.4 mm) thick for an area which is greater than 24 square inches (155 cm^2) or in which any dimension is greater than 6 inches (152 mm), and shall be not less than 1/16 inch (1.6 mm) thick for an area which is 24 square inches (155 cm^2) or less in which no dimension is greater than 6 inches (152 mm), and shall be at least 1/4 inch (6.4 mm) thick at threaded holes for conduit.

7.1.3 Securing Means

Removable or hinged parts of enclosures such as doors, covers, etc., shall be provided with means for firmly securing them in place.

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Table 7-1
THICKNESS OF CARBON OR STAINLESS-STEEL SHEET METAL ENCLOSURES
MAXIMUM DIMENSIONS OF ANY SURFACE, INCHES

Without Supporting Frame*		With Supporting Frame or Equivalent Reinforcing*		Minimum Thickness	
Maximum Width **	Maximum Length †	Maximum Width **	Maximum Length	Uncoated	Zinc Coated
4.0	Not limited	6.25	Not limited	0.020††	0.023††
4.75	5.75	6.75	8.25	0.020††	0.023††
6.0	Not limited	9.5	Not limited	0.026††	0.029††
7.0	8.75	10.0	12.5	0.026	0.029
8.0	Not limited	12.0	Not limited	0.032	0.034
9.0	11.5	13.0	16.0	0.032	0.034
12.5	Not limited	19.5	Not limited	0.042	0.045
14.0	18.0	21.0	25.0	0.042	0.045
18.0	Not limited	27.0	Not limited	0.053	0.056
20.0	25.0	29.0	36.0	0.053	0.056
22.0	Not limited	33.0	Not limited	0.060	0.063
25.0	31.0	35.0	43.0	0.060	0.063
25.0	Not limited	39.0	Not limited	0.067	0.070
29.0	36.0	41.0	51.0	0.067	0.070
33.0	Not limited	51.0	Not limited	0.080	0.084
38.0	47.0	54.0	66.0	0.080	0.084
42.0	Not limited	64.0	Not limited	0.093	0.097
47.0	59.0	68.0	84.0	0.093	0.097
52.0	Not limited	80.0	Not limited	0.108	0.111
60.0	74.0	84.0	103.0	0.108	0.111
63.0	Not limited	97.0	Not limited	0.123	0.126
73.0	90.0	103.0	127.0	0.123	0.126

*A supporting frame structure is an angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments applied via the enclosure surface when it is deflected. Construction which is considered to have equivalent reinforcing may be accomplished by a multiplicity of designs that will produce a structure which is as rigid as one built with a frame of angles or channels. Constructions considered to be "without supporting frame" include:

a. A single sheet with single formed flanges (formed edges)

b. A single sheet which is corrugated

c. An enclosure surface loosely attached to a frame as, for example, with spring clips

** The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure and supported at all four edges; where a surface is supported at fewer than four edges, the width is to be considered the maximum dimension between supporting edges. Supported at the edge means fastened to or otherwise having a relatively solid support, stiffened member, or reinforcing by forming so as to prevent or minimize the deflection of the sheet metal. Adjacent surfaces shall be permitted to have supports in common and be made of a single sheet.

†"Not limited" applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

††Sheet steel for an enclosure intended for outdoor use shall be not less than 0.034 inch (0.86 mm) thick if zinc coated and not less than 0.032 inch (0.81 mm) thick if uncoated.

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Table 7-2
THICKNESS OF ALUMINUM, COPPER, OR BRASS SHEET-METAL ENCLOSURES MAXIMUM DIMENSIONS OF ANY SURFACE, INCHES

Without Supporting Frame*		With Supporting Frame or Equivalent Reinforcing*		
Maximum Width **	Maximum Length†	Maximum Width**	Maximum Length	Minimum Thickness of Sheet
3.0	Not limited	7.0	Not limited	0.023††
3.5	4.0	8.5	9.5	0.023††
4.0	Not limited	10.0	Not limited	0.029
5.0	6.0	10.5	13.5	0.029
6.0	Not limited	14.0	Not limited	0.036
6.5	8.0	15.0	18.0	0.036
8.0	Not limited	19.0	Not limited	0.045
9.5	11.5	21.0	25.0	0.045
12.0	Not limited	28.0	Not limited	0.058
14.0	16.0	30.0	37.0	0.058
18.0	Not limited	42.0	Not limited	0.075
20.0	25.0	45.0	55.0	0.075
25.0	Not limited	60.0	Not limited	0.095
29.0	36.0	64.0	78.0	0.095
37.0	Not limited	87.0	Not limited	0.122
42.0	53.0	93.0	114.0	0.122
52.0	Not limited	23.0	Not limited	0.153
60.0	74.0	130.0	160.0	0.153

*A supporting frame structure is an angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments applied via the enclosure surface when it is deflected. Construction which is considered to have equivalent reinforcing may be accomplished by a multiplicity of designs that will produce a structure which is as rigid as one built with a frame of angles or channels. Constructions considered to be "without supporting frame" include:

a. A single sheet with single formed flanges (formed edges)

b. A single sheet which is corrugated

c. An enclosure surface loosely attached to a frame as, for example, with spring clips

**The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure and supported at all four edges; where a surface is supported at fewer than four edges, the width is to be considered the maximum dimension between supporting edges. Supported at the edge means fastened to or otherwise having a relatively solid support, stiffened member, or reinforcing by forming so as to prevent or minimize the deflection of the sheet metal. Adjacent surfaces shall be permitted to have supports in common and be made of a single sheet.

