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NEMA STANDARDS PUBLICATION NO. ICS 9

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Industrial Control and Systems Power Circuit Accessories

NEMA

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

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NEMA Standards Publication No. ICS 9-1993

INDUSTRIAL CONTROL AND SYSTEMS
POWER CIRCUIT ACCESSORIES

Published by

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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 9-1993 supersedes the following parts of ICS 2-1988:

Part 1 supersedes Part ICS 2-220
Part 2 supersedes Part ICS 2-213
Part 3 supersedes Part ICS 2-214

In 1988, unrevised portions of all NEMA Standards Publications for Industrial Controls and Systems (the ICS series) were reaffirmed.

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

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

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

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

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

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

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

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

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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 editions.

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

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INTRODUCTION

The standards pertaining to power circuit accessories in NEMA Standards Publication No. ICS 9 are subdivided as shown below:

Part 1: Electromechanical Brakes
Part 2: Resistors and Rheostats
Part 3: Autotransformers and Reactors

Each part is subdivided into the following clauses:

1 General

Includes referenced standards, scope and normative references.

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 information, installation and maintenance

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 Publication No. — Title

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
Part 8: AC Noncombination Vacuum-break Magnetic Controllers Rated 1500 Volts

ICS 3-1993 *Industrial Control and Systems*
Factory-Built Assemblies
Part 1: Motor Control Centers Rated Not More Than 600 Volts AC
Part 2: Medium Voltage Controllers Rated 2001 to 7200 Volts AC
Part 3: AC General-purpose Controllers for Synchronous Motors

ICS 4-1993 *Industrial Control and Systems*
Terminal Blocks

ICS 5-1993 *Industrial Control and Systems*
Control Circuit and Pilot Devices
Part 1: General Standards for Control Circuit and Pilot Devices
Part 2: Industrial Control Relays
Part 3: Industrial Control Input Devices Actuated by Force, Temperature and Pressure
Part 4: Proximity Switches
Part 5: Pushbuttons, Selector Switches, Indicating Lights and Pushbutton Stations

ICS 6-1993 *Industrial Control and Systems Enclosures*

ICS 7-1993 *Industrial Control and Systems*
Adjustable Speed Drives
Part 1: General Standards for Drive Converters, Drives, and Drive Systems
Part 2: Loop Position and Tension Control Drive Systems
Part 3: Wind and Unwind Drive Systems
Part 4: Variable-Frequency, Three-Phase Controllers, Rated Not More Than 600 Volts
Part 5: Adjustable-Voltage Packaged-Drive Systems (Where DC Armature Power Is Obtained from AC Lines Using Controlled Semiconductor Rectifiers)
Part 6: Variable-Frequency Drive Systems Rated Not More Than 600 Volts Using Semiconductor Power Conversion
Part 7: Variable-Frequency. Three-Phase Drives, Rated 601 to 7,200 Volts

ICS 8-1993 *Industrial Control and Systems*
Crane and Hoist Controllers
Part 1: General Standards for Crane Controllers Rated 600 Volts or Less AC and DC
Part 2: Constant-Voltage DC Magnetic Controllers for Motors on Cranes
Part 3: Adjustable-Voltage DC Controllers for Motors on Cranes
Part 4: Magnetic Controllers for AC Wound-Rotor Motors on Cranes
Part 5: Static Controllers for AC Wound-Rotor Motors on Cranes
Part 6: Crane and Hoist Power-Circuit Limit Switches
Part 7: Heavy-Duty DC Magnetic Contactors Rated 600 Volts

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ICS 9-1993 *Industrial Control and Systems*
Power-Circuit Accessories
Part 1: Electromagnetic Brakes
Part 2: Resistors and Rheostats
Part 3: Autotransformers and Reactors

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

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Part 1
ELECTROMAGNETIC BRAKES

1 General Requirements

1.1 Referenced Standards

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

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

250	*Enclosures for Electrical Equipment (1000 Volts Maximum)*
ICS 1-1993	*Industrial Control and Systems* *General Requirements*
ICS 1.3-1991	*Preventive Maintenance of* *Industrial Control and Systems Equipment*
ICS 5-1993	*Industrial Control and Systems* *Control Circuit and Pilot Devices*
ICS 6-1993	*Industrial Control and Systems* *Enclosures*
MG 1 -1993	*Motors and Generators*

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 674-1994	*Electric Motors and Generators for Use in Hazardous Locations, Class I, Groups C and D, Class 2, Groups E, F, and G.*

Association of Iron and Steel Engineers
Three Gateway Center, Suite 2350
Pittsburg, PA 15222

AISE 1-1968	*DC Mill Motor Standard*
AISE 1A-1964	*AC Mill Motor Standard*
AISE 6-1991	*Cranes*

Crane Manufacturers Association of America
8720 Red Oak Blvd. Suite 201
Charlotte, NC 28217

CMMA Publication No. 70-1994	*Specifications for Electric Overhead Traveling Cranes*

Institute of Electrical and Electronics Engineers
IEEE Customer Service
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855

ANSI/IEE 100-1992#	*Standard Dictionary of Electrical and Electronics Terms*

#also available from ANSI

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1.2 Scope

The standards in this part apply to electromagnetic friction brakes which are spring, hydraulic, permanent magnet, or electromagnetically set. Brakes may include provisions for manual release.

1.3 Normative References

The definitions and standards of NEMA Standards Publication No. ICS 1, also apply to this part.

2 Definitions

For the purposes of this NEMA Standards Publication, the following definitions apply:

2.1 Indicators

adjustment indicator: a mechanism that incorporates a method for indicating the condition of the brake with respect to its specified adjustment. It shows if readjustment is required as a result of wear of the braking surfaces or other parts and provides indication of proper brake adjustment.

electrical release indicator: A brake mounted control circuit contact complying with NEMA Standards Publication No. ICS 5, Part 1, that changes state when the brake setting mechanism has moved to the release position.

mechanical release indicator: A brake mounted visual indicator that changes state when the brake setting mechanism has moved to the release position.

wear indicator: A device which shows when lining replacement is required.

2.2 Manual Release Mechanisms

manual release: A device by which the braking surfaces are manually disengaged without disturbing the torque adjustment.

manual release with automatic-reset: A manual release which, when operated, will maintain the braking surfaces in disengagement but will automatically disengage the release mechanism as soon as electric power is again applied.

manual release with manual-reset: A manual release which requires an additional manual action to disengage the release mechanism.

manual release which is self-resetting: A manual release which is operative only while it is held manually in the release position.

2.3 Other Mechanisms

self-adjusting brake: A brake which incorporates a mechanism which automatically compensates for lining wear by maintaining a predetermined position relationship between the braking surfaces.

setting mechanism: A spring, hydraulic, permanent magnet, or electromagnetic actuator which provides a force that is transmitted to the braking surfaces through the brake linkages. Combinations of setting mechanisms shall be permitted to be used on the same brake when adjustable service braking and fixed parking braking are provided.

3 Classifications

3.1 Brake Types

3.1.1 Series Brakes

Used with DC series motors. The brake release coil is connected in series with the motor armature and field, motor, or both.

3.1.2 Shunt Brakes

Used with either DC or AC motors and with the brake release coil arranged for connection across a motor or power source.

3.1.3 Rectifier Operated Brakes

Used with an AC power source and are provided with DC shunt release coils.

3.2 Manual Release Types

Manual-release devices for brakes, when supplied, shall be one of the following types:

a. Manual release with automatic reset
b. Manual release with manual reset
c. Manual release with self-resetting

3.3 Mounting Arrangements

3.3.1 Shoe Brakes (Bracket or Base-Mounted)

3.3.1.1 Type I—Floor-Mounted Horizontal-Shaft Brake

A floor-mounted horizontal-shaft brake is a brake which is arranged for floor mounting with the wheel located on a shaft which is approximately parallel to the floor and with the brake actuator located at the side of the brake wheel.

3.3.1.2 Type I—A-Floor-Mounted Horizontal-Shaft Brake

Similar to Type I, except that the brake actuator is located either above or below the brake wheel.

3.3.1.3 Type II—Wall-Mounted Horizontal-Shaft Brake

A wall-mounted horizontal-shaft brake is a brake which is arranged for wall mounting with the wheel located on a shaft which is approximately parallel to the floor and to the wall and with the brake actuator located above or below the brake wheel.

