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Safety Standard for Construction and Guide for Selection, Installation, and Use of Electric Motors and Generators

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NEMA STANDARDS PUBLICATION

NEMA MG 2

SAFETY STANDARD FOR CONSTRUCTION AND GUIDE FOR SELECTION, INSTALLATION, AND USE OF ELECTRIC MOTORS AND GENERATORS

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

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NEMA Standards Publication No. MG 2-1989 (R 1994)

SAFETY STANDARD FOR CONSTRUCTION AND GUIDE FOR SELECTION, INSTALLATION, AND USE OF ELECTRIC MOTORS AND GENERATORS

Reaffirmed November 30, 1994

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Foreword

The use of electric machines, like that of all other utilization of concentrated power, is potentially hazardous. The degree of hazard can be greatly reduced by proper design, selection, installation, and use, but hazards cannot be completely eliminated. The reduction of hazard is the joint responsibilty of the user, the manufacturer of the driven or driving equipment, and the manufacturer of the machine. The words "driven or driving equipment" as used in this publication mean equipment driven by a motor or equipment driving a generator.

In this publication, Section 2 deals with construction details and tests, both of which contribute to safety. It is intended to assist the machine manufacturer to design and build them with features which will reduce hazards and also to assist the user and the manufacturer of the driven or driving equipment in the seleciton of machines that have been designed and built to have features that contribute to safety.

The machine manufacturer has little, if any, control over the selection, installation, and use of these machines. Since the reduction of hazards depends greatly on how machines are selected, installed, and used, Section 3 of this publication has been prepared as a guide to assist the user and the manufacturer of the driven or driving equipment in the proper selection, installation, and use of machines. It points out possible hazards and suggests ways and means to reduce them. If the guidelines given in Section 3 are followed, the possible hazards and risks of using machines will be reduced.

MG 2-1989 completely revises and supersedes MG 2-1983.

This publication is periodically reviewed by the Motor and Generator Section of NEMA for any revisions necessary to keep it up to date with advancing technology. Proposed or recommended revisions should be submitted to:

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Scope

This publication defines construction requirements of electric machines intended for use in circuits of 50 volts and higher and provides recommendations for their selection, installation, and use in such a manner as to provide for the practical safeguarding of persons and property.

Excluded from the scope of this publication are the following:

1. Welding generators.
2. Booster, dynamic braking, and absorption-type machines.
3. Isolated electric farm lighting plants.
4. Variable-speed generator equipment for railway passenger cars.
5. Main propulsion motors, generators, and motor-generator sets mounted on railroad and transit locomotives and cars.
6. Automotive motors, generators, and motor-generator sets.
7. Motors, generators, exciters, and motor-generator or exciter sets mounted on airborne craft.
8. Toy motors and small synchronous motors of the type generally used in household clocks and timing devices.
9. Additional specific features required in machines for use in hazardous (classified) location. Such locations might be in mines or in areas defined in the *National Electrical Code* (ANSI/NFPA 70-1990), Chapter 5.
10. Machines built to military specifications having requirements which conflict with or override the provisions of this publication.
11. Machine parts intended for installation in a hermetically sealed enclosure.
12. Nonsalient-pole generators and their exciters.
13. Generators larger than 10,000kVA, and their exciters, for hydraulic turbine drive, including reversible motor-generator units.
14. Synchronous condensers, frequency changers, and phase converters.

Since any machine can be installed or operated in such a manner that hazards can ocur, compliance with this publication does not by itself assure a safe installation. However, when a machine complying with this publication is properly selected with respect to the driven load and environment, and is installed in accordance with the applicable provisions of national codes and sound local practices, the hazards to persons and property will be reduced.

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SAFETY STANDARD FOR CONSTRUCTION AND GUIDE FOR SELECTION, INSTALLATION, AND USE OF ELECTRIC MACHINES

Section 1
REFERENCED STANDARDS AND DEFINITIONS

In this publication, reference is made to the following standards and other publications listed below. Copies are available from the indicated sources.

American National Standards Institute (ANSI)
1430 Broadway
New York, NY 10018

ANSI/ASME B15.1-1984 — *Safety Standard for Mechanical Power Transmission Apparatus*

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

ASTM D635-81 — *Test for Flammability of Self-Supporting Plastics*

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

NEMA MG 1-1987 — *Motors and Generators*

National Fire Protection Association (NFPA)
Batterymarch Park
Quincy, MA 02269

ANSI/NFPA 70-1990 — *National Electrial Code*

Underwriters Laboratories, Inc. (UL)
333 Pfingsten Road
Northbrook, Il 60062

ANSI/UL 674-1984 — *Electric Motors and Generators for Use in Hazardous Locations, Class I Groups C and D, Class II Groups E, F and G*

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1.1 ENCLOSURES

Ventilation and other design considerations of machines frequently require openings in the exterior enclosures in the vicinity of uninsulated live metal parts, space heaters, or moving mechanical parts of the machine. Machine enclosures in general use are defined in 1.1.1 and 1.1.2.

NEMA Standard 11-16-1989.

1.1.1 Open Machine

An open machine is one having ventilating openings which permit passage of external cooling air over and around the windings of the machine. The term open machine, when applied to large apparatus without qualification, designates a machine having no restriction to ventilation other than that necessitated by mechanical construction.

NEMA Standard 11-3-1983.

1.1.1.1 DRIPPROOF MACHINE

A dripproof machine is an open machine in which the ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle from 0 to 15 degrees, downward from the vertical.

NEMA Standard 11-3-1983.

1.1.1.2 SEMIGUARDED MACHINE

A semiguarded machine is an open machine in which part of the ventilating openings in the machine, usually in the top half, are guarded as in the case of a guarded machine but the others are left open.

NEMA Standard 11-3-1983.

1.1.1.3 GUARDED MACHINE

A guarded machine is an open machine in which all openings giving direct access to live metal or rotating parts (except smooth rotating surfaces) are limited in size by the structural parts or by screens, baffles, grilles, expanded metal, or other means to prevent accidental contact with hazardous parts. Openings giving direct access to such live or rotating parts shall not permit the passage of a cylindrical rod 0.75 inch in diameter.

The opening in the machine enclosure must be such that: (1) a probe, as illustrated in Figure 1-1, when inserted through the openings, shall not touch an uninsulated live metal part or a hazardous rotating part, and (2) a probe, as illustrated in Figure 1-2, when inserted through the openings, shall not touch film-coated wire.

NEMA Standard 11-16-1972.

NOTE: Certain machine applications may require openings smaller than those specified for a guarded machine.

Authorized Engineering Information 11-16-1989.

1.1.1.4 DRIPPROOF GUARDED MACHINE

A dripproof guarded machine is a drip resistant machine whose ventilating openings are guarded in accordance with 1.1.1.3.

NEMA Standard 11-3-1983.