†"Not limited" applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

†† Sheet copper, brass, or aluminum for an enclosure intended for outdoor use shall be not less than 0.029 inch (0.74 mm) thick.

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7.2 Ventilating Openings

7.2.1 General

Ventilating openings shall be designed to prevent entry of a rod having the diameter specified in NEMA Standards Publication No. 250 for the type of ventilated enclosure.

7.2.2 Perforated or Expanded Sheet Metal

Except as noted in the following paragraph, the thickness of sheet metal employed in expanded metal mesh and perforated sheet metal shall be not less than 0.042 inch (1.07 mm) where made of steel and 0.058 inch (1.47 mm) where made of nonferrous material. Where the mesh openings or perforations are greater than 1/2 square inch (323 mm^2) in area, the thickness of the metal shall be not less than 0.080 inch (2.03 mm) where made of steel and 0.112 inch (2.84 mm) where made of nonferrous material.

An expanded metal mesh of not less than 0.020 inch (0.51 mm) steel or not less than 0.029 inch (0.74 mm) non-ferrous material shall be permitted to cover an opening where an indentation will not affect the operation of a movable part or the clearance between uninsulated current-carrying parts and grounded metal provided that either:

a. The total area of the exposed mesh on any one side of the enclosure is not greater than 72 square inches (464 cm^2) and has no dimension which is greater than 12 inches (305 mm).

b. The width of an opening so protected is not greater than 3-1/2 inches (89 mm).

7.2.3 Screen Enclosures

All enclosures which are composed of wire mesh, perforated screens or grill work shall be provided with a supporting frame.

7.2.4 Minimum Screen Wire Size

Where openings are screened, the wire gauge of the screen shall be not less than No. 16 AWG. Where the screen mesh openings are greater than 1/2 square inch (323 mm^2) in area, the wire gauge shall be not less than No. 12 AWG.

7.2.5 Type 5 and Type 12 Ventilated Enclosures

Enclosure Types 5 and 12 may include sections or compartments that are ventilated. These sections or compartments need not meet the dust test requirements but should meet the test requirements for Type 1 and Type 2 enclosures. In such a case either a separate designation for each type compartment should be placed on each compartment or a single nameplate may state: Type 12 with Type 1 compartment.

7.3 Wire Entrances

7.3.1 Knockouts

Table 7-3 lists the ranges of conduit sizes for which knockouts are to be provided in enclosures for AC controllers Size 5 or smaller. The table is based on using one conduit entrance for line wires and one conduit entrance for load wires.

7.3.2 Knockout Diameters and Conduit Bushing Dimensions

Table 7-4 shows the knockout diameters and conduit bushing dimensions to be taken into consideration when designing enclosures and mounting the enclosed apparatus (See Figure 7-1).

7.3.3 Threaded Conduit Hubs

Where provided, conduit entrances for type 3, 3R, 3S, 4, 4X, 6, 7, 8, 9 and 10 enclosures shall be in the top and in the bottom of the enclosure. Where provisions are made for threaded conduit connections in these enclosures for AC controllers Size 5 or smaller, there shall be one 3/4-inch conduit entrance in the bottom of magnetic controllers for control wires plus one conduit entrance in the top of manual and magnetic controllers for line conductors and one conduit entrance in the bottom of manual and magnetic controllers for load conductors in accordance with Table 7-5.

7.3.4 Threaded Holes for Rigid Conduit

Tapered pipe threads for rigid steel electrical conduit and conduit connections are a special application of pipe threads where a longer engagement is desirable for grounding and strength considerations.

The pitch diameter of the external thread on the conduit remains the same as for standard pipe threads, but the pitch diameter at the entrance to the internal thread is made larger to provide for longer thread engagement.

Table 7-6 specifies the tapered internal thread engagement which should be provided for in enclosures designed with integral bushings to accept rigid conduit. The turns engagement method of gauging determines that an adequate number of threads are available. The plug gauge is screwed hand-tight into the enclosure. A threaded hole with integral bushings is acceptable if the hand-tight engagement of the gauge is within the limits given in Table 7-6 and there is a minimum of one full thread available beyond the end of the plug gauge. This clearance ensures that the smallest permissible external thread will tighten against the thread, and not bottom against the bushing. See Figure 7-2. Some recommended hole sizes for rigid conduit threads with integral bushings are shown in Table 7-7 (See Figure 7-3 and 7-4). The sizes shown permit tapping to meet the ANSI Standards requirements of Table 7-6.