3.3.1.4 Type III—Ceiling-Mounted Horizontal-Shaft Brake

A brake which is arranged for ceiling mounting with the wheel located on a shaft which is approximately parallel to the floor and with the brake actuator located at the side of the brake wheel.

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Table 1-4-1
GENERAL PURPOSE SHOE BRAKE TORQUE RATINGS FOR USE WITH OTHER THAN 600 FRAME, 800 FRAME, WOUND ROTOR MOTORS AND AC FRAME AISE† MILL MOTORS, AND SHORT TIME RATED CRANE AND HOIST MOTORS

Direct-Current-Operated Brakes				50- and 60-hertz Alternating Current-Operated Brakes	
Torque of Shunt Brake, Pound-feet		Torque of Series Brake, Pound-feet		Torque Ratings, Pound-feet	
Continuous*	1-hour*	1-hour*	½-hour*	Continous*	1-hour or ½-hour*
3	—	—	—	1.5	—
10	15	—	—	3	—
25	35	—	—	10	15
50	75	—	—	25	35
70	90	60	90	50	75
150	200	135	200	125	160
400	525	350	525	325	400
675	900	600	900	600	800
1350	1800	1200	1800	1200	1600
2700	3600	2400	3600	2400	3200

* These refer to the continuous, 1-hour or ½-hour thermal ratings of the operator or coils.

† Refers to AISE Standards 1 and 1-A.

Table 1-4-2
TORQUE RATINGS OF DC OPERATED SHOE BRAKES FOR USE WITH 600 FRAME, 800 FRAME, WOUND-ROTOR MOTORS, AC FRAME AISE† MILL MOTORS, AND SHORT TIME RATED CRANE AND HOIST MOTORS

	TORQUE RATINGS (LBS.-FT.)					
	SHUNT		SERIES		RECTIFIER OPERATED	
Brake Size (Wheel Diameter)	Cont.* (8 Hour) Duty	1 Hour (50% Duty Cycle) or 8 Hour (100% Duty) Hi-Speed Forced	1 Hour* (50% Duty Cycle)	½ Hour* (30% Duty Cycle)	8 Hour (100% Duty)**	1 Hour (50% Duty Cycle) or 8 Hour (100% Duty) Hi-Speed Forced**
8"	75	100	65	100	75	100
10"	150	200	130	200	150	200
13"	400	550	365	550	400	550
16"	750	1000	650	1000	750	1000
19"	1500	2000	1300	2000	1500	2000
23"	3000	4000	2600	4000	3000	4000
30"	6750	9000	6000	9000	6750	9000

* Ratings shown for 8-hour, 1-hour and ½-hour are the thermal ratings of the coil. The duty cycles apply providing the on-time does not exceed 10 minutes.

The torque ratings apply at a worn lining condition defined as the point where the brake readjusts, or where adjustment is required as recommended by the brake manufacturer.

** See 3.1.3

Refers to AISE Standards 1 and 1-A.

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Table 1-4-3
TORQUE RATINGS FOR DISC BRAKES

Brake Size	Motor Frame	Brake Torque, Pound-Feet
A	56C*, 143TC*, 182TCH*, 145TC*, 148TCH*	Static Torque Range—1 to 25 (1-1/2, 3, 6, 10, 15, 20, 25–Typical Static Torque Increments)
B	182TC*, 184TC*, 213TC*, 215TC*, 254TC*, 256TC*	Static Torque Range—10 to 105 (10, 15, 25, 35, 50, 75, 105–Typical Static Torque Increments)
C	284TFC, 286TFC	Static Torque Range—25 to 175 (25, 35, 50, 70, 75, 105, 125, 175–Typical Static Torque Increments)
D	324TFC, 356TFC, 364TFC, 365TFC, 404TFC, 405TFC	Static Torque Range—75 to 550 (75, 90, 105, 125, 175, 230, 345, 460, 550–Typical Static Torque Increments)

*Certain brakes can be used on drive end, but when the face for mounting is at the end opposite the drive, the prefix F shall be used, making the suffix letter FC.

3.3.1.5 Type IV—Wall-Mounted Vertical-Shaft Brake

A brake which is arranged for wall mounting with the wheel located on a shaft which is approximately perpendicular to the floor and with the brake actuator located at the side of the brake wheel.

3.3.2 Disc Brakes

Standard disc brakes shall be suitable for mounting to horizontal shaft motor frames as shown in 11.34 and 11.35 of NEMA Standard MG1.

Mounting to other than horizontal shaft motors is non-standard and shall be specified when required.

4 Characteristics and Ratings

4.1 General Purpose Shoe Brake Torque Ratings

The torque ratings of shoe brakes with series or shunt coils shall be as shown in Table1-4-1.

Direct-current brakes with rectifiers, when applied on alternating-current circuits, may be given the direct-current one-hour shunt torque ratings shown in Table 1-4-1 if used with one-hour coils. If used with continuous duty coils, continuous torque ratings may be given.

Table 1-4-1 applies to brakes for application on other than the 600 frame, 800 frame, wound-rotor motors and AC frame AISE* mill motors and short time rated crane and hoist motors.

4.2 Torque Ratings of DC Operated Shoe Brakes

The torque ratings of DC operated shoe brakes with series or shunt coils for use with the 600 frame, 800 frame, wound-rotor motors, AC frame AISE* mill motors, and short-time rated crane and hoist motors shall be as shown in Table 1-4-2.

*Refers to AISE Standards 1 and 1-A

4.3 Torque Ratings for Disc Brakes

Torque ratings for alternating- and direct-current disc brakes, corresponding to motor frame sizes, shall be as shown in Table 1-4-3.

Brake designations A, B, C, and D refer to brake diameter. No attempt is made to identify a specific diameter. For each size of brake, there are various torque ratings available which may be obtained by varying the number of discs which, in turn, will vary the length of the brake.

4.4 Shoe Brake Coil Ratings of the Brake Types Indicated in 4.2

Coil ratings are established based on the brake operating duty cycle and thermal capacity of the operating coil. Refer to the manufacturer for maximum current coil ratings.

4.5 Brake Operating Time

Brake release and set times are different for each manufacturer and can be obtained by contacting the manufac-

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turer. These operating times can be provided based on rated operating conditions or as described in 8.1.

5 Product Information, Installation and Maintenance

5.1 Brake Mounting Tolerances

For shoe brakes indicated in 4.2 see Table 1-7-1 for mounting tolerances, with respect to the motor, required for the proper operation of the brake.

5.2 Maintenance

In order to assure proper equipment operation, a periodic maintenance program should be established. Maintenance instructions should be obtained from the manufacturer for incorporation into this program.

5.2.1 Inspection

Brakes should be inspected to see that magnet gaps and torque spring settings are correct. The brake should be operated to verify that the brake linings are being released from the wheel or disc. Linings should be examined to determine if new linings are needed. Electrical connections and mechanical joints should be inspected for proper tightness; in particular, the hardware securing the wheel to the motor shaft and the brake mounting bolts. Dirt and dust should be removed from the brake with particular attention being given to the armature gap which tends to collect magnetic particles. The brake wheel or disc should be examined for unusual scoring, overheating, cracking, or wear, to determine the need for replacement. The condition of bearings and bushing should be checked along with the overall mechanical and electrical integrity of the complete braking system.

5.2.2 User Testing

The user should establish a schedule to test for the following.

a. The brake operates properly
b. The brake can stop and hold the rated load

5.2.3 Preventive Maintenance Guide

See Nema Standards Publication No. ICS 1.3.

6 Service and Storage Conditions

6.1 Unusual Environmental Conditions

Consult with the manufacturer for any special precautions or modifications required when any of the following conditions exist.

a. Airborne magnetic particles
b. Ambient temperatures above 40°C or below 0°C
c. High shock or vibration
d. Airborne oil, salt, corrosives, abrasives or water
e. Exposure to radiation
f. Other unusual environmental conditions.
g. In hazardous (classified) locations, as defined in NEMA Standards Publication No. 250, Section 5, special consideration should be given to non-sparking friction materials or NEMA Type 7 and NEMA Type 10 enclosures.