1.1.1.5 WEATHER-PROTECTED MACHINE, TYPE I

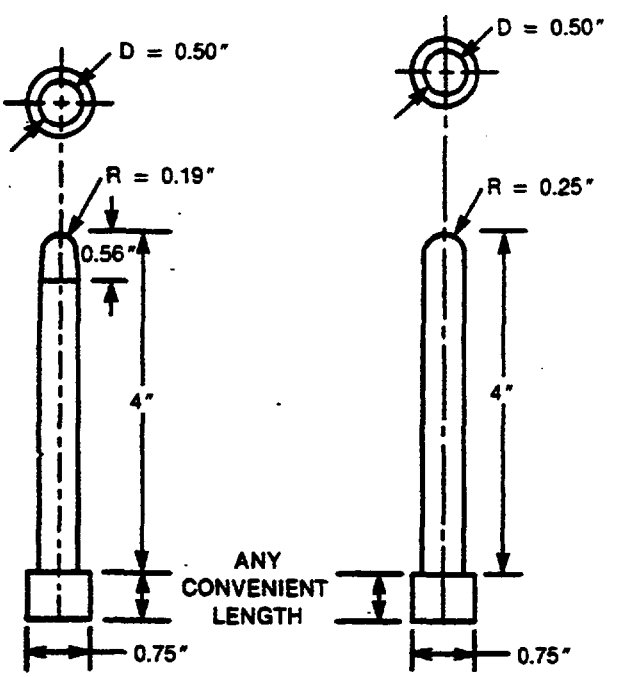
A weather-protected Type I machine is an open machine with its ventilating passages so constructed as to minimize the entrance of rain, snow, and airborne particles to the electric parts and having its ventilated openings so constructed as to prevent the passage of a cylindrical rod 0.75 inch in diameter.

NEMA Standard 11-3-1983.

1.1.1.6 WEATHER-PROTECTED MACHINE, TYPE II

A weather-protected Type II machine shall have, in addition to the enclosure defined for a weather-protected Type I machine, its ventilating passages at both intake and discharge so arranged that high-velocity air and airborne particles blown into the machine by storms or high winds can be discharged without entering the internal ventilating passages leading directly to the electric parts of the machine itself. The normal path of the ventilating air which enters the electric parts of the machine shall be so arranged by baffling or separate housings as to provide at least three abrupt changes in direction, none of which shall be less than 90 degrees. In addition, an area of low velocity not exceeding 600 feet per minute shall be provided in the intake air path to minimize the possibility of moisture or dirt being carried into the electric parts of the machine.

NEMA Standard 11-3-1983.



PROBE
Figure 1-1

PROBE
Figure 1-2

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1.1.2 Totally Enclosed Machine

A totally-enclosed machine is one so enclosed as to prevent the free exchange of air between the inside and the outside of the case but not sufficiently enclosed to be termed airtight.

NEMA Standard 11-3-1983.

1.1.2.1 TOTALLY ENCLOSED NONVENTILATED MACHINE

A totally-enclosed nonventilated machine is a totally-enclosed machine which is not equipped for cooling by means external to the enclosing parts.

NEMA Standard 11-3-1983.

1.1.2.2 TOTALLY ENCLOSED FAN-COOLED MACHINE

A totally enclosed fan-cooled machine is a totally enclosed machine equipped for exterior cooling by means of a fan or fans integral to the machine but external to the enclosing parts.

NEMA Standard 11-3-1983.

1.1.2.3 TOTALLY ENCLOSED FAN-COOLED GUARDED MACHINE

A totally enclosed fan-cooled guarded machine is a totally enclosed fan-cooled machine in which all openings giving direct access to the fan are limited in size by the structural parts or by screens, grilles, expanded metal, and so forth, to prevent accidental contact with the fan. Such openings shall be guarded as in the case of guarded machines (see 1.1.1.3).

NEMA Standard 11-3-1983.

1.1.2.4 TOTALLY ENCLOSED WATER-AIR-COOLED MACHINE

A totally enclosed water-air-cooled machine is a totally enclosed machine which is cooled by circulating air which, in turn, is cooled by circulating water. It is provided with a water-cooled heat exchanger for cooling the internal air and a fan or fans, integral to the rotor shaft or separate, for circulating the internal air.

NEMA Standard 11-3-1983.

1.1.2.5 TOTALLY ENCLOSED PIPE-VENTILATED MACHINE

A totally enclosed pipe-ventilated machine is a machine with openings so arranged that when inlet and outlet ducts or pipes are connected to them there is no free exchange of the internal air and the air outside the case. Totally enclosed pipe-ventilated machines may be self-ventilated (air circulated by means integral to the machine) or forced-ventilated (air circulated by means external to and not a part of the machine).

NEMA Standard 11-3-1983.

1.1.2.6 TOTALLY ENCLOSED AIR-OVER MACHINE

A totally enclosed air-over machine is a totally enclosed machine intended for exterior cooling by a ventilating means external to the machine.

NEMA Standard 11-3-1983.

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Section 2
CONSTRUCTION AND TESTS

2.1 GENERAL

The provisions of the definitions in 1.1.1 and 1.1.2 for machine enclosures may be obtained by the construction of the machine housing or by the use of a supplemental enclosure, shield, or structure, provided such item is securely held in place; or by a combination of two or more such items when the machine is assembled to the driven or driving device.

Authorized Engineering Information 11-16-1989.

Tests for compliance with the definitions for guarded machine given in 1.1.1.3 and 1.1.2.3 shall be made from the exterior of the supplemental enclosure.

A machine enclosure, including that of parts mounted on a machine, shall be so constructed that it will have the strength and rigidity necessary to resist the normal service to which it may be subjected without reduction or spacings or displacement of parts.

Enclosures of nonmetallic material shall be resistant to adverse effects from exposure to moisture, oil, and temperature under normal conditions of use and shall be flame retardant.

In the case of capacitors mounted on or in the machine, the capacitor, or its supplementary enclosure, shall prevent the emission of flying fragments, flame, or molten material resulting from failure of the capacitor.

Totally enclosed water-air-cooled machines shall have interior baffles, or other means, to prevent cooler-tube leakage and condensation from contacting the machine winding. The interior of the machine base shall be constructed so that cooler leakage will collect and drain from the machine before reaching the level of the windings.

For the selection and use of machine enclosures, see Section 3.

NEMA Standard 11-16-1989.

2.2 CORROSION PROTECTION

Iron and steel parts,* except bearings, laminations, and minor parts of iron and steel, such as washers, screws, and similar parts, shall be suitably protected against corrosion by enamelling, galvanizing, plating, or by other equivalent means, if the failure of such unprotected parts would be likely to result in a hazardous condition.

NEMA Standard 11-16-1972.

*In certain instances where the oxidation of iron or steel caused by the exposure of the metal to air and moisture is not likely to be appreciable (thickness of metal and temperature also being factors), the surfaces of sheet steel and cast-iron parts within an enclosure need not be protected against corrosion.

Authorized Engineering Information 11-16-1972.

2.3 LIFTING MEANS

Machines may include provisions for lifting the machine by means of eyebolts, lifting rings, integrally cast bosses, and so forth. When lifting means are provided, they shall be designed to lift the machine at any angle from the designed lifting direction between 0 degrees and 30 degrees for machines with single lifting points, or between 0 degrees and 45 degrees for machines with multiple lifting points (see Figure 3-1 and 3-2) with a safety factor of at least 5 (based on the ultimate strength and the use of all intended lifting points). This is to allow for overloads due to acceleration, deceleration, or shock forces encountered in handling. Any means provided for lifting only a sub-assembly of the machine shall be so identified.

The lifting means shall be designed so that when the machine is lifted in the intended manner the suspended mass is stable, i.e., normal handling forces will not cause a permanent shift or rotation of the load.

NOTE: See 3.16.7.

NEMA Standard 11-16-1989.

2.4 WIRING CONNECTIONS

Means shall be provided to electrically connect the machine to its source of power or to its load.

NEMA Standard 9-7-1977.

Connecting means may be rigidly mounted wiring terminals, wiring leads, or cord assemblies.

Authorized Engineering Information 11-16-72.