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Table 7-3
RANGES OF WIRE AND KNOCKOUT SIZES

Controller Size	Knockouts for Three Line or Three Load Wires** Range of Wire Sizes Required for Line and Load,*AWG or ke Mil Copper	Aluminum	Range of Sizes of Conduit for Copper Wire Alone	Ranges of Sizes of Conduit for Aluminum and Copper Wire
00	14	12	1/2	1/2
0	14-10	12-8	1/2	1/2, 3/4
1	14-8	12-6	1/2, 3/4	1/2, 3/4, 1
1P	8-6	8-4	1/2, 3/4	1/2, 3/4, 1
2	10-4	10-3	1/2, 3/4, 1	1/2, 3/4, 1, 1-1/4
3	8-1/0	8-3/0	3/4, 1, 1-1/4, 1-1/2	3/4, 1, 1-1/4, 1-1/2, 2
4	4-3/0	2-250	1, 1-1/4, 1-1/2, 2	1, 1-1/4, 1-1/2, 2, 2-1/2
5	2/0-500	4/0-700	1-1/2, 2, 2-1/2, 3	1-1/2, 2, 2-1/2, 3, 3-1/2

*Derating factors for 60°C and 75°C wire in a 40°C ambient are 0.82 and 0.88, respectively, with not more than three conductors in raceway. The maximum wire size shown is for a 40°C ambient based on the ampacity required for service limit current or 125 percent of maximum motor full load current corresponding to horsepower, whichever is greater. The minimum wire size shown is for 75°C insulation in a 30°C ambient and minimum motor full load current corresponding to horsepower.

**Largest knockout is based on use of 60°C wire for controller sizes 00 through 3 and 75°C wire for controller sizes 4 and 5.

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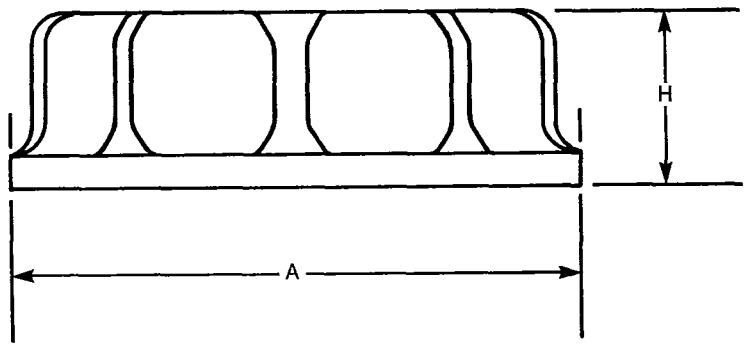
Table 7-4
KNOCKOUT DIAMETERS AND CONDUIT BUSHING DIMENSIONS
(See Figure 7-1)

Bushing Nominal Size of Conduit Inches	Knockout Diameter Inches*		Minimum Diameter at Flange,** Inches	Minimum Over Inches	Height, Knockout Inches	
	Nominal†	Minimum	Maximum	(Dimension A)		(Dimension H)
1	2	3	4	5	6	7
1/2	0.875	0.859	0.906	1.00	0.033	0.375
3/4	1.109	1.094	1.141	1.23	0.021	0.422
1	1.375	1.359	1.406	1.54	0.040	0.516
1-1/4	1.734	1.719	1.766	1.92	0.045	0.562
1-1/2	1.984	1.958	2.016	2.18	0.045	0.594
2	2.469	2.433	2.500	2.68	0.047	0.625
2-1/2	2.969	2.938	3.000	3.20	0.053	0.750
3	3.594	3.563	3.625	3.83	0.056	0.812
3-1/2	4.125	4.063	4.156	4.40	0.060	0.937
4	4.641	4.563	4.672	4.94	0.062	1.000
4-1/2	5.109	5.063	5.166	5.51	0.130	1.062
5	5.719	5.625	5.750	6.05	0.071	1.187
6	6.813	6.700	6.844	7.20	0.081	1.250

*These diameters apply to single or concentric types only and exclude any projection of breakout ears or tabs.

**These diameters at the flange of the conduit bushing are minimum in order to obtain the overlap shown in Column 6 with maximum knockout diameter.

†It is desirable that the diameter of the knockout be held as close as possible to the nominal diameter given in Column 2.



(ILLUSTRATION IS NOT A DESIGN DETAIL)

Figure 7-1
BUSHING DIMENSIONS

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Table 7-5
CONDUIT SIZES FOR CONTROLLERS*

Size of Controller	Conduit Sizes for Line or Load Wires, Inches
00	3/4
0	3/4
1	1
1P	1
2	1-1/2
3	2
4	2-1/2
5	3-1/2

*The values given are based on the use of wires whose insulation is rated either 60°C or 75°C.