7 Construction

7.1 Dimensions of Shoe Brakes

The outline and mounting dimensions of DC operated shoe brakes for the 600 frame, 800 frame, wound-rotor motors, AC frame AISE* mill motors, and short-time rated crane and hoist motors shall be as shown in Table 1-7-1. These brakes are floor mounted and are of open construction. The brake lining width is 1/4 inch less than dimension C. Brake mounting tolerances, both horizontal and vertical with respect to the motor, shall be as indicated in Table 1-7-1.

* Refers to AISE Standards 1 and 1-A.

7.2 Device Markings

Brakes shall be marked with the following data:

a. Rated voltage, current, or both
b. Torque
c. Brake identification number
d. Manufacturer's name or identification mark
e. Special mounting arrangements (disc brakes only)

7.3 Maximum Allowable Brake Wheel Unbalance for Brakes

For the maximum allowable brake wheel unbalance, see Table 1-7-2.

7.4 Mounting Dimensions for Disc Brakes

Dimensions for Type FC face-mounted disc brakes on the end opposite the drive of alternating-current motors are shown in Table 1-7-3.

The disc brake mounting surface shall have bolt holes suitable for tabulated FBF screw sizes in the motor face. Such holes shall be located on diametral lines 45 degrees from the vertical centerline of the brake.

Any hole or holes required by the disc brake for leads from the motor shall be provided within an available area defined by a circle having the diameter and radial location as shown. This provision shall not apply to disc brakes employing Type 7 enclosures. See NEMA Standards Publication No. ICS 6.

Standards for disc brake hub bore, keyway and permissible length of motor shaft extension have not been developed.

7.5 Enclosures

7.5.1 General

Enclosures for brakes shall comply with NEMA Standards Publication No. ICS 6.

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Table 1-7-1
DIMENSIONS OF DC OPERATED SHOE BRAKES FOR THE 600 FRAME, 800 FRAME, ROUND-ROTOR MOTORS AND AC FRAME AISE* MILL MOTORS AND SHORT TIME RATED CRANE AND HOIST MOTORS**

Wheel Size-Inches D	Motor Frame Size	Wheel Dimensions - Inches				Mounting Dimensions - Inches						
		C	E	F	O	A	B	H	J	Z***	K	L
8	254X	3¼	2½	$1^{13}/_{16}$	$2^{11}/_{16}$	3¼ ±.032	$2^{7}/_{8}$ ±.032	$^{11}/_{16}$	7±.032	—	—	¾
	256X	"	2¾	$2^{3}/_{16}$	$3^{5}/_{16}$	"	"	"	"	—	—	¾
	284X	"	"	"	"	"	"	"	"	—	0	0
	286X	"	"	"	"	"	"	"	"	—	0	0
	324X	"	3	$1^{1}/_{16}$	$2^{6}/_{17}$	"	"	"	"	—	—	1
	326X	"	"	"	"	"	"	"	"	—	—	1
	364X	"	$3^{5}/_{8}$	2	4	"	"	"	"	—	—	2
	365X	"	"	"	"	"	"	"	"	—	—	2
	2 602 802	"	3	$2^{5}/_{8}$	"	"	"	"	"	8¼	$^{5}/_{8}$	—
	603 803	"	3½	$2^{1}/_{8}$	"	"	"	"	"	9	1½	—
	604 804	"	"	"	"	"	"	"	"	9½	2	—
	606	"	4	$1^{5}/_{8}$	"	"	"	"	"	9½	3	—
	AC1 AC2	"	3	$2^{5}/_{8}$	"	"	"	"	"	$9^{5}/_{8}$	0	0
	AC4	"	"	"	"	"	"	"	"	$10^{1}/_{8}$	1	—
	AC8	"	4	$1^{5}/_{8}$	"	"	"	"	"	$10^{5}/_{8}$	2	—
10	284X	3¾	$2^{3}/_{4}$	$2^{5}/_{8}$	3¾	4±.032	$3^{1}/_{8}$ ± 032	$^{11}/_{16}$	$8^{3}/_{8}$ ± 032	—	—	$1^{3}/_{8}$
	286X	"	"	"	"	"	"	"	"	—	—	$1^{3}/_{8}$
	324X	"	"	"	"	"	"	"	"	—	—	$^{3}/_{8}$
	326X	"	3	$2^{1}/_{8}$	3¼	"	"	"	"	—	—	$^{3}/_{8}$
	364X	"	$3^{5}/_{8}$	$1^{7}/_{8}$	$3^{5}/_{8}$	"	"	"	"	—	$^{5}/_{8}$	—
	365X	"	"	"	"	"	"	"	"	—	$^{5}/_{8}$	—
	404X	"	$3^{7}/_{8}$	$1^{7}/_{8}$	$3^{7}/_{8}$	"	"	"	"	—	$1^{5}/_{8}$	—
	405X	"	"	"	"	"	"	"	"	—	$1^{5}/_{8}$	—
	444X	"	4¼	1½	"	"	"	"	"	—	$2^{5}/_{8}$	—
	445X	"	"	"	"	"	"	"	"	—	$2^{5}/_{8}$	—
	602 802	"	3	$3^{1}/_{8}$	4¼	"	"	"	"	8½	—	$^{3}/_{4}$
	603 803	"	3½	$2^{5}/_{8}$	"	"	"	"	"	9¼	$^{1}/_{8}$	—
	604 804	"	"	"	"	"	"	"	"	9¾	$^{5}/_{8}$	—
	606 806	"	4	$2^{1}/_{8}$	"	"	"	"	"	9¾	$1^{5}/_{8}$	—
	608	"	4½	$1^{5}/_{8}$	"	"	"	"	"	$9^{7}/_{8}$	$2^{7}/_{8}$	—
	AC1 AC2	"	3	$3^{1}/_{8}$	"	"	"	"	"	$9^{7}/_{8}$	—	$1^{3}/_{8}$
	AC4	"	"	"	"	"	"	"	"	$10^{3}/_{8}$	—	$^{3}/_{8}$
	AC8	"	4	$2^{1}/_{8}$	"	"	"	"	"	$10^{7}/_{8}$	$^{5}/_{8}$	—
	AC12		"	"	"	"	"	"	"	$11^{5}/_{8}$	$1^{5}/_{8}$	—

*Refers to AISE Standards 1 and 1-A.
**Per NEMA Standards Publication No. MG-1, Clauses MG 1-18.506, 18.519 and 18.520.
***Z dimension has not been established for wound-rotor motors. Refer to MG1-18.520.

(continued)

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Table 1-7-1
DIMENSIONS OF DC OPERATED SHOE BRAKES FOR THE 600 FRAME, 800 FRAME, ROUND-ROTOR MOTORS AND AC FRAME AISE* MILL MOTORS AND SHORT TIME RATED CRANE AND HOIST MOTORS**
(Continued)