2.4.1 Rigidly Mounted Wiring Terminals

A rigidly mounted wiring terminal may be one of the following types:

1. A soldering lug or pressure wire connector, securely fastened in place.
2. A wire-binding screw if provisions are made to hold the wire in position. These screws, if used, shall be threaded in metal and shall have not less than two full threads of engagement. Metal thickness for these threads may be provided by extruding the metal.
3. Threaded terminal studs to which lead assemblies are secured by a nut, and, for user wiring terminals, a cupped washer or equivalent.
4. Plugs, receptacles, jacks, sockets, or other recognized connectors for power cable.
5. Blades or pins for individual conductor connection used only for factory-wired assemblies, not for user wiring terminals.
6. Bus bars.

Authorized Engineering Information 9-7-1977.

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A wire-binding screw or stud and nut intended for connection in the field of a No. 10 AWG or smaller conductor, shall be not smaller than No. 10, except that a No. 8 may be used at a terminal intended only for the connection of a No. 14 AWG conductor. (Suggested Standard for Future Design 11-3-83.)

Wiring terminals shall be securely fastened to prevent rotation.

The wires of stranded leads for connections to wiring terminals shall be confined in pressure connectors, eyelets, soldering lugs, soldered, or welded in place, or otherwise retained to prevent grounding or short-circuiting by stray strands.

If terminal screws, nuts, or studs are of ferrous metal, they shall be plated to prevent corrosion.

If factory-wired terminals (see Table 2-6, Note "g") are to be reconnected in service to change voltage or speed or to reverse rotation, the reconnection means shall be rigid links or flexible leads with factory-assembled terminals. The minimum spacing for factory-wired terminals shall be maintained for each connection.

2.4.2 Wiring Leads

Wiring leads are flexible machine conductors supplied for connecting the machine windings to the line, for changing winding connections and for making connections to auxiliary devices except those supplied for thermocouple, resistance temperature detectors or thermistors. Leads shall be of suitable ampacity. A wiring lead intended for connection in the field shall not be smaller than 18 AWG.

Lead insulation shall be capable of withstanding the high-potential test voltage applied to the electric circuit involved. Provision shall be made to prevent the leads from (1) coming into contact with the internal rotating parts, (2) interfering with the operation of internal devices, and (3) being abraded.

Terminal lugs, when supplied with the wiring leads, shall be selected to conform with the provisions of the *National Electrical Code*, Section 110-14.

2.4.3 Wiring Cords and Plugs

When a machine is provided with a flexible cord or with a flexible cord having an attachment-plug cap for connection to the supply circuit, the flexible cord shall be of a type suitable for the particular application. It shall be suitable for use at a voltage not less than the rated voltage of the machine and shall have an ampacity, as given in the *National Electrical Code* Section 400-5, not less than the current rating of the machine. Such cords shall be provided with a grounding conductor unless grounding is not required, and the attachment-plug cap, when supplied, shall be of a type suitable for the rated voltage of the machine and shall have a current-carrying capacity not less than 125 percent of the rated current of the machine.

If the machine has provision for use on different values of voltage by field alternation of internal connections, the attachment-plug cap provided with the machine shall be suitable for the voltage for which the machine is connected when shipped from the factory.

If a machine is provided with a flexible cord as the means for line connection, strain relief shall be provided to prevent transmission of cord pull to the winding connection or to other internal electrical connections. Wiring cords shall be capable of withstanding the high-potential test voltage applied to the machine. Provisions shall be made to prevent the cord from coming into contact with the internal rotating parts and from interfering with the operation of internal devices.

At any point where a flexible cord passes through an opening in a wall, barrier or enclosing case, there shall be a suitable bushing, or the equivalent, which is substantial and has a smooth, well-rounded surface against which the cord may bear. The bushing shall be reliably secured in place.

NEMA Standard 11-16-1989.

2.5 TERMINAL HOUSINGS

2.5.1 Construction

Terminal housings of machines are the enclosures surrounding the winding terminals of leads of the machine in which connections to the incoming or outgoing power supply leads are made.

They may be separate enclosures mounted on the outside of the machine or they may be partially or completely a part of the machine enclosure. The degree of enclosure of the terminal housing shall be consistent with the basic enclosure of the machine; however, the minimum enclosure shall be dripproof guarded except:

1. For openings for conduit connections.
2. When the intended mounting arrangements for large machines having the power leads located at the bottom of the frame limits accessibility to the terminal connections, the terminal housing may be open at the bottom.

Terminal housings, when supplied, shall be of substantial construction. For machines more than 7 inches in diameter,= the terminal housings shall be capable of withstanding without failure a vertical loading of 240 pounds on the horizontal surfaces when the machine is mounted in any intended position. For conduit boxes having a horizontal surface of less than 12 square inches the load shall be calculated on the basis of 20 pounds per square inch of horizontal surface. This load shall be applied through a 2-inch diameter flat metal surface. Bending or deforming of the housing shall not be considered a failure unless it results in spacing between the housing and any rigidly mounted line terminals less than indicated in Tables 2-5 and 2-7.

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In other than hazardous classified locations, substantial non-metallic, nonburning== terminal housings may be used on motors and generators larger than 34 inches in diameter, shall be permitted on machines, provided internal grounding means between the machine frame and the conduit connection is incorporated with the housing.

NEMA Standard 11-16-1989.

= This is a diameter measured in the plane of the laminations of the circle circumscribing the stator frame, excluding lugs, fins, boxes, etc., used solely for motor cooling, mounting assembly or connection.

== See American Society for Testing and Materials' *Test for Flammability of Self-Supporting Plastics*, ASTM D635-81, more than 0.050 inch (0.127 centimeter) in thickness, for the non-burning test.

2.5.2 Threaded Conduit Openings

Those conduit openings intended to receive threaded conduit shall be capable of withstanding (a) bending moment in any direction and (b) torque in the direction of tightening, applied to a short length of pipe, in accordance with the following values:

Conduit Size, Inches	Pound Inches
½	300
¾	500
1	700
1 ¼	1,000
1 ½	1,200
2 and larger	1,600

NEMA Standard 11-3-1983.

2.5.3 Terminal Housing Temperature

The temperature within the terminal housing, and on the supply conductors, shall not exceed the values in Table 2-1, except that higher temperatures not exceeding 110°C are permitted if the machine is marked as follows:

"CAUTION: USE SUPPLY CONDUCTORS SUITABLE FOR ____°C" or equivalent wording.

The value of temperature to be marked shall be 90°C or 110°C for terminal housing temperature ranges of 76-90°C or 91-110°C, respectively. The marking shall appear on the nameplate, in the terminal housing or near the point where the supply connections will be made.

NEMA Standard 11-3-1983.

The maximum temperatures are based on an ambient temperature of 30°C. Temperature tests shall be conducted at any room temperature between 10°C and 40°C and the variation below or above 30°C shall be respectively added to or subtracted from the observed temperatures.

NEMA Standard 11-3-1983.

The temperature test shall be conducted under the following conditions:

1. The supply conductor ampacity shall be 125 percent of the motor full load current rating, or 100 percent of the generator rated current;
2. The supply conductors shall be of copper and their ampacity shall be based on a 75°C insulation rating;
3. The conductors shall extend not less than 4 feet from the terminal box;
4. The conductors shall be in conduit; and
5. All unused terminal box openings shall be closed.

NEMA Standard 11-16-1989.

Table 2-1
MAXIMUM ALLOWABLE TERMINAL BOX TEMPERATURE
(Based on an ambient temperature of 30°C)

Machine Enclosure	Temperature, Degrees C Class of Insulation System			
	A	B	F	H
All enclosures except totally enclosed non-ventilated:	75	75	90	110
Totally enclosed non-ventilated:	75	90	110	110

2.5.4 Dimensions and Space, Motors with Rigidly Mounted Terminals

When these terminal housings enclose rigidly mounted motor terminals, the terminal housing shall be of sufficient size to provide minimum usable volumes in accordance with the following:

Usable Volumes	
Power Supply, Conductor Size, AWG	Minimum Usable Volume per Power Supply Conductor, Cubic Inches
14	1.0
12 and 10	1.25
8 and 6	2.25

For larger wire sizes or when motors are installed as a part of factory-wired equipment, without additional connection being required at the motor terminal housing during equipment installation, the terminal housing shall be of ample size to make connections, but the foregoing provisions for the volumes of terminal housings need not apply.