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Table 7-6
INTERNAL THREAD REQUIREMENTS FOR RIGID CONDUIT IN ENCLOSURES WITH INTEGRAL BUSHINGS

Standards Nominal or Trade Size of Conduit Inches	Threads per Inch	Institute Publications					Canadian Standards Association Publications					
		Applicable to All ANSI		Min. Threads Engaged			CSA C22.2-0-M* Min. Threads Engaged			CSA C22.2-0/5 Min. Threads Engaged		
		Min. Turns Penetration**	Max. Turns Penetration†	ANSI C80.5**	ANSI C33.76 (UL508)	ANSI C33.30 (UL698)	Other Than Class 1 Loc.	Class 1 Haz. Loc.	Min. Turns Penetration	Max. Turns Penetration	Other Than Class Loc.	Class 1 Haz. Loc.
1/2	14	6	9	5	3-1/2	5	3-1/2	5	5	7	3-1/2	5
1/4	14	6	9	5	3-1/2	5	3-1/2	5	5-1/4	7-1/4	3-1/2	5
1	11-1/2	6	9	5	3-1/2	5	3	5	5-1/8	7-1/8	3	5
1-1/4	11-1/2	6	10	5	3-1/2	5	3	5	5-3/8	7-3/8	3	5
1-1/2	11-1/2	6	10	5	3-1/2	5	3	5	5-3/8	7-3/8	3	5
2	11-1/2	6	10	5	3-1/2	5	3	5	5-1/2	7-1/2	3	5
2-1/2	8	6	10	5	3-1/2	5	3	5	6	8	3	5
3	8	6	10	5	3-1/2	5	3	5	6-5/8	8-5/8	3	5
3-1/2	8	7	11	5	3-1/2	5	3	5	7-1/8	9-1/2	3	5
4	8	7	11	5	3-1/2	5	3	5	7-1/4	9-1/4	3	5
4-1/2	8	7	11	5	3-1/2	5	3	5	7-1/2	9-1/2	3	5
5	8	7	11	5	3-1/2	5	3	5	8	10	3	5
6	8	7	11	5	3-1/2	5	3	5	8-1/8	10-1/2	3	5

*CSA C22.2-0-M does not specify thread fit.

**As gauged with a working gauge complying with Section 7 of ANSI B1.20.1

†ANSI C80.5 requires five full threads engagement unless otherwise specified.

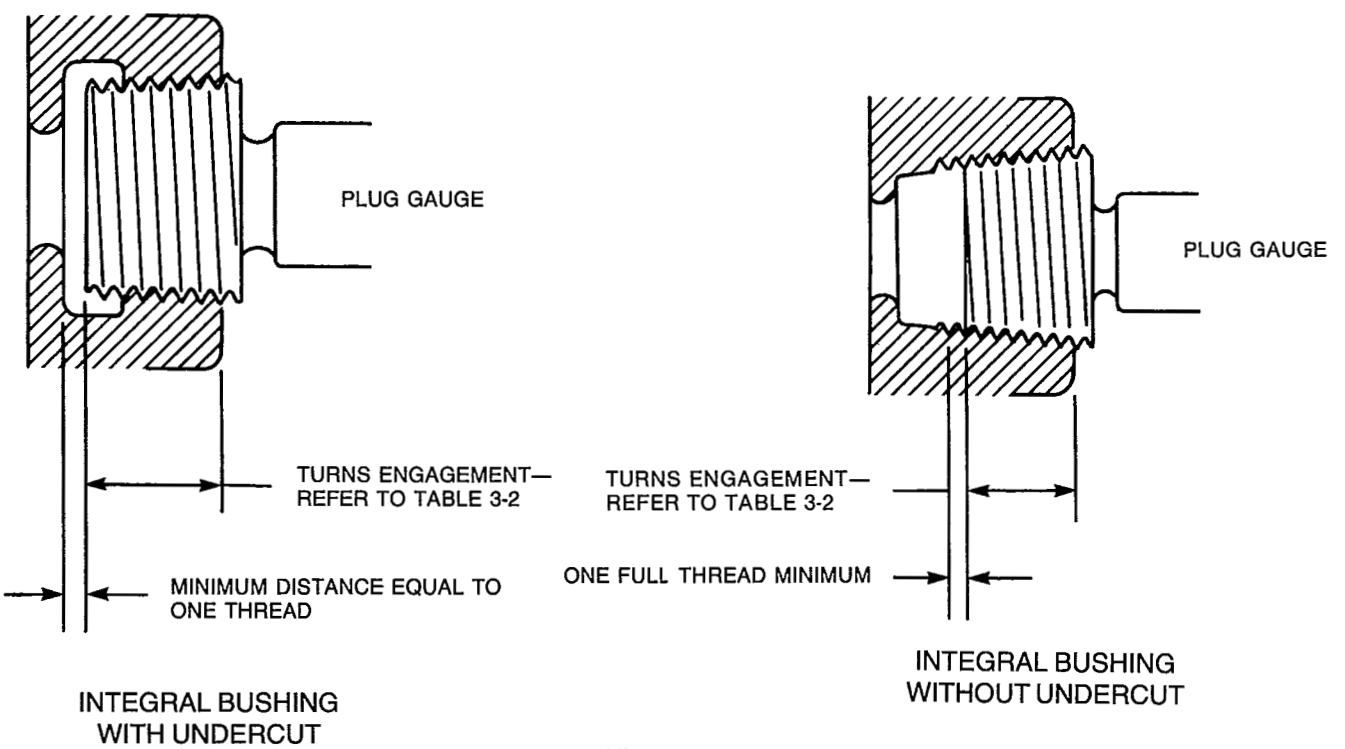


Figure 7-2
TURNS ENGAGEMENT METHOD OF GAUGING THREADED HOLES

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Table 7-7
RECOMMENDED DIMENSIONS, INCHES, FOR RIGID CONDUIT CONNECTIONS IN ENCLOSURES WITH INTEGRAL BUSHINGS