Wheel Size-Inches D	Motor Frame Size	Wheel Dimensions - Inches				Mounting Dimensions - Inches					
		C	E	F	O	A	B	H	J	Z***	K
13	324X	5¾	3	4 3/8	4½	5¾ ± .032	4½ ± .032	13/16	9 7/8 ± 045	—	—
	326X	"	"	"		"	"	"	"	—	—
	364X	"	3 5/8	4 5/16	5 1/16	"	"	"	"	—	—
	365X	"	"	"	"	"	"	"	"	—	—
	404X	"	3 7/8	3 3/8	4 3/8	"	"	"	"	—	1/8
	444X	"	"	"		"	"	"	"	—	1/8
	444X	"	4¼	2½	3 7/8	"	"	"	"	—	1 1/8
	445X	"	"	"	"	"	"	"	"	—	1 1/8
	603 803	"	3½	4 3/8	5	"	"	"	"	10	—
	604 804	"	"	"	"	"	"	"	"	10½	—
	606 806	"	4	3 7/8	5 3/8	"	"	"	"	10½	1/8
	608 808	"	4½	3¾	—	"	"	"	"	11	1 3/8
	610 810	"	"	"	"	"	"	"	"	11 5/8	2 3/8
	612 812	"	5	3¼	"	"	"	"	"	12 1/8	3½
	614 814	"	"	"	"	"	"	"	"	13 1/8	4 7/8
	AC8	"	4	3 7/8	5	"	"	"	"	11 5/8	
	AC12	"	"	"	"	"	"	"	"	12 3/8	1/8
	AC18	"	4½	3 3/4	5 3/8	"	"	"	"	14 11/32	2 5/8
	AC25 AC30	"	5	3¼	"	"	"	"	"	15 13/16	4 5/8
16	404X	6¾	3 7/8	5 3/8	5 7/8	7½ ± 032	5 3/8 ± .032	1 1/16	12 1/8 ± 045	—	—
	405X	"	"	"	"	"	"	"	"	—	—
	444X	"	4¼	4½	5 3/8	"	"	"	"	—	—
	445X	"	"	"	"	"	"	"	"	—	—
	606 806	"	4	5 7/8	6½	"	"	"	"	12	—
	608 808	"	4½	5 3/8	"	"	"	"	"	12 1/8	—
	610 810	"	"	"	"	"	"	"	"	12¾	1/8
	612 812	"	5	4 7/8	"	"	"	"	"	13¼	1¼
	614 814	"	"	"	"	"	"	"	"	14¼	2 5/8
	616 816	"	5½	4 3/8	"	"	"	"	"	15½	3 7/8
	AC18	"	4½	5 3/8	"	"	"	"	"	15 15/32	3/8
	AC25 AC30	"	5	4 7/8	"	"	"	"	"	16 15/16	2 3/8
	AC40 AC50	"	"	"		"	"	"	"	18½	4 7/8
19	444X	8¾	4¼	5 9/16	5 7/16	9¼ ± 032	6½ ± .032	1 1/16	13¼ ± 062	—	—
	445X	"	"	"	"	"	"	"	"	—	—
	608 808	"	4½	7 3/8	7½	"	"	"	"	13 1/8	—
	610 810	"	"	"	"	"	"	"	"	13¾	—
	612 812	"	5	6 7/8	"	"	"	"	"	14¼	1/8
	614 814	"	"	"	"	"	"	"	"	15¼	1½
	616 816	"	5½	6 3/8	"	"	"	"	"	16½	2¾
	618 818	"	6	5 7/8	"	"	"	"	"	16	4½
	620	"	6¾	5 1/8	"	"	"	"	"	16	7 5/8
	AC25 AC30	"	5	6 7/8	"	"	"	"	"	17 15/16	1¼
	AC40 AC50	"		"		"	"	"	"	19½	3¾

(continued)

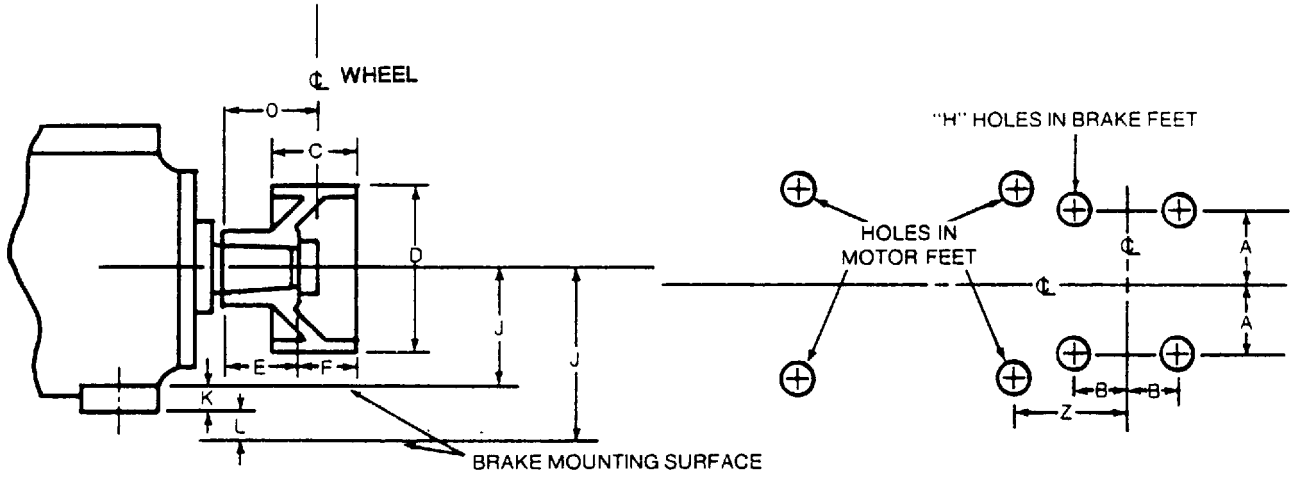
***Z dimension has not been established for wound-rotor motors. Refer to MG 1-18.520.

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Table 1-7-1
DIMENSIONS OF DC OPERATED SHOE BRAKES FOR THE 600 FRAME, 800 FRAME, ROUND-ROTOR MOTORS AND AC FRAME AISE* MILL MOTORS AND SHORT TIME RATED CRANE AND HOIST MOTORS**
(Continued)

Wheel Size-Inches D	Motor Frame Size	Wheel Dimensions - Inches				Mounting Dimensions - Inches						
		C	E	F	O	A	B	H	J	Z***	K	L
23	612 812	11¼	5	8⅞	8¼	11¼ ± .032	8 ± 032	1⁵/₁₆	15⅞ ± .062	15	—	2½
	614 814	"	"	"	"	"	"	"	"	16	—	1⅛
	616 816	"	5½	8⅜	"	"	"	"	"	17¼	⅛	—
	618 818	"	6	8⅜	8¾	"	"	"	"	17¼	1⅞	—
	620	"	6¾	8⅝	9¾	"	"	"	"	18¼	5	—
	622	"	7¼	8⅛	"	"	"	"	"	17½	7⅛	—
	624	"	9¼	6⅛	"	"	"	"	"	18¼	8⅛	—
	AC25 AC30	"	5	8⅞	8¼	"	"	"	"	18¹¹/₁₆	—	1⅜
	AC40 AC50	"	"	"	"	"	"	"	"	20¼	1⅛	—
30	616 816	14¼	5½	11⅞	10¼	15 ± 032	9½ ± 032	1⁹/₁₆	20¾ ± .075	19¼	—	4¾
	618 818	"	6	11⅜	"	"	"	"	"	18¾	—	3
	620	"	6¾	10⅝	"	"	"	"	"	18¾	⅛	—
	622	"	7¼	10⅝	10¾	"	"	"	"	18½	2¼	—
	624	"	9¼	8⅝	"	"	"	"	"	19¼	3¼	—

***Z dimension has not been established for wound-rotor motors. Refer to MG 1-18.520.



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Table 1-7-2
MAXIMUM ALLOWABLE BRAKE WHEEL UNBALANCE

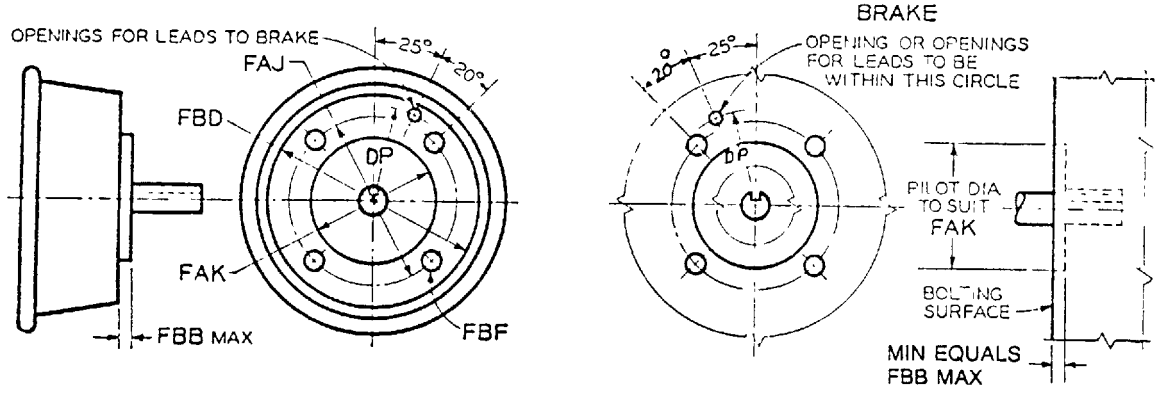
Wheel Diameter	Maximum Unbalance In Ounce-Inches
8	4
10	5
13	6
16	10
19	19
23	32
30	60