NEMA Standard 11-3-1983.

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2.5.5 Dimensions and Space, Wire-to-Wire Connections

When these terminal housings enclose wire-to-wire connections, they shall have minimum dimensions and usable volumes in accordance with Tables 2-2 and 2-3. Auxiliary leads for such items as brakes, thermostats, space heaters, exciting fields, and so forth, may be disregarded if their current-carrying area does not exceed 25 percent of the current-carrying area of the machine power leads.

NEMA Standard 11-3-1983.

2.5.6 Accessory Leads

1. For machines rated 601 volts and higher, accessory leads shall terminate in a terminal box or boxes separate from the machine's terminal housing. As an exception, current and potential transformers located in the machine terminal housing shall be permitted to have their secondary connections terminated in the machine terminal housing if separated from the machine leads by a suitable physical barrier to prevent accidental contact.
2. For machines rated 601 volts and higher, the termination of leads of accessory items normally operating at a voltage of 50 volts (rms) or less shall be separated from other leads by a suitable physical barrier to prevent accidental contact or terminated in a separate box.

NEMA Standard 11-16-1989.

2.6 BONDING AND GROUNDING

2.6.1 Bonding

When a machine is required to be grounded, all exposed noncurrent-carrying metal parts which are likely to become energized under abnormal conditions shall make metal-to-metal contact or otherwise be electrically connected or bonded together to provide a common ground connection.

NEMA Standard 9-7-1977.

2.6.2 Grounding Means for Field Wiring

When machines are provided with terminal housings for wire-to-wire connections or fixed terminal connections, a means for attachment of an equipment grounding conductor termination shall be provided inside, or adjacent with accessibility from, the terminal housing. Unless its intended use is obvious, it shall be suitably identified. The termination shall be suitable for the attachment and equivalent fault current ampacity of a copper grounding conductor as shown in Table 2-4.

A screw, stud, or bolt intended for the termination of a grounding conductor shall be not smaller than shown in Table 2-4. For motor full load currents in excess of 30 amperes ac or 45 amperes dc, external tooth lockwashers, serrated screw heads, or the equivalent shall not be furnished for a screw, bolt, or stud intended as a grounding conductor termination.

When a machine is provided with a grounding terminal, this terminal shall be of the solderless type, and shall be on a part of the machine not normally disassembled during operation or servicing.

When a terminal housing mounting screw, stud, or bolt is used to secure the grounding conductor to the main terminal housing there shall be at least one other equivalent securing means for attachment of the terminal housing to the machine frame.

Suggested Standard for Future Design 11-16-1989.

2.7 INTERNAL ELECTRICAL CIRCUITS

2.7.1 Current-carrying Parts

Current-carrying parts shall be of silver, copper, a copper alloy, aluminum, plated iron or steel, or other material suitable for the particular application and shall be properly connected and mechanically secured.

NEMA Standard 11-16-1972.

2.7.2 Internal Wiring

Internal wiring shall be of a type suitable for the temperature, voltage, environment, and other conditions of service for which the machine is designed. All splices and connections shall be mechanically secure and shall provide adequate and reliable electrical contact.

NEMA Standard 11-16-1972.

2.8 INSULATING SUPPORTS AND BARRIERS

Insulating materials used to support or separate live parts shall have thermal, mechanical, and electrical properties suitable for the service for which the machine is designed.

NEMA Standard 11-16-1972.

2.9 INTERNAL AND TERMINAL SPACINGS INVOLVING LIVE AND GROUNDED PARTS

The spacing through air and over surfaces for machines shall be not less than those indicated in Tables 2-5, 2-6, or 2-7. The voltage rating of the machine circuit for the winding or other live part under consideration shall be used in applying the tables except as modified by Notes 6 and 7. In those cases where windings, or components, or both, are in two different electric circuits,* the higher of the two rated circuit voltages shall be used in applying the table to spacings between live parts of the two circuits. Linings or barriers of insulating materials may be used where spacings are less than the values specified in the tables, provided that such linings or barriers are securely fastened in place and are capable of withstanding the high-potential test.

Where windings are varnish-treated as an assembly, butt and lap joint s in the insulation are considered to be continuous insulation.

For windings with supplemental insulation on the coil or conductor, such as taping, encapsulation, and so forth, the spacings may be less than those given in the tables pro-

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vided the machine is capable of withstanding the high-potential test.

The spacings in the tables do not apply to components or to electronic assemblies used in control circuits.

NEMA Standard 11-16-1989.

*An electric circuit consists of all windings and other live parts of a machine which are conductively connected to the same power supply or load bus when starting or running. Fields of direct-current machines shall be considered to be separate circuits unless they are permanently connected in the machine. Interconnected polyphase windings are considered as one circuit.

Table 2-2
MACHINES 11 INCHES IN DIAMETER* OR LESS

Hp	Cover Opening, Minimum Dimensions, Inches	Usable Volume, Minimum, Cubic Inches
1 and smaller (1)	1.62	7.50
1½, 1, and 3 (2)	1.75	12.00
5 and 7½	2.00	16.00
10 and 15	250	26.00

*This is a diameter measured in the plane of the laminations of the circle circumscribing the stator frame, excluding lugs, fins, boxes, and such, used solely for motor cooling, mounting, assembly or connections.

NOTE 1—For motors rated 1 horsepower and smaller and with the terminal housing partially or wholly integral with the frame or endshield, the volume of the terminal housing shall be not less than 0.8 cubic inch per wire-to-wire connection. The minimum cover opening dimension is not specified.

NOTE 2—For motors rated 1½, 2, and 3 horsepower and with the terminal housing partially or wholly integral with the frame or endshield, the volume of the terminal housing shall be not less than 1.0 cubic inch per wire-to-wire connection. The minimum cover opening dimension is not specified.

Table 2-3
MACHINES MORE THAN 11 INCHES IN DIAMETER*

Induction Motors—600 Volts and Less

Maximum Full-load Current for Motors with Maximum of Twelve Leads Amperes	Terminal Housing		Typical Maximum Horsepower Three Phase	
	Minimum Dimension, Inches	Minimum Usable Volume, Cubic Inches	230 Volt	460 Volt
45	2.5	26	15	30
70	3.3	55	25	50
110	4.0	100	40	75
160	5.0	180	60	125
250	6.0	330	100	200
400	7.0	600	150	300
600	8.0	1100	250	500
900	8.0	2000	...	700
1200	10.0	3200	...	1000

Induction Motors—2300 Volts and Above

Voltage	Maximum Full-load Current	Terminal Housing†		Minimum Centerline Distance,‡ Inches	Typical Maximum Horsepower
		Minimum Dimension,Inches	Minimum Usable Volume, Cubic Inches		
2300	160	5	180	...	600
	250	6	330	...	1000
	400	7	600	...	1750
	600	8	1100	...	2500
	900	8	2000	...	4000
4000	160	8	2000	12.5	1000
	700	14	5600	16	5000
	1000	16	8000	20	7000
6600	260	14	5600	16	3000
	680	16	8000	20	8000

*This is a diameter measured in the plane of the laminations of the circle circumscribing the stator frame, excluding lugs, fins, boxes, and such, used solely for motor cooling, mounting, assembly or connections.