		Without Undercut (Figure 7-3)				With Undercut (Figure 7-4)			
Nominal or Trade Size of Conduit	Threads per Inch	Entrance Diameter D1	Depth L1	Entrance Diameter D1	Depth L1	Undercut Diameter D2	Undercut Depth 1.2	Throat Min.	Diameter D3 Max.
1/2	14	0.723	0.929	0.723	0.786	0.840	0.214	0.560	0.622
3/4	14	0.932	0.929	0.932	0.786	1.050	0.214	0.742	0.824
1	11.5	1.170	1.130	1.170	0.957	1.315	0.261	0.944	1.047
1-1/4	11.5	1.514	1.217	1.514	1.044	1.660	0.261	1.242	1.380
1-1/2	11.5	1.753	1.217	1.753	1.044	1.900	0.261	1.449	1.610
2	11.5	2.226	1.217	2.226	1.044	2.375	0.261	1.860	2.067
2-1/2	8	2.658	1.750	2.658	1.500	2.875	0.375	2.222	2.467
3	8	3.279	1.750	3.279	1.500	3.500	0.375	2.761	3.066
3-1/2	8	3.783	1.875	3.783	1.625	4.000	0.375	3.193	3.548
4	8	4.280	1.875	4.280	1.625	4.500	0.375	3.623	4.026
4-1/2	8	4.810	1.875	4.810	1.625	5.032	0.375	4.084	4.537
5	8	5.337	1.875	5.337	1.625	5.563	0.375	4.542	5.045
6	8	6.392	1.875	6.392	1.625	6.625	0.375	5.458	6.065

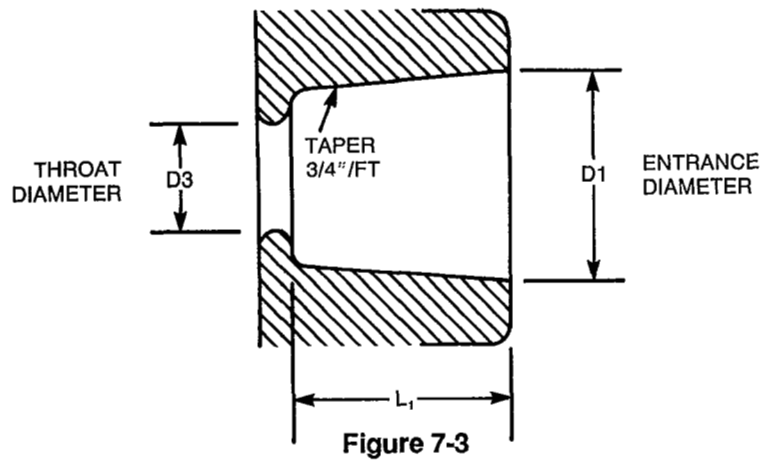


Figure 7-3
RIGID CONDUIT, INTEGRAL BUSHING WITHOUT UNDERCUT

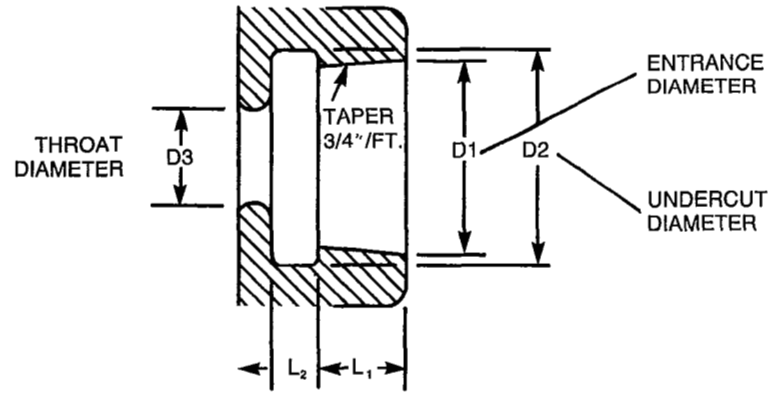


Figure 7-4
RIGID CONDUIT, INTEGRAL BUSHING WITH UNDERCUT

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Table 7-8
HOLE SIZES AND WALL THICKNESS, INCHES, FOR RIGID CONDUIT CONNECTIONS USING BUSHINGS ATTACHED TO END OF CONDUIT