Table 1-7-3
DIMENSIONS FOR TYPE FC FACE-MOUNTED DISC BRAKES

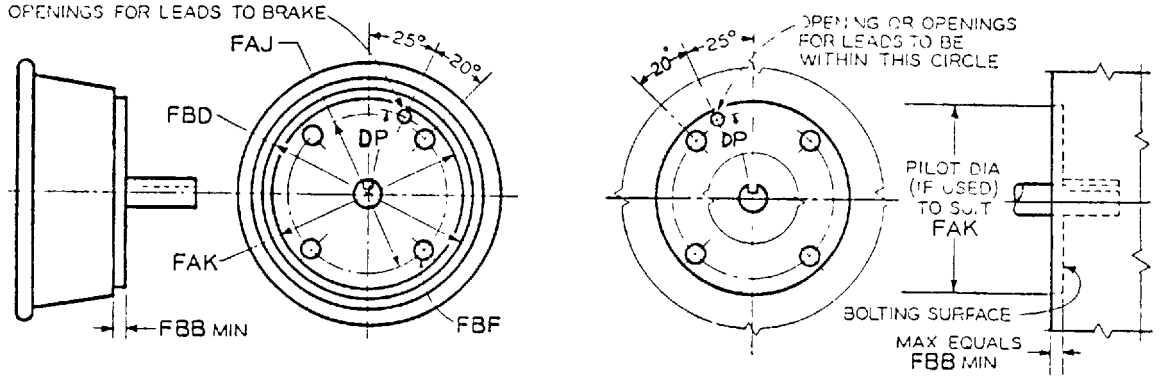
Type FC Face Mounting Dimensions (See MG 1-11.35)								Brake Data		
		FBF Hole			FBD	FAK	FBB		Area for Leads	
Frame Designation	FAJ Bolt Circle	Number	Tap Size	Min Depth	Outside Diameter of Face	Outside Diameter of Pilot	Depth of Pilot	Size	Diameter	DP Radial Location
*56C										
143TFC,145TFC	5.875	4	3/8-16	0.56	6.50 Nom	4.50	0.16 Max	A	0.41	2.81
182TFC,184TFC	5.875	4	3/8-16	0.56	6.50 Nom	4.50	0.16 Max	A	0.41	2.81
213TFC,215TFC	7.250	4	1/2-13	0.75	9.00 Min	8.50	0.25 Min	B	0.62	3.81
254TFC,256TFC	7.250	4	1/2-13	0.75	10.00Min	8.50	0.25 Min	B	0.62	3.81
284TFC,286TFC	9.000	4	1/2-13	0.75	11.25Min	10.50	0.25 Min	C	0.62	4.50
324TFC,326TFC	0.56	4	5/8-11	0.94	14.00Min	12.50	0.25 Min	D	0.62	5.25

*Mounting dimensions not standardized

MOTOR FRAMES 143TFC THROUGH 184TFC



MOTOR FRAMES 213TFC THROUGH 326TFC



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7.5.2 Brake Coil Terminal Enclosures

Brake coil terminal enclosures, if supplied, shall be suitable for the environment specified and shall be in accordance with NEMA Standards Publication No. ICS 6.

7.5.3 Disc Brakes Employing Type 7D Enclosures

Disc brakes employing Type 7D enclosures (when the brake hub is supported as it would be on the Type C motor face) for installation in hazardous locations shall conform to the Underwriters Laboratories Inc., Publication No. UL 674.

8 Performance Requirements and Tests

8.1 Range of Operating Voltage and Current

8.1.1 DC brakes operated by series coils shall release at 40 percent or less of rated motor current and shall set at 10 percent or less of rated motor current.

8.1.2 DC brakes operated by shunt coils shall release at 80 percent or less of rated voltage and shall operate satisfactorily at 110 percent of rated voltage.

8.1.3 AC brakes operated by shunt coils shall release at 85 percent of rated voltage and shall operate satisfactorily at 110 percent of rated voltage.

8.1.4 A brake which is operated by a shunt coil shall operate successfully at its minimum voltage when the temperature of the brake coil or of the operator is at the maximum temperature obtainable under its normal operating rating.

8.2 Temperature Rise of Coils

The operating coil of a shoe or disk brake shall not exceed the temperature rise specified in Clause 8.3 of ICS 1 when operated at rated voltage and duty cycle.

Exception: When Class F coil insulation is incorporated, a temperature rise, determined by resistance, of 115°C above an ambient of 40°C, shall be allowed.

8.3 Braking Torque

8.3.1 Shoe Brake

A new shoe brake should equal or exceed the rated torque value in Tables 1-4-1 and 1-4-2 in both a dynamic and static mode and at operating temperatures of the braking surfaces as defined by the manufacturer, when installed, adjusted and aligned per the manufacturer's instructions. For exceptions, see 9.4.2.

8.3.2 Disc Brake

A new disc brake should have a static torque of not less than 90% of rated torque after following the manufacturer's recommended installation procedures. This brake should maintain a minimum of 90% of rated static torque at operating temperatures determined by the heat dissipation capabilities listed by the manufacturer.

8.4 Dielectric Test

The operating coil shall withstand a power frequency dielectric test as specified in Clause 8.4 of NEMA Standards Publication No. ICS 1.

9 Application

9.1 Brake Energy Dissipation

9.1.1 One-Time Emergency Energy Dissipation

Starting from an operating temperature as defined by the manufacturer, a new shoe brake of the type indicated in 4.2, should be capable of the one-time emergency energy dissipation available from the manufacturer, without apparent damage to the brake or brake wheel.

9.1.2 Allowable Rate of Energy Dissipation

The rate of energy dissipation allowable, under operating duty cycle conditions, in order not to exceed the normal operating temperature of the brake and brake wheel, can be obtained from the brake manufacturer if the manufacturer is provided with the brake size, number of brakes, maximum system Wk^2 running motor speed, accelerating time, running time, stopping time, off time, and ambient temperature for each duty cycle sequence.

9.2 Shunt Brake Coil Control

9.2.1 Shunt brakes provided with series resistors or with other voltage reduction control methods are used to enable the use of one-hour torque ratings on continuously energized brakes. They may also be used to obtain quicker setting and releasing than the standard brake.

9.2.2 A control system including a suitable rectifier and series resistors or with other voltage reduction methods is used to enable the use of one-hour torque ratings on continuously energized brakes. They may also be used to obtain quicker setting and releasing than the standard brake.

9.3 Brake Lining Replacement

See Table 1-9-1 for minimum brake lining thickness prior to replacement for the DC operated shoe brakes described in 4.2.

9.4 Special Precautions

9.4.1 Consult with the manufacturer for any special precautions required when mounting brakes in positions other than floor or horizontal-shaft mounted, since certain modifications may be required for proper operation of the brake.

9.4.2 Since the brake torque may vary due to conditions such as moisture on the friction surfaces, rusty wheels or discs, lining glaze, alignment of linings and brake wheels or discs, and other variables, allowance for these variations should be considered during application and use.

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Table 1-9-1
MINIMUM BRAKE LINING THICKNESS FOR DC OPERATED SHOE BRAKES

Wheel Dia. (Inches)	Max Rpm	* Min. Wheel Dia. (Inches)	Lining Thickness (Inches)**	
			*** Riveted	Bonded
8	5000	7.94	.010	.016
10	4000	9.92	.010	.020
13	3300	12.90	.010	.026
16	2600	15.87	.015	.032
19	2300	18.87	.015	.038
23	1900	22.87	.015	.046
30	1600	29.87	.015	.060

* Minimum after remachining
** Minimum permissible prior to replacement
***Above rivet head at maximum wear point

9.4.3 One hundred percent contact of braking surfaces is not required. Refer to the manufacturer for recommendations.

9.5 Brake Wheel Overheating

Brakes included in this standards publication may overheat if the thermal rating of the brake is exceeded, or if the linings are rubbing due to improper adjustments or mechanical or electrical failure, resulting in the brake not releasing.

Expansion of overheated braking surfaces may take up the brake operating clearance and may result in rapid deterioration of the braking surfaces. Overheating of the braking surfaces may also result in fade (reduction of braking torque).

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Part 2
RESISTORS AND RHEOSTATS

1 General

1.1 Scope

The standards in this section apply to resistors and rheostats used in power circuits of industrial control apparatus.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. ICS 1, also apply to this part.