‡Minimum distance from the entrance plate for conduit entrance to the centerline of machine leads.

†Terminal housings containing surge capacitors, surge arrestors, current transformers, or potential transformers require individual consideration.

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Table 2-3 (continued)
MACHINES MORE THAN 11 INCHES IN DIAMETER*

Synchronous Motors						
Voltage	Maximum Full-load Current	Terminal Housing†		Minimum Centerline Distance,** Inches	Typical Maximum Horsepower	
		Minimum Dimension, Inches	Minimum Usable Volume, Cubic Inches		1.0 Power Factor	0.8 Power Factor
460	400	7	600	...	400	300
	600	8	1100	...	600	500
	900	8	2000	...	900	700
	1200	10	3200	...	1250	1000
2300	160	5	180	...	800	600
	250	6	330	...	1250	1000
	400	7	600	...	2000	1750
	600	8	1100	...	3000	2500
	900	8	2000	...	4500	4000
4000	160	8	2000	12.5	1250	1000
	700	14	5600	16	6000	5000
	1000	16	8000	20	8000	7000
6600	260	14	5600	16	3500	3000
	680	16	8000	20	10000	8000

Synchronous Generators				
Voltage	kVA	Minimum Dimension, Inches	Minimum Usable Volume, Cubic Inches	Minimum Centerline Distance,‡ Inches
480	201–312, incl.	7	600	...
	313–500, incl.	8	1100	...
	501–750, incl.	8	2000	...
	751–1000, incl.	10	3200	...
2400	251–625, incl.	5	180	...
	626–1000, incl.	6	330	...
	1001–1563, incl.	7	600	...
	1564–2500, incl.	8	1100	...
	2501–3750, incl.	8	2000	...
4160	351–1250, incl.	8	2000	12.5
	1251–5000, incl.	14	5600	16
	5001–7500, incl.	16	8000	20
6900	876–3125, incl.	14	5600	16
	3126–8750, incl.	16	8000	20

*This is a diameter measured in the plane of the laminations of the circle circumscribing the stator frame, excluding lugs, fins, boxes, etc., used solely for motor cooling, mounting, assembly or connections.
‡Minimum distance from the entrance plate for conduit entrance to the centerline of machine leads.
†Terminal housings containing surge capacitors, surge arresters, current transformers, or potential transformers require individual consideration.

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Table 2-3 (continued)
MACHINES MORE THAN 11 INCHES IN DIAMETER*

Direct-Current Machines		
Maximum Full-Load Current for Machines with Maximum of Six Leads	Terminal Housing†	
	Minimum Dimensions, Inches	Minimum Usable Volume, Cubic Inches
68	2.5	26
105	3.3	55
165	4.0	100
240	5.0	180
375	6.0	330
600	7.0	600
900	8.0	1100

*This is a diameter measured in the plane of the laminations of the circle circumscribing the stator frame, excluding lugs, fins, boxes, and such, used solely for motor cooling, mounting, assembly or connections.
†Terminal housings containing surge capacitors, surge arresters, current transformers, or potential transformers require individual consideration.

Table 2-4
MINIMUM SIZE GROUNDING CONDUCTOR TERMINATION

Motor Full Load Current ≤		Minimum Size of Grounding Conductor Termination Attachment Means, AWG	Minimum Size of Screw, Stud, or Bolt	
AC	DC		Steel	Bronze
12	12	14	#6	...
16	16	12	#8	...
30	40	10	#10	...
45	68	8	#12	#10
70	105	6	5/16"	#12
110	165	4	5/16"	5/16"
160	240	3	3/8"	5/16"
250	375	1	1/2"	3/8"
400	600	2/0	...	1/2"
600	900	3/0	...	1/2"

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2.10 HIGH POTENTIAL TESTING

The high potential test voltage specified in Table 2-8 shall be applied to the windings of each new machine in accordance with the test procedures specified in NEMA Standards Publication MG 1, *Motors and Generators.*

NEMA Standard 11-16-1989.

WARNING—Because of the high voltages used, high potential tests should be conducted only by trained personnel and the following minimum safety precautions stated in 2.10.1 through 2.10.4 should be taken to avoid injury to personnel and damage to property.

Authorized Engineering Information 9-7-1977.

2.10.1 Grounding

To minimize the safety hazards, as a general rule the frame or core and all external metal parts of the machine being tested should be grounded with all windings and components not under test connected together and to the frame or core. If the machine under test is to be ungrounded, proper precautions (which may include the selection of test equipment) should be taken to render the test and the area safe for personnel.

Authorized Engineering Information 9-7-1977.

2.10.2 Accessories and Components

All accessories such as surge capacitors, lightning arresters, current transformers, and so forth, which have leads connected to the rotating machine terminals shall be disconnected during the test, with the leads connected together and to the frame or core. These accessories shall have been subjected to the high-potential test applicable to the class of apparatus at their point of manufacture. Capacitors of capacitor-type motors must be left connected to the winding in the normal manner for machine operation (running or starting).

Component devices and their circuits such as space heaters and temperature sensing devices in contact with the winding (thermostats, thermocouples, thermistors, resistance temperature detectors, and so forth) connected other than in the line circuit, shall be connected to the frame or core during machine winding high-potential tests. Each of these component device circuits, with leads connected together, shall then be tested by applying a voltage between the circuit and the frame or core, equal to twice the circuit rated voltage plus 1000 volts, or equal to the high-potential test voltage of the machine, whichever is lower. During each device circuit test all other machine windings and components shall be connected together and to the frame or core. Unless otherwise stated, the rated voltage of temperature sensing devices shall be taken as follows:

Thermostats—600 volts

Thermocouples, thermistors, RTD's—50 volts.

When conducting a high-potential test on an assembled brushless exciter and synchronous machine field winding, the brushless circuit components (diodes, thyristors, and so forth) shall be short circuited (not grounded) during the test.

NEMA Standard 11-16-1989.

Table 2-5
MINIMUM SPACING AT FIELD-WIRING TERMINALS* —600 VOLTS AND LESS

Potential Involved in Volts	Minimum Spacings in Inches Through Air or Over Surface†
50 to 250, incl.	1/4
251 to 600, incl.	3/8

*Field wiring terminals of machines are those to which supply line connections are made, at the point of use, by or on behalf of the user. The user is the ultimate consumer or user of the machine and its driven or driving equipment or of the equipment on which the machine is employed.

†Applies to the sum of the spacings involved where an isolated dead metal part is interposed. See Note 4.

NOTE 1—The spacing between field-wiring terminals of opposite polarity, and a spacing between a field-wiring terminal and any other uninsulated metal part (dead or live) not always of the same polarity, shall be not less than that indicated.

NOTE 2—If an uninsulated live part is not rigidly fixed in position by means other than friction between surfaces or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that the minimum acceptable spacing will be maintained.

NOTE 3—The spacings do not apply to the inherent spacings of a component of the machine, such as a snap switch; such spacings are judged on the basis of the requirements for the component in question. The spacings do apply between a component live part, such as on a snap switch, and adjacent metal parts. For a repulsion motor, a repulsion-induction motor, or a repulsion-start induction motor, the spacings do not apply to the commutator, the brush assembly, or the jumpers that short-circuit the brushes. Any uninsulated conductor of the rotor circuit is regarded as a dead metal part with respect to the stator circuit, and the appropriate spacing is required between uninsulated stator and rotor conductors.

NOTE 4—If an isolated dead metal part is interposed between or is in close proximity to (1) live parts of opposite polarity, (2) a live part and an exposed dead metal part, or (3) a live part and a dead metal part that may be grounded, the spacing may be not less than 3/64 inch between the isolated dead metal part and any one of the parts previously mentioned, if the total spacing between the isolated dead metal part and the two other parts is not less than the value indicated.