Nominal or Trade Size of Conduit	Threads per Inch	Entrance Diameter Cored or Reamed (Taper 3/4 in./ft.)	Enclosure Wall Thickness	
			Min.	Max.
1/2	14	0.723	0.250	0.286
3/4	14	0.932	0.250	0.286
1	11.5	1.170	0.305	0.348
1-1/4	11.5	1.514	0.305	0.348
1-1/2	11.5	1.753	0.305	0.348
2	11.5	2.226	0.305	0.348
2-1/2	8	2.658	0.438	0.500
3	8	3.279	0.438	0.500
3-1/2	8	3.783	0.438	0.625
4	8	4.280	0.438	0.625
4-1/2	8	4.810	0.438	0.625
5	8	5.337	0.438	0.625
6	8	6.392	0.438	0.625

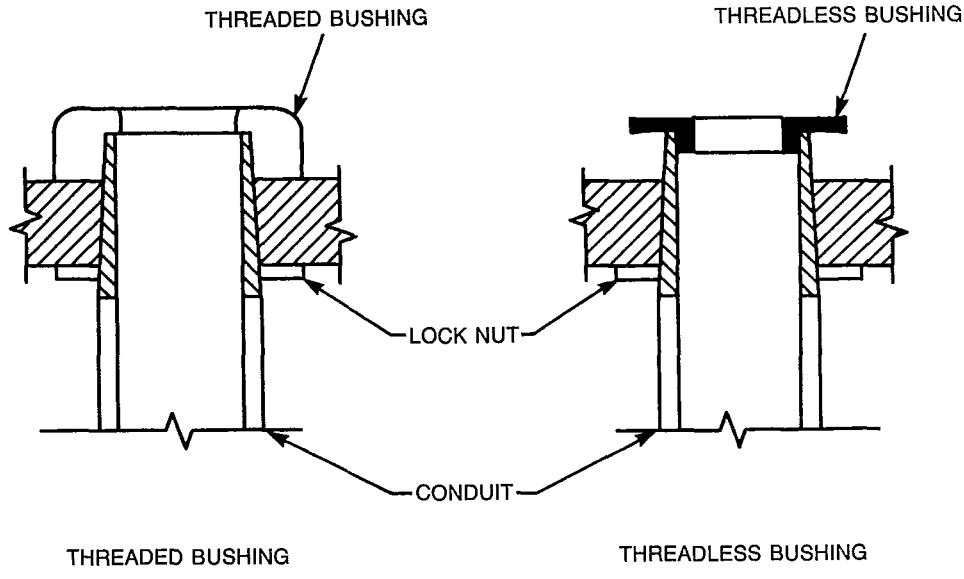


Figure 7-5
CONDUIT BUSHINGS

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When integral bushings are not provided in enclosures designed to accept rigid conduit, the enclosure wall thickness should be held to the values shown in Table 7-8 so that sufficient threads will protrude through the wall for attachment of a separate bushing, without requiring additional threading of the conduit. (See Figure 7-5.)

7.4 Electrical Spacings

Spacings between any live part and the enclosure wall shall be as shown in ICS 1, Part 7, except that a greater spacing is required if the enclosure is not rigid. The spacings shall be permitted to be less than those shown in ICS 1, Part 7 if the enclosure is lined with an insulating material.

7.5 Wire-Bending Space

Enclosures shall be constructed so that, after the apparatus has been mounted within the enclosure, there will be adequate room for wiring (see Tables 7-9, 7-10 and 7-11). This wiring space is the distance between the end of the lug, pressure wire connector, or terminal screw (whichever is least) and the point on the wall of the enclosure toward which the conductor will be initially directed. Where a conductor is restricted from bending, by means of barriers or otherwise, as it leaves the lug, the distance shall be measured from the end of the restriction.

7.6 Provisions for Grounding

Nonmetallic enclosures and enclosures used as pendants require a terminal to bond the apparatus to a grounding conductor included in the cable or nonmetallic conduit. The fundamental requirement is a continuous low-impedance circuit between all metal conduit and all metallic parts which project through the enclosure.

Where a grounding conductor is furnished by the apparatus manufacturer, it should be green with or without a yellow stripe. Where a screw is furnished for the installer to use in making a grounding connection, a screw with a slotted hexagonal green-colored head is preferred.

7.7 Legends

Legends and instruction information appearing on the exterior of the enclosure should be applied in such a manner as to have a degree of permanence and legibility commensurate with the environment and application for which the enclosure is intended.

Table 7-9
WIRE-BENDING SPACE FOR FIELD CONNECTIONS (ENCLOSED MOTOR CONTROLLERS)

Maximum Wire Size AWG or MCM	Minimum Bending Space, Inches	
	1 wire per pole	2 wires per pole *
14-10 AWG	Not Specified	...
8-6	1-1/2	...
4-3	2	...
2	2-1/2	...
1	3	...
0	5	5
00	6	6
000-0000 MCM	7	7
250	8	8
300	10	10
350-500	12	12
600-700	14	16
750-900	18	19

* Where provision for three or more wires per terminal exists, the minimum wire-bending space shall be in accordance with the requirements of Article 373, National Electrical Code.