2 Definitions

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

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

class number: A number that identifies a resistor's current carrying capability under a specified duty cycle.

dimmer: A rheostat that may be inserted into a lamp circuit for the purpose of reducing the luminous intensity of the lamp.

primary resistor: A resistor inserted into the circuit supplying the primary winding of a motor for the purpose of limiting the inrush current to the motor.

resistor:* A device the primary purpose of which is to introduce resistance into an electric circuit.

Note: A resistor as used in electric circuits for purposes of operation, protection, or control, commonly consists of an aggregation of units. Resistors, as commonly supplied, consist of wire, metal ribbon, cast metal, or carbon compounds supported by or embedded in an insulating medium. The insulating medium may enclose and support the resistance material as in the case of the porcelain tube type or the insulation may be provided only at the points of support as in the case of heavy duty ribbon or cast iron grids mounted in metal frames.

rheostat:* An adjustable resistor so constructed that its resistance may be changed without opening the circuit in which it may be connected.

secondary resistor:* A resistor connected in the secondary of a wound-rotor motor for the purpose of controlling motor acceleration.

series-wound motor:* A commutator motor in which the field circuit and armature circuit are connected in series, i.e, the excitation is supplied by a winding or windings connected in series with or carrying a current proportional to that in the armature winding.

shunt-wound motor:* A DC motor in which the field circuit and armature circuit are connected in parallel.

starting duty: A resistor application in a motor circuit where the resistor is removed from the circuit when the motor is operating at rated speed.

wound-rotor motor:* An induction motor in which a primary winding of one member (usually the stator) is connected to the alternating-current power source and a secondary polyphase coil winding on the other member (usually the rotor) carries alternating current produced by elecromagnetic induction.

Note: The terminations of the rotor winding are usually connected to collector rings. The brush terminals may be either short-circuited or closed through suitable adjustable circuits.

3 Classification

3.1 Resistors, General

Resistors shall be designated by class numbers in accordance with Tables 2-3-1 through 2-3-5.

3.2 Separate Dynamic Braking Resistors

Separate dynamic braking resistors shall be designated by class numbers in accordance with Table 2-3-5.

4 Characteristics and Ratings

4.1 Characteristics

4.1.1 Starting-Duty and Intermittent-Duty Resistors

Starting-duty and intermittent-duty resistors are primarily designed for use with motors which require an initial torque corresponding to the stated percent of full-load current on the first point and which require an average accelerating current (rms value) of 125 percent of full-load current.

4.1.2 Secondary-Resistor AC Controllers

With a secondary-resistor AC controller, the figures given in the tables for the percent of full-load current on the first point, starting from rest, apply to rotor (secondary) current and to torque. The primary current will, in general, be a higher percentage of the full-load current.

4.1.3 Starting-Duty and Intermittent-Duty Primary Resistors

Starting-duty and intermittent-duty primary resistors which are designed for use with squirrel-cage motors and which meet the test described in 8.2.2 are included in the tables.

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Table 2-3-1
CLASS NUMBERS OF RESISTORS FOR NONREVERSING SERVICE AND REVERSING NONPLUGGING SERVICE WITHOUT ARMATURE SHUNT OR DYNAMIC BRAKING

Approximate Percentage of Full-load Current on First Point Starting from Rest	Class Numbers						
	Duty Cycles						
	5 Seconds ON 75 Seconds OFF	10 Seconds ON 70 Seconds OFF	15 Seconds ON 75 Seconds OFF	15 Seconds ON 45 Seconds OFF	15 Seconds ON 30 Seconds OFF	15 Seconds ON 15 Seconds OFF	Continuous Duty*
25	111	131	141	151	161	171	91
50	112	132	142	152	162	172	92
70	113	133	143	153	163	173	93
100	114	134	144	154	164	174	94
150	115	135	145	155	165	175	95
200 or over	116	136	146	156	166	176	96

* For speed-regulating duty, see Table 2-3-4.

When an armature shunt resistor is added, the class number shall include the suffix AS. For example, Class 155-As is a resistor which includes an armature shunt and which will allow an initial inrush of 150 percent with the armature shunt open.

When a dynamic braking resistor is added, the class number shall include the suffix DB. For example, Class 155-DB.

Table 2-3-2
CLASS NUMBERS OF RESISTORS FOR REVERSING PLUGGING SERVICE WITHOUT ARMATURE SHUNT OR DYNAMIC BRAKING

Approximate Percent of Full-load Current on First Point Starting from Rest with All Resistance in Circuit	Class Numbers			
	Duty Cycles			
	15 Seconds ON 45 Seconds OFF	15 Seconds ON 30 Seconds OFF	15 Seconds ON 15 Seconds OFF	Continuous Duty
25	151P	161P	171P	91P
50	152P	162P	172P	92P
70	153P	163P	173P	93P
100	154P	164P	174P	94P

The class numbers apply to the complete resistor, but the duty cycles apply to the accelerating resistor only.

When an armature shunt resistor is added, the class number shall include the suffix AS. For example, Class 153P-AS is a plugging resistor which includes an armature shunt and which will allow an initial inrush of 70 percent with the armature shunt open.

When a dynamic braking resistor is added, the class number shall include the suffix DB. For example, Class 153P-DB.

Table 2-3-3
CLASS NUMBER OF RESISTORS FOR DYNAMIC LOWERING CRANE AND HOIST CONTROLLERS

Approximate Percent of Full-load Current on First Point Hoisting Starting from Rest without Armature Shunt	Class Numbers			
	Duty Cycles			
	15 Seconds ON 45 Seconds OFF	15 Seconds ON 30 Seconds OFF	15 Seconds ON 15 Seconds OFF	Continuous Duty
50	152DL	162DL	172DL	92DL
70	153DL	163DL	173DL	93DL

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Table 2-3-4
CLASS NUMBERS OF RESISTORS FOR CONTINUOUS-DUTY SPEED-REGULATING SERVICES WITH DIRECT-CURRENT SHUNT MOTORS AND ALTERNATING-CURRENT WOUND-ROTOR MOTORS

Percent Speed Reduction	Class Numbers						
	Percent of Rated Motor Torque at Reduced Speed						
	40	50	60	70	80	90	100
5	405	505	605	705	805	905	1005
10	410	510	610	710	810	910	1010
15	415	515	615	715	815	915	1015
20	420	520	620	720	820	920	1020
25	425	525	625	725	825	925	1025
30	430	530	630	730	830	930	1030
35	435	535	635	735	835	935	1035
40	440	540	640	740	840	940	1040
45	445	545	645	745	845	945	1045
50	450	550	650	750	850	950	1050

(a) The stability of the motor speed obtained by simple rheostatic control is dependent upon the stability of the load on the motor. The degree of instability is directly proportional to the amount of speed reduction. Variations in load have a greater proportional effect on the speed when the load is light. For these reasons, Table 2-3-4 has not been carried beyond a speed reduction of 50 percent and a load torque of 40 percent.

(b) With a DC shunt motor, the percent of rated motor current which is obtained at the reduced speed is assumed to be the same as the percent of rated torque.

With a DC series motor operating at less than 100 percent current, the percent of torque is less than the percent of current.

With a wound-rotor motor and resistor in the motor circuit, the percent of rated rotor (secondary) current which is obtained at the reduced speed is assumed to be the same as the percent of rated torque.

(c) A speed-regulating resistor is so designed that it may be operated continuously at any point in the speed-regulating range when the load follows its normal speed-torque curve. When additional resistance is required to obtain the starting current specified, the additional portion of the resistor shall be designed for a duty cycle selected from Table 2-3-1. The resulting resistor may be completely specified by a compound number.

(d) If the speed-regulating resistor alone is used, the approximate percent of rated current which will be obtained on the first point of the controller, starting from rest, may be determined from the equation:

$$\text{Percent current} = \frac{\text{Percent torque at reduced speed}}{\text{Percent speed reduction}} \times 100$$

Table 2-3-5
CLASS NUMBERS OF DYNAMIC BRAKING RESISTORS

Peak Braking Current as a Percentage of Rated Full-Load Current	Number of Steps		
	1	2	3
100	DB11	DB12	DB13
150	DB21	DB22	DB23
200	DB31	DB32	DB33
250	DB41	DB42	DB43
300 or over	DB51	DB52	DB53

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4.1.4 Starting Resistor for an Adjustable-Speed DC Motor

An adjustable-speed DC motor having a given horsepower rating, when started with full field generally requires a resistor having a larger ohmic value than does a constant-speed motor of the same horsepower rating. For this reason, the current on the first point and the capacity of the complete resistor of the same NEMA classification for an adjustable-speed motor may be different from that for a constant-speed motor of the same horsepower.