NOTE 5—The minimum spacings shall not be reduced by changes in the clearance and creepage spacings due to the assembly of terminal leads in various positions.

NOTE 6—The minimum spacings for the field winding of synchronous machines shall be based upon the higher of:

a. The voltage range corresponding to the rated excitation voltage, or

b. The next lower voltage range corresponding to the maximum rms voltage appearing across the poles (or groups of poles when segregated) during starting with rated voltage applied to the stator terminals.

NOTE 7—The minimum spacings for the secondary winding of wound-rotor motors shall be based upon the maximum voltage induced between collector rings on open circuit at standstill (or running if under this condition the induced voltage is greater) with rated primary voltage applied to the stator terminals.

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Table 2-6
MINIMUM SPACING AT OTHER THAN FIELD-WIRING TERMINALS—600 VOLTS AND LESS

Potential Involved in Volts	Parts Involved	Minimum Spacings in Inches			
		Diameter 7 Inches or Less[a]		Diameter More than 7 Inches[a]	
		Over Surface	Through Air	Over Surface	Through Air
50-125	Commutator or collector rings	1/16	1/16	3/16[b]	1/8[b]
	Elsewhere in the machine[g,h]	3/32[c]	3/32[c]	1/4[b,d]	1/8[b,d]
126-250	Commutator or collector rings	1/16	1/16	3/16[b]	3/16[b]
	Elsewhere in the machine[g,h]	3/32	3/32	1/4b,d	1/4[b,d]
251-600	Commutator or collector rings and live parts of the brush rigging	1/4	1/4[e]	3/8	1/4
	Elsewhere in the machine[g,h]	1/4[d,e]	1/4[d,e]	3/8[d,f]	3/8[d,f]

[a] This is the diameter, measured in the plane of the laminations, of the circle circumscribing the stator frame, excluding lugs, fins, boxes, and so forth, used solely for machine mounting, cooling, assembly, or connection.

[b] Spacing of not less than 3/32 inch are acceptable throughout a universal motor.

[c] For a motor rated 1/3 horsepower or less, these spacings may be not less than 1/16 inch.

[d] Enamel-insulated wire is considered to be an uninsulated live part. However, a spacing of not less than 3/32 inch (over surface and through air) between enamel-insulated wire, rigidly supported and held in place on a coil, and a dead metal part is acceptable.

[e] Through-air spacings involving a collector ring may be not less than 1/8 inch.

[f] Spacings not less than 1/4 inch are acceptable between live parts and dead metal parts (1) within a subassembly and (2) between parts in different subassemblies of the following types only:

1. a terminal board not intended for field wiring,
2. centrifugally-operated (1) starting, (2) auxiliary, and (3) interlock switches,
3. a starting relay, and
4. a capacitor.

This applies only to subassemblies mounted on or inside a machine.

[g] Elsewhere in the machine includes factory-wired terminals. Factory-wired terminals are terminals to which connections are made by the machine manufacturer or the equipment manufacturer, but not the user as defined in the single asterisked note in Table 1-5.

[h] A capacitor that employs an internal interrupter to prohibit expulsion of a flammable dielectric, in the event of rupture of its enclosure, shall have additional through-air spacing in the axial direction to allow movement of the terminals.

Such axial movement requires a total of 9/16 inch through-air spacing to a dead metal enclosure if the machine is intended for connection to a source of potential rated up to 300 volts, and 5/8 inch total if the machine is intended for connection to a source of potential rated 301-600 volts.

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Table 2-7
MINIMUM SPACINGS—VOLTAGES OVER 600 VOLTS

Rating Range, Volts	Minimum Spacing Between Bare Live Parts of Opposite Polarity and Between Bare Live Parts and Parts Which May Be Grounded When Machine Is in Operation			
	Clearance, Inches		Creepage Distance, Inches	
601-1000	3/8		3/4	
1001-2000	3/4		1 3/8	
2001-3000	1		2	
	Line to Line	Line to Ground	Line to Line	Line to Ground
3001-5000	3 1/4	2 1/2	4	3
5001-7500	4	3	5	3 1/2
7501-12500	5 1/4	4 3/8	7	5
12501-15000	6	5	8	5 3/4

Authorized Engineering Information 9-7-1977.2.10.3

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Table 2-8
HIGH POTENTIAL TEST VOLTAGES (See 1.10)

1. Motors	
A. Universal Motors (rated for operation on circuits not exceeding 250 volts)	
1. Motors rated 1/2 horsepower and larger and all motors for portable tools	1000 volts + 2 times the rated voltage of the motor.
2. All other motors*	1000 volts.
B. Induction and Nonexcited Synchronous Motors	
1. Motors rated 1/2 horsepower and larger	
a. Stator windings	1000 volts + 2 times the rated voltage of the motor.
b. For secondary windings of wound rotors of induction motors	1000 volts +2 times the maximum voltage induced between collector rings on open circuit at standstill (or running if under this condition the voltage is greater) with rated primary voltage applied to the stator terminals.
c. For secondary windings of wound rotors of reversing motors	1000 volts + 4 times the maximum voltage induced between collector rings on open circuit at standstill with rated primary voltage applied to the stator terminals.
2. Motors rated less than 1/2 horsepower	1000 volts.
a. Rated 250 volts or less	1000 volts +2 times the rated voltage of the motor.
b. Rated above 250 volts	
C. Direct-current Motors	
1. Motors rated 1/2 horsepower and larger	
a. Armature or field windings for use on adjustable-voltage electronic power supply	1000 volts +2 times the ac line-to-line voltage of the power supply selected for the basis of rating.
b. All other armature or field windings	1000 volts +2 times the rated voltage† of the motor.
2. Motors rated less than 1/2 horsepower	
a. 240 volts or less	1000 volts.
b. Rated above 240 volts	See 1.C.1.a. and 1.C.1.b above.
D. Synchronous Motors—except for nonexcited synchronous motors (see 1B)	
1. Armature windings	1000 volts + 2 times the rated voltage of the motor.
2. Field windings including brushless exciters	See NEMA Standard MG 1, Part 21.
2. Generators	
A. Generators rated 250 watts or more—except for field windings of synchronous generators (See2.C.)	1000 volts + 2 times the rated voltage† of the generator.
B. Generators rated less than 250 watts	
1. Rated 250 volts or less but above 35 volts	1000 volts.
2. Rated above 250 volts	1000 volts + 2 times the rated voltage† of the generator.
C. Field windings of synchronous generators (rated 250 watts or more) including brushless exciters	See NEMA Standard MG 1, Parts 16 & 22.

• Complete motors less than 1/2 horsepower shall be considered to be in the "all other" category unless marked to indicate that they are motors for portable tools.

†Where the voltage rating of a separately excited field of a direct-current machine is not stated, it shall be assumed to be 1.5 times the field resistance in ohms at 25°C times the rated field current.

NEMA Standard 11-3-1983.

NOTE 1—Certain applications may require high-potential test voltages higher than those specified.

NOTE 2—The normal production high-potential test voltage may be 1.2 times the specified 1-minute high-potential test voltage, applied for 1 second.

NOTE 3—A direct instead of an alternating voltage is sometimes used for high-potential tests on primary windings of machines rated 6000 volts or higher. In such cases, a test voltage equal to 1.7 times the specified alternating-current test voltage (effective value) is recommended.

NOTE 4—To avoid excessive stressing of the insulation, repeated application of the high-potential test voltage is not recommended. Immediately after manufacture, when equipment is installed or assembled with other apparatus and a high-potential test of the entire assembly is required, it is recommended that the test voltage not exceed 85 percent of the original test voltage or, when in an assembled group, not exceed 85 percent of the lowest test voltage of the group.