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Table 7-10
WIRE BENDING SPACE, INCHES (MILLIMETERS), FOR CONDUCTORS LEAVING THE ENCLOSURE THROUGH THE WALL OPPOSITE THE TERMINALS (MOTOR CONTROL CENTERS)

Wire Size, + AWG or MCM (mm^2)		Minimum Bending Space, Inches (mm)* Wires Per Terminal											
		1			2			3			4 or More		
14–10 AWG	(2.1–5.3)	Not Specified											
8	(8.4)	1-1/2	(38.1)		—			—			—		
6	(13.3)	2	(50.8)		—			—			—		
4	(21.2)	3	(76.2)		—			—			—		
3	(26.7)	3	(76.2)		—			—			—		
2	(33.6)	3-1/2	(88.9)		—			—			—		
1	(42.4)	4-1/2	(114)		—			—			—		
0	(53.5)	5-1/2	(140)		5-1/2	(140)		7	(178)		—		
2/0	(67.4)	6	(152)		6	(152)		7-1/2	(191)		—		
3/0	(85.0)	6-1/2	(165)	[6]	6-1/2	(165)	[6]	8	(203)		—		
4/0	(107)	7	(178)	[6]	7-1/2	(191)	[6]	8-1/2	(216)	[8]	—		
250 MCM	(127)	8-1/2	(216)	[6–1/2]	8-1/2	(216)	[6-1/2]	9	(229)	[8]	10	(254)	
300	(152)	10	(254)	[7]	10	(254)	[8]	11	(279)	[10]	12	(305)	
350	(177)	12	(305)	[9]	12	(305)	[9]	13	(330)	[10]	14	(356)	[12]
400	(203)	13	(330)	[10]	13	(330)	[10]	14	(356)	[11]	15	(381)	[12]
500	(253)	14	(356)	[11]	14	(356)	[11]	15	(381)	[12]	16	(406)	[13]
600	(304)	15	(381)	[12]	16	(406)	[13]	18	(457)	[15]	19	(483)	[16]
700	(355)	16	(406)	[13]	18	(457)	[15]	20	(508)	[17]	22	(559)	[19]
750	(380)	17	(432)	[14]	19	(483)	[16]	22	(559)	[19]	24	(610)	[21]
800	(405)	18	(457)		20	(508)		22	(559)		24	(610)	
900	(456)	19	(483)		22	(559)		24	(610)		24	(610)	
1000	(507)	20	(508)			—			—			—	
1250	(633)	22	(559)			—			—			—	
1500–2000	(760–1010)	24	(610)			—			—			—	

*Bending space at terminal shall be measure in a straight line from the end of the lug or wire conncector in a direction perpendicular to the enclosure wall. For removable wire terminals intended for only wire, bending space shall be permitted to be reduced by the number of inches shown in brackets.

Table 7-11
WIRE BENDING SPACE, INCHES (MILLIMETERS), FOR ALL OTHER CONDUCTORS NOT COVERED BY TABLE 7-10 (MOTOR CONTROL CENTERS)

Size of Wire AWG or MCM	Wires per Terminal					
	1		2	3	4	5
14-10 AWG	Not Specified		...	...	...	...
8-6	1-1/2	(38)	...	...	...	...
4-3	2	(51)	...	...	...	...
2	2-1/2	(64)	...	...	...	...
1	3	(76)	...	...	...	...
0-00	3-1/2	(89)	5 (127)	7 (178)	...	...
000-0000 MCM	4	(102)	6 (152)	8 (203)	...	...
250	4-1/2	(114)	6 (152)	8 (203)	10 (254)	...
300-350	5	(127)	8 (203)	10 (254)	12 (305)	...
400-500	6	(152)	8 (203)	10 (254)	12 (305)	14 (356)
600-700	8	(203)	10 (254)	12 (305)	14 (356)	16 (406)
750-900	8	(203)	12 (305)	14 (356)	16 (406)	18 (457)
1,000-1,250	10	(254)	...	...	...	...
1,500-2,000	12	(305)	...	...	...	...

Bending space at terminals shall be measured in a straight line from the end of the lug or wire connector (in the direction that the wire leaves the terminal) to the wall, barrier, or obstruction.

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8 Performance Requirements and Tests

8.1 General

See NEMA Standards Publication No. 250 for enclosure test requirements.

8.2 Nonmetallic Enclosures

Polymeric enclosures shall also be evaluated in accordance with UL 508.

8.3 Type 5 and Type 12 Enclosures with Ventilated Compartment

See 7.2.5.

9 Application

See NEMA Standards Publication No. 250 for application information.

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Supplement 1
SCOPE OF THE INDUSTRIAL CONTROL AND SYSTEMS SECTION

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

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

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

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

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

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

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

Also included, but not limited to, are:

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

1. Operational amplifiers
2. Computer elements
3. Encoders
4. Tape readers
5. Sensors

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6. Man-machine interface devices
7. Gaging equipment

j. Renewal parts for Industrial Control and System products.