4.1.5 Continuous-Duty Resistor

A continuous-duty resistor for motor applications shall be so designed that the controller may be operated continuously on any point when the load follows its normal speed-torque curve, except that the motor must not be operated continuously below the minimum speed specified.

4.2 Ratings

Resistors shall be rated in ohms, amperes and class of service.

5 Product Information, Installation and Maintenance

5.1 Product Information for Nonstandard Braking Resistors

Where the load inertia or the number of stops, or both, exceeds that specified in 8.3.1, a separate dynamic breaking resistor may be designated as "Similar to Class _____ except _____," spelling out the difference. In this case, the following data are required:

a. Motor horsepower and voltage rating
b. Maximum motor speed
c. Motor inertia
d. The load inertia reflected to the motor shaft

5.2 Specific Maintenance Instructions

In order to assure proper equipment operation, a periodic maintenance program should be established. Maintenance instructions should be obtained from the manufacturer for incorporation into this program.

Resistors should be examined for evidence of overheating and all connections should be checked for proper tightness. Check to see that proper clearance is maintained to any combustible material near the resistor. The resistor mounting feet, any supporting structures, or both, should be checked for tightness of mounting hardware.

CAUTION: Disconnect all power sources to the resistors before attempting preventive maintenance.

5.3 Preventive Maintenance Guide

See NEMA Standards Publication ICS 1.3.

6 Service and Storage Conditions

6.1 Normal Service Conditions

The service and storage conditions of ICS 1 apply for altitudes up to 6600 feet.

6.2 High Altitude Applications

For altitudes between 6600 feet (2000 meters) and 12,000 feet (3500 meters):

a. Continuous-duty resistors shall be derated to 75 percent of their normal power rating
b. Starting-duty and Intermittent-duty resistors shall be applied on a duty cycle which is selected on the basis of the next higher "time-on" classification

7 Construction

7.1 Marking End Connectors for Resistor Units

Where a resistor consists of two or more units which are to be connected, the use of the letters "A" to "A," "B" to "B," etc., is recommended.

7.2 Direction of Rotation for Rheostats

7.2.1 A rheostat which is connected in series with the shunt field of a motor shall increase the speed of the motor when the operating handle is turned in a clockwise direction, viewed from the operator's position.

7.2.2 A rheostat which is connected in series with the shunt field of a generator for the ultimate purpose of controlling the voltage of the generator shall increase the voltage of the generator when the operating handle is turned in a counterclockwise direction, viewed from the operator's position.

7.2.3 A rheostat, or rheostats, applied to a DC adjustable-voltage drive shall increase the speed of the motor when the generator rheostat or the motor rheostat is turned in a clockwise direction, viewed from the operator's position.

8 Performance Requirements and Tests

8.1 Temperature Rise Performance Criteria

Temperature rise limits are a performance requirement for resistors.

When a temperature rise test is made on a resistor, rheostat or dimmer at the current values, duty cycle and elapsed time specified, the temperature rise above the ambient temperature and the methods of temperature measurement shall be in accordance with the following:

a. For bare resistive conductors the temperature rise shall not exceed 375°C as measured by a thermocouple in contact with the resistive conductor.
b. For resistor units, rheostats and wall-mounted rheostatic dimmers which have an embedded resistive conductor the temperature rise shall not exceed 300°C as measured by a thermocouple in

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contact with the surface of the embedding material.

c. For rheostatic dimmers which have embedded resistive conductors and which are arranged for mounting on switchboards or in noncombustible frames the temperature rise shall not exceed 350°C as measured by a thermocouple in contact with the surface of the embedding material.

d. The temperature rise of the issuing air shall not exceed 175°C as measured by a mercury thermometer at a distance of 1 inch from the enclosure.

8.2 Temperature Rise Tests

8.2.1 Resistors

8.2.1.1 Starting-Duty or Intermittent-Duty Resistor

When a temperature rise test is made on a starting-duty or intermittent-duty resistor without its motor, the resistor shall be connected to a voltage which will give the initial inrush current specified. In addition, the steps shall be cut out at equal intervals of time in the time-on period of the cycle specified, and the current shall be maintained at 125 percent of the full-load current for those steps through which 125 percent of full-load current can flow. The specified cycle shall be repeated for one hour.

8.2.1.2 Continuous-Duty Resistor

When a temperature rise test is made on a continuous-duty resistor without its motor, any tested step shall be subjected to 100 percent of the current for which the resistor is designed, and this value of current shall be maintained until the maximum temperatures are reached.

8.2.1.3 Rheostatic Dimmer

When a temperature rise test is made on a rheostatic dimmer, it shall be performed on a single plate which is operated at rated voltage and connected in series with lamps totalling the rated lamp load.

Single plates meeting this test will operate at safe temperatures when assembled into switchboard groups because of the diversity of loading of the various plates. The maximum temperature rise may be approximated by setting the lever so that the dimmer is dissipating maximum wattage.

8.2.2 Primary Resistors for Squirrel-Cage Motors

When a temperature rise test is made on a general-purpose single-step primary starting resistor for a squirrel-cage motor, the resistor shall be tested with 300 percent of normal full-load current of the motor for which the resistor is designed, and the current shall be maintained for a duty cycle as indicated in the resistor classification. This cycle shall be repeated for one hour, after which period the temperature rise shall not exceed the limitations given in 8.1.

8.3 Separate Dynamic Braking Resistors

Separate dynamic braking resistors shall not exceed their rated temperature rise (starting from ambient temperature) when the drive is braked by dynamic braking, from maximum speed to standstill, three times in rapid succession with a load inertia which is equal to or less than the motor inertia.

8.4 Current-Carrying Ability

Continuous-duty resistors shall be capable of carrying continuously the current for which they are designed without exceeding the specified temperature rise. See ICS 8.1.

9 Application

9.1 Current-Carrying Capacity of Resistor Wires for Wound-Rotor Motors

The connecting wires between the rotor of a wound-rotor motor and its resistors shall have minimum current-carrying capacity in accordance with Table 2-9-1.

9.2 Resistor Application Table

Table 2-9-2 is intended as a guide in specifying and designing resistors. The classifications are those which experience has shown to be correct for the average installation. It is recognized that there will be exceptions. Table 2-9-2 applies to resistors composed of wire-wound units or cast grids. It is also applicable to unbreakable resistors provided that the time-on period does not exceed the values given in 4.1.3. Table 2-9-2 gives the basic class number. Where plugging, dynamic braking, armature shunt or dynamic lowering functions are required, the appropriate suffix letters shown in Tables 2-3-2 and 2-3-3 should be added to the basic number.

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Table 2-9-1
CONDUCTOR CAPACITY

Resistor Class Number (See 3.1)	Minimum Current-carrying Capacity, Percent of Full-load Secondary Current
101 to 106, 111 to 116	35
131 to 136	45
141 to 146	55
151 to 156	65
161 to 166	75
171 to 176	85
91 to 96	110

Table 2-9-2
APPLICATION GUIDE

Installation	Class No. of Resistor
Blowers –	
Centrifugal	133-93
Constant pressure	135-95
Brick Plants –	
Augers	135
Conveyors	135
Dry pans	135
Pug mills	135
By-product Coke Plants –	
Door machine	153
Leveler ram	153
Pusher bar	153
Valve reversing machines	153
Cement Mills –	
Conveyors	135
Crushers	145
Elevators	135
Rotary dryers	145-95
Grinders and pulverizers	135
Kilns	135-95
Coal and Ore Bridges –	
Bridge	153
Closing	162
Holding	162
Trolley	162, 163
Coal Mines –	
Car hauls	162
Conveyors	135-55
Cutters	135
Crushers	145
Fans	134-93
Hoists –	
Slope	172
Vertical	162
Jigs	135
Picking tables	135
Rotary car dumpers	153
Shaker screens	135
Compressors –	
Constant speed	135
Varying speed –	
Centrifugal	93
Plunger type	95
Concrete Mixers	135
Cranes – Service Classes A, B, and C*	
Hoist	152, 153
Bridge or Trolley with –	
Sleeve bearings	153
Roller bearings	152
Cranes – Service Classes D and E*	
Hoist	162, 163
Bridge or trolley with –	
Sleeve bearings	163
Roller bearings	162
Flour Mills –	
Line shafting	135
Food Plants –	
Butter churns	135
Dough mixers	135
Hoists –	
Winch	153
Mine slope	172
Mine vertical	162
Contractor's hoists	152
Larry Cars	153
Lift Bridges	152