Authorized Engineering Information 9-7-1977.

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2.10.3 Discharging Windings After Test

As a result of the alternating voltage high-potential test, the tested winding may retain a significant charge. Unless it is known that the retained charge is insignificant, the tested winding should be discharged to ground before it is touched by personnel.

Following a direct-voltage high-potential test, the tested windings should be discharged to ground. The insulation rating of the winding and the test level of the voltage applied, determine the period of time required to dissipate the charge and, in many cases, the ground should be maintained for several hours to dissipate the charge to avoid hazard to personnel.

Authorized Engineering Information 11-16-1989.

2.10.4 Guarding

In the interest of safety, precautions shall be taken to prevent anyone from coming in contact with any part of the circuit or apparatus while high-potential tests are in progress.

NEMA Standard 11-16-1989.

2.11 THERMAL PROTECTION

Motors provided with a thermal protector conforming to the requirements of MG 1-1.71, Thermal Protector, (definition) shall be stamped *Thermally Protected** on the nameplate.

A *thermally protected* motor is a motor which is protected against dangerous overheating due to overload and failure to start.

* Motors rated 100 watts and less may be marked "TP."

2.12 IMPEDANCE PROTECTION

Motors supplied as impedance protected shall be stamped *Impedance Protected** on the nameplate.

An *Impedance Protected* motor is one in which the impedance of the motor windings is sufficient to prevent overheating due to failure to start.

* Motors rated 100 watts and less may be marked "ZP."

2.13 OVERSPEED

It may be hazardous to operate a machine for a significant length of time at higher than rated speed. However, machines shall be so constructed that, in an emergency not to exceed one minute, they will withstand without mechanical injury, overspeeds in accordance with the following specifications.

NEMA Standard 9-7-1977.

2.13.1 INDUCTION MOTORS

Synchronous Speeds, Rpm	Overspeed, Percent of Synchronous Speed	
	200 Hp and Smaller	Over 200 Hp
1801 and over	25	20
1201 to 1800	25	25
1200 and below	50	25

NEMA Standard 9-7-1977.

2.13.2 Direct-Current Motors

2.13.2.1 SHUNT-WOUND MOTORS

Direct-current shunt-wound motors shall withstand an overspeed of 25 percent above the highest rated speed or 15 percent above the corresponding no-load speed, whichever is greater.

NEMA Standard 9-7-1977.

2.13.2.2 COMPOUND-WOUND MOTORS HAVING SPEED REGULATION OF 35 PERCENT OR LESS

Compound-wound direct-current motors having a speed regulation of 35 percent or less shall withstand an overspeed of 25 percent above the highest rated speed or 15 percent above the corresponding no-load speed, whichever is greater, but not exceeding 50 percent above the highest rated speed.

NEMA Standard 9-7-1977.

2.13.2.3 SERIES-WOUND MOTORS AND COMPOUND-WOUND MOTORS HAVING SPEED *REGULATION GREATER* THAN 35 PERCENT

Since these motors require special consideration, depending upon the application for which they are intended, the manufacturer shall assign a maximum safe operating speed which shall be stamped on the nameplate. These motors shall withstand an overspeed of 10 percent above the maximum safe operating speed.

Small motors usually are capable of withstanding a speed of 10 percent above no-load speed. When this is the case, the safe operating speed marking is not required.

NEMA Standard 11-16-1989.

2.13.2.4 PERMANENT-MAGNET-EXCITED MOTORS

Permanent-magnet-excited motors shall withstand the overspeeds specified in 2.13.2.1, except that, if the motor also has a series winding, it shall withstand the overspeed specified in 2.13.2.2 or 2.13.2.3.

NEMA Standard 9-7-1977.

2.13.3 Alternating-Current Series and Universal Motors

Alternating-current series and universal motors shall be capable of withstanding a speed which is 10 percent above the no-load speed at rated voltage.

NEMA Standard 9-7-1977.

NOTE: For motors which are integrally attached to loads that cannot become accidentally disconnected, the words "no-load speed" shall be interpreted to mean the highest speed attainable with the integrally attached load.

NEMA Standard 9-7-1977.

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2.13.4 Salient-Pole Synchronous Motors

Salient-pole synchronous motors shall withstand overspeeds above rated synchronous speed as follows:

Synchronous Speed, Rpm	Overspeed, Percent of Synchronous Speed
1800-1500	20
1499 and below	25

NEMA Standard 9-7-1977.

2.13.5 Salient-Pole Synchronous Generators

Salient-pole synchronous generators shall withstand an overspeed of 25 percent above rated synchronous speed.

NEMA Standard 9-7-1977.

2.13.6 Direct-Current Generators

Direct-current generators shall withstand an overspeed of 25 percent above rated speed.

NEMA Standard 9-7-1977.

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Section 3
GUIDE FOR SELECTION, INSTALLATION, AND USE OF ELECTRIC MACHINES

3.1 GENERAL

The construction provisions set forth in Section 2 of this publication cannot by themselves assure safety in use of machines. There is as great a need for safeguards in the selection, installation, and use of machines as there is for safeguards in their design and manufacture. The following recommendations are generally applicable but there may be situations where conflict with other safety measures or operational requirements will necessitate that these recommendations be modified. Where the above-mentioned safeguards and past experience of the user are not sufficient to serve as a guide, the manufacturer of the driven or driving equipment or the machine manufacturer, or both, should be consulted to develop further information. This further information should be considered by the user, his consultants, or others most familiar with the details of the application involved when making the final decision.

The importance of communication between manufacturer and user cannot be over-emphasized. The chances for preventing hazardous incidents and limiting their consequences are greatly improved when both user and manufacturer are correctly and fully informed with respect to the intended use and all environmental and operating conditions. Since such intended use and environmental and operating conditions are under the sole control of the user, who has the most complete knowledge of the intended use and the environmental and operating conditions, the user should select and install machines which will optimize safety in use. This guide is intended only to assist him in such selection, installation, and use.

Authorized Engineering Information 11-16-1989.

3.2 SAFETY IN MACHINE APPLICATION

The applications for machines are so numerous that exceptions can be cited to almost every recommendation for safe application. Among the many factors that must be considered in machine application are:

1. Proper matching of the machine to the load.
2. Degree of enclosure.
3. Service conditions.
4. Use of back-up equipment where the application requires exceptional reliability for the protection of life and health, property or perishable products.

Where the application or performance information beyond that contained in this publication is needed, NEMA Publication MG 1 or the machine manufacturer, or both, should be consulted.

Authorized Engineering Information 11-16-1989.

3.3 MATCHING OF THE MACHINE TO THE LOAD

The application information required for the proper matching of a machine to the infinite variety of load requirements is beyond the scope of this publication. NEMA Publication MG 1 provides basic application information along with minimum performance characteristics for machines to assist the user in making the proper selection of the machine for the particular application.

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3.4 DEGREE OF ENCLOSURE

3.4.1 General

The required degree of enclosure of a machine, for personnel safety, is dependent upon the installation and application of the equipment. Therefore, the user or the manufacturer of the driven or driving equipment should consider the following questions when selecting the degree of enclosure for the machines:

1. Will the equipment be installed in:
   a. Residences?
   b. Places regularly open to the public?
   c. Places frequented only by persons employed on the premises?
   d. Places accessible only to qualified personnel?
2. Will the equipment be attended by an operator when it is in use?
3. Are the size, location, appearance, and working arrangement of the equipment such that they will discourage inappropriate use or approaches to the equipment?
4. Is it possible to encounter hazard in the installed machine if it is approached or serviced in a manner other than the manner for which it was designed? If so, are the hazards of such actions visibly obvious to the personnel operating, servicing, and generally having access to the machine?