Examples of Industrial Control and System products are:

a. Manual, magnetic and solid-state (static) starters and controllers
b. Relays and contactors
c. Automatic transfer switches and controllers, and associated by-pass isolation switches
d. Drum switches
e. Overload devices intended primarily for the starting and running protection of electric motors, including inherent overload protective devices
f. Rheostats and resistors
g. Autotransformers and reactors of the type principally used in reduced-voltage starters
h. Control-circuit and pilot devices including, but not limited to, timers, pushbuttons, indicating (pilot) lights, solenoids, photoelectric relays, and plugging switches, speed switches, domestic water pump pressure switches
i. limit, pressure, vacuum, temperature and liquid-level switches.
j. AC and DC brakes, clutches, and electrical operators
k. Resistance dimmers, autotransformer dimmers, reactor dimmers, and solid-state (static) dimmer systems
l. Solid-state logic devices
m. Control panels for machine tool and similar machines
n. Terminal blocks of the molded barrier or sectional type and terminal strips used for the connection of conductors, electrical and electronic circuits and equipment. These include, but are not limited to, terminal blocks using, wire binding screws, pressure wire connectors, stud and nut, quick connect, solder lug, and solderless wrapped terminations, and terminal blocks which incorporate fuse holders, test/disconnect features, indicator lamps, diodes, etc.
o. Automatically regulated adjustable speed drive systems such as: rolling mill drives, paper mill drives, slasher drives
p. Programmable controllers and their accessories devices used for the supervision, or control or command of industrial machines and processes

Exclusions:

Excluded from the product scope are:

a. Specific components and systems covered by the product scopes of other NEMA sections
b. Automatic and manual temperature and humidity controls and panels that are in the scope of the Residential Controls Section of the types principally used in air conditioning, refrigeration, and comfort heating of nonindustrial areas
c. Motors, generators and motor-generators, which function as control when constituting part of adjustable speed drives.

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NEMA STANDARDIZATION BACKGROUND

The purpose of NEMA standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 1)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 6)

Categories of Standards

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

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 5)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 5)

Identification of Status

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

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

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INDUSTRIAL CONTROL AND SYSTEMS SECTION OF THE NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

ABB Control, Inc.
Wichita Falls, TX 76306

AEG Automation
Systems Corporation
Pittsburgh, PA 15238-0830

Allen-Bradley Company
Milwaukee, WI 53204

Amerace Electronic Components
Punta Gorda, FL 33950

Automatic Switch Company
Florham Park, NJ 07932

Balluff, Inc.
Florence, KY 41042

USD Products
Bussman, Div. of Cooper Ind.
Chicago, IL 60656

CEGELEC Automation Inc.
Macon, GA 31206

Challenger Electrical Equipment Corp.
Raleigh, NC 27609

Eaton Corporation
Cutler Hammer Products
Milwaukee, WI 53216

Electrical Power Systems Inc.
Tulsa, OK 74131

Electro Switch Corporation
Weymouth, MA 02189-2103

Elliott Control Company
Hollister, CA 95024-1329

Emerson Electric Company
Grand Island, NY 14072

Entrelec, Inc.
Irving, TX 75038-4312

Firetrol, Inc.
Cary, NC 27512

Furnas Electric Company
Batavia, IL 60510

GE
Plainville, CT 06062

General Equipment & Manufacturing
Company, Inc.
Louisville, KY 40213

Gettys Corporation
Racine, WI 53404

Giddings & Lewis, Inc.
Fond du Lac, WI 54936-1658

Halmar Robicon Group
Pittsburgh, PA 15239-2982

Harnischfeger Corporation
Milwaukee, WI 53215-1707

Honeywell, Inc.
Ft. Washington, PA 19034

Hubbell Incorporated
Madison, OH 44057

Joslyn Clark Controls, Inc.
Lancaster, SC 29720

Killark-Stahl, Inc.
St. Louis, MO 63115

Klockner Moeller Corporation
Franklin, MA 02038

Lexington Switch & Controls
Madison, OH 44057

Master Controls Systems, Inc.
Lake Bluff, IL 60044

Metron, Inc.
Denver, CO 80223

Micro Switch (Div. of Honeywell)
Freeport, IL 61032

Modicon Inc.
No. Andover, MA 01845

NAMCO Controls
An Acme Cleveland Corporation
Mentor, OH 44060

Omron Electronics, Inc.
Schaumburg, IL 60173

Onan Corporation
Minneapolis, MN 55432

OZ Gedney
Unit of General
Signal Corporation
Brooklyn, NY 11208

Pepperl + Fuchs, Inc.
Twinsburg, OH 44087

Phoenix Contact, Inc.
Harrisburg, PA 17111

Reliance Electric Company
Cleveland, OH 44117

Russelectric, Inc.
Hingham, MA 02043

Siemens Energy & Automation,Inc.
Alpharetta, GA 30201

Siemens Industrial Automation, Inc.
Johnson City, TN 37601

Square D Company
Palatine, IL 60067

R. Stahl, Inc.
Woburn, MA 01801

Texas Instruments, Inc.
Attleboro, MA 02703

Toshiba International Corporation
Houston, TX 77041

Turck, Inc.
Minneapolis, MC 55441-2656

Weidmuller Inc.
Richmond, VA 23236

Westinghouse Electric Corporation
Pittsburgh, PA 15220

Zenith Controls, Incorporated
Chicago, Il 60609

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