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Table 2-9-2 (continued)
APPLICATION GUIDE

Installation	Class No. of Resistor
Machine Tools –	
Bending rolls	163-164
Boring mills	135
Bulldozers	135
Drills	115
Gear cutters	115
Grinders	135
Hobbing machines	115
Lathes	115
Milling machines	115
Presses	135
Punches	135
Saws	115
Shapers	115
Metal Mining –	
Ball, rod and tube mills	135
Car dumpers – rotary	153
Converters – copper	154
Conveyors	135
Crushers	145
Tilting furnace	153
Paper Mills –	
Beaters	135
Calenders	154-92
Pipeworking –	
Cutting and threading	135
Expanding and flanging	135-95
Power Plants –	
Clinker grinders	135
Coal crushers	135
Conveyors –	
Belt	135
Screw	135
Pulverized fuel feeders	135
Pulverizers –	
Ball type	135
Centrifugal	134
Stokers	135-93
Pumps –	
Centrifugal	134-93
Plunger	135-95
Rubber Mills –	
Calenders	155
Crackers	135
Mixing mills	135
Washers	135
Steel Mills –	
Accumulators	153
Casting machines – pig	153

*Definition per Association of Iron & Steel Engineers A.I.S.E. Standard No.6, May 1, 1969.

Installation	Class No. of Resistor
Steel Mills (continued) –	
Charging machines –	
Bridge	153-163
Peel	153-163
Trolley	153-163
Coiling machines	135
Converters – metal	154
Conveyors	135-155
Cranes	*
Crushers	145
Furnace doors	155
Gas valves	155
Gas washers	155
Hot metal mixers	163
Ingot buggy	153
Kickoff	153
Levelers	153
Manipulator fingers	153-163
Pickling machine	153
Pilers – slab	153
Racks	153
Reelers	135
Saws – hot or cold	155
Screw downs	153-163
Shears	155
Shuffle bars	155
Side guards	153-163
Sizing rolls	155
Slab buggy	155
Soaking pit covers	155
Straighteners	153
Tables –	
Approach	153
Lift	153-163
Main roll	153-163
Roll	153
Shear approach	153-163
Transfer	153
Tilting furnace	153
Wire-stranding machine	153
Woodworking Plants –	
Boring machines	115
Lathe	115
Mortiser	115
Moulder	115
Planers	115
Power trimmer and mitre	115
Sanders	115
Saws	115
Shapers	115
Shingle machine	115

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Part 3
AUTOTRANSFORMERS AND REACTORS

1 General

1.1 Scope

The standards in this section apply to AC 50 Hz and 60 Hz autotransformers and reactors of the type used to supply reduced voltage for motor controllers for motors which are rated 10,000 horsepower or less. They do not cover the application of autotransformers and reactors to synchronous condensers and frequency changers since such autotransformers and reactors are, in general, quite large and usually require special taps. The autotransformers covered by this section are for applications where the windings are in the circuit only during the starting period.

1.2 Normative References

The definitions and standards of ICS 1 also apply to this section.

2 Definitions

For the purposes of this section, the following definitions apply:

* Identical to ANSI/IEEE Standard 100.

autotransformer:* A transformer in which at least two windings have a common section.

reactor:* A device used for introducing impedance into an electric circuit, the principal element of which is inductive reactance.

current-limiting reactor:* A reactor intended for limiting the current that can flow in a circuit under short-circuit conditions, or under other operating conditions such as starting, synchronizing, etc.

3 Classification

Autotransformers and reactors shall be classified as suitable for heavy-duty or medium-duty service in accordance with 3.1.1 and 3.1.2.

3.1 Heavy Duty

Heavy-duty service includes applications which require frequent starting or jogging, such as certain steel-mill drives and other special drives, including those having extremely high inertia.

3.2 Medium Duty

Medium-duty service includes applications to motors which drive loads such as fans, pumps, compressors, line shafts, etc.

4 Characteristics and Ratings

4.1 Duty Cycle Rating Conditions

Ratings for heavy-duty and medium-duty controllers shall be based on the duty cycles and load conditions specified in 4.2 through 4.5.

4.2 Heavy Duty

ON	1 minute
OFF	1 minute
REPEAT	4 times (for a total of five cycles)
REST	2 hours
ON	1 minute
OFF	1 minute
REPEAT	4 times (for a total of five cycles)
TAP	lowest tap
LOAD	motor with rotor blocked or connected to equivalent inductive load

4.3 Medium Duty—Manual Controllers for Motors Rated 300 Horsepower or Less

ON	15 seconds
OFF	3 minutes 45 seconds
REPEAT	3 times (for a total of four cycles)
REST	2 hours
ON	15 seconds
OFF	3 minutes 45 seconds
REPEAT	3 times (for a total of four cycles)
TAP	65 percent
TAP CURRENT	300 percent of motor full-load current
POWER FACTOR	50 percent or less

4.4 Medium Duty—Magnetic Controllers for Motors Rated 200 Horsepower or Less

ON	15 seconds
OFF	3 minutes 45 seconds
REPEAT	14 times (for a total of fifteen cycles)
REST	2 hours
ON	15 seconds
OFF	3 minutes 45 seconds
TAP	65 percent
TAP CURRENT	300 percent of motor full-load current

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POWER FACTOR	50 percent or less

4.5 Medium Duty—Magnetic Controllers for Motors, Rated 201 Horsepower to 3000 Horsepower, Inclusive

ON	30 seconds
OFF	330 seconds
REPEAT	2 times (for a total of three cycles)
REST	1 hour
ON	30 seconds
OFF	30 seconds
REPEAT	2 times (for a total of three cycles)
TAP	65 percent
TAP CURRENT	300 percent of motor full-load current
POWER FACTOR	50 percent or less

5 Product Information, Installation and Maintenance

See ICS 1.3 for general maintenance information.

6 Service and Storage Conditions

See ICS 1, Clause 6.

7 Construction

7.1 Marking

7.1.1 Autotransformers

The taps and the coils shall be marked as follows: the end of the winding which is connected to the wye or delta point and which is the start of the winding shall be marked "0." The intermediate taps shall be marked with the approximate percentage of line voltage which will be delivered to the motor under the specified load conditions. The end connection which goes to the line shall be marked "100." For example, medium-duty autotransformers for motors rated more than 50 horsepower shall be marked "0-50-65-80-100."

7.1.2 Reactors

The start of the winding shall be marked "0", and the taps shall be marked "1," "2," "3," "4," etc. The nameplate or terminal board shall show the connections to be used for each of the specified voltages.

7.2 Starting Taps

7.2.1 Autotransformers

Autotransformers shall have starting taps in accordance with Table 3-7-1. For heavy-duty service, the load conditions are governed by the particular application. For medium-duty service, the stalled motor current at full voltage shall be assumed to be six times the normal full-load current for the purpose of determining the tap voltage under load conditions. The load taken from the taps shall be an inductive load having a power factor of 0.5 or less.

7.2.2 Reactors

Assuming the same load conditions as those given for autotransformers and with the motor stalled, reactors shall provide the motor terminal voltages shown in Table 3-7-1.

8 Performance Requirements and Tests

The temperature rise of autotransformer and reactor coils, when measured by the resistance method at the duty cycle given in 4.1 and at specified normal voltage, shall not exceed the limits specified in ICS 1.

9 Application

Autotransformers and reactors shall be applied in duty cycles no more severe than those shown in 4.1.

Table 3-7-1
REACTOR TAPS AND MOTOR TERMINAL VOLTAGES

Service Classification	Horsepower Rating of Motors	Starting Taps, Motor Terminal Voltages (Approximate Percent of Line Voltage)
Medium duty	50 and less	65-80
	More than 50	50-65-80
Heavy duty	50 and less	65-80
	More than 50	50-65-80

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Supplement 1

SCOPE OF THE INDUSTRIAL CONTROL AND SYSTEMS SECTION

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

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

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

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

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

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

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

Also included, but not limited to, are:

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

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5. Sensors
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 bypass 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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