The following recommendations for the selection of machine enclosures are given as a guide. If other than the recommended machine enclosures are to be applied, it is recommended that the installation be isolated and made inaccessible by fencing, by isolation in a room, by additional enclosures, or by other means, so that access to the isolated areas is limited only to qualified personnel. Qualified personnel are those who are familiar with the construction and operation of the equipment and with the hazards involved.

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3.4.2 Application in Residences and in Places Regularly Open to the Public

For those applications in residences and in places which are regularly open to the public and which cannot be isolated from the public, only the following machines should be used:

1. Guarded machines;1
2. Totally-enclosed nonventilated machines;
3. Totally-enclosed fan-cooled guarded machines;
4. Totally-enclosed water-air-cooled machines;
5. Totally-enclosed pipe-ventilated machines;
6. Weather-protected machines; and
7. Open machines when the enclosure of the equipment provides the equivalent of a guarded machine.

[1]Certain machine applications may require openings smaller than those mentioned for a guarded machine.

Authorized Engineering Information 11-16-1989.

3.4.3 Applications in Places Restricted to Persons Employed on the Premises

Many years of experience in industrial plants, light commercial installations, and other areas where access to the equipment is normally restricted to persons employed on the premises have established that the following machines have a successful and satisfactory safety record:

1. Dripproof machines;
2. Semi-guarded machines;
3. Totally-enclosed fan-cooled machines; and
4. Machines recommended above for use in places regularly open to the public.

Authorized Engineering Information 9-7-1977.

3.4.4 Application in Places Accessible Only to Qualified Personnel

Any of the machine enclosures mentioned in 2.4.3 may be used in these places. In addition, many years of experience in power plants and in other applications where machines are so located or installed that they are accessible only to qualified personnel have established that open machines have a successful and satisfactory safety record

Authorized Engineering Information 9-7-1977.

3.5 AC MOTORS FOR CLASS I, DIVISION 2, HAZARDOUS LOCATIONS

Open or nonexplosion-proof enclosed motors are allowed by the *National Electrical Code* as long as they do not have brushes, switching mechanisms, or other similar arc-producing devices. Accordingly, the user has two possibilities when selecting a motor for Class I, Division 2 applications.

The recommended approach for the user is to select an explosion-proof motor, which in accordance with Underwriters Laboratories Inc. requirements, shall not exceed the specified external surface temperature under any operating condition.

As an alternative, the user may select an open or nonexplosion-proof enclosed motor for submission to the local authority for approval. Since the enclosure is not explosion-proof, the user should consider the temperature of external and internal surfaces of the motor to which the surrounding atmosphere has access.

For open, ambient-air-breathing ac integral and large machines, the operating surface temperature of insulated windings will normally be associated with the insulation class. NEMA standards do not establish values of total temperature; only values of observable temperature rise are given. However, the following table can be used as a guide based on a 40°C ambient temperature and observable continuous temperature rises as specified in NEMA MG 1-12.42, MG 1-12.43, MG 1-20.40, and MG 1-21.40.

Insulation Class	Typical Total Winding Temperature	
	1.15 Service Factor	1.0 Service Factor
Class H	...	180°C
Class F	165°C	155°C
Class B	140°C	130°C
Class A	115°C	105°C

The rotor surface temperature of squirrel-cage induction motors cannot be accurately measured on production units. The rotor surface temperature varies greatly with enclosure type, cooling method, insulation class, and slip, but may be in the range of 150-225°C for Class B or Class F insulated normal slip motors when operating at rated load and in a 40°C ambient temperature.

The above insulated winding temperature and rotor surface temperature values are typical values based on continuous operation at rated voltage and rated frequency under usual service conditions. Margin for voltage and frequency variations, manufacturing variation, overload, or hot start and acceleration is not included. The motor manufacturer should be consulted for further information.

When motor-mounted space heaters are to be furnished, it is recommended that the exposed surface temperature be limited to 80 percent of the ignition temperature of the gas or vapor involved with rated space heater voltage applied and the motor deenergized.

The range of ignition temperatures is so great and variable that it is not practical for the motor manufacturer to determine if a given motor is suitable for a Division 2 area. The user's knowledge of the area classification, the application requirements, the insulation system class, and past experience are all factors which should be considered by the user, his consultant, or others most familiar with the details of the application involved when making the final decision.

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3.6 PROPER SELECTION OF APPARATUS

Machines should be properly selected with respect to their usual or unusual service conditions, both of which involve the environmental and operating conditions to which the machine is subjected. Machines conforming to the Scope and Section 1 of this publication are designed for operation in accordance with their ratings under usual service conditions. Some machines may also be capable of operating in accordance with their ratings under one or more unusual service conditions. Definite-purpose or special-purpose machines may be required for some unusual conditions.

Service conditions, other than those specified as usual, may involve some degree of hazard. The additional hazard depends upon the degree of departure from usual operating conditions and the severity of the environment to which the machine is exposed. The additional hazard results from such things as overheating, mechanical failure, abnormal deterioration of the insulation system, corrosion, fire, or explosion.

Although past experience of the user may often be the best guide, the manufacturer of the driven or driving equipment or the machine manufacturer, or both, should be consulted for further information regarding any unusual service conditions which increase the mechanical or thermal duty of the machine and, as a result, increase the chances for failure and consequent hazard. This further information should be considered by the user, his consultants, or others most familiar with the details of the application involved when making the final decision.

3.7 VARIATION FROM RATED VOLTAGE AND RATED FREQUENCY

3.7.1 Induction Motors

3.7.1.1 RUNNING

Motors will operate successfully under running conditions at rated load with a variation in the voltage or the frequency up to the following:

a. Plus or minus 10 percent of rated voltage with rated frequency.
b. Plus or minus 5 percent of rated frequency with rated voltage.
c. A combined variation in voltage and frequency of 10 percent (sum of absolute values) of the rated values, provided the frequency variation does not exceed plus or minus 5 percent of rated frequency.

Performance within these voltage and frequency variations will not necessarily be in accordance with the standards established for operation at rated voltage and frequency.

3.7.1.2 STARTING

The limiting values of voltage and frequency under which a motor will successfully start and accelerate to running speed depend on the margin between the speed-torque curve of the motor at rated voltage and frequency and the speed-torque curve of the load under starting conditions. Since the torque developed by the motor at any speed is approximately proportional to the square of the voltage and inversely proportional to the square of the frequency, it is generally desirable to determine what voltage and frequency variations will actually occur at each installation, taking into account any voltage drop resulting from the starting current drawn by the motor. This information and the torque requirements of the driven machine define the motor speed torque-curve, at rated voltage and frequency, which is adequate for the application.

3.7.1.3 OPERATION FROM VARIABLE-FREQUENCY OR VARIABLE-VOLTAGE POWER SUPPLIES OR BOTH

Induction motors to be operated from solid-state or other types of variable-frequency or variable-voltage power supplies, or both, for adjustable-speed-drive applications may require individual consideration to provide satisfactory performance. Especially for operation below rated speed, it may be necessary to reduce the motor torque load below the rated full-load torque to avoid overheating the motor. The motor manufacturer should be consulted before selecting a motor for such applications.

WARNING: High frequency harmonics of inverters can cause an increase in the level of leakage current in the motor. Therefore users are cautioned to follow established grounding practices for the motor frame.

3.7.2 Synchronous Motors

3.7.2.1 RUNNING

Motors will operate successfully in synchronism, rated exciting current being maintained, under running conditions at rated load with a variation in the voltage or the frequency up to the following:

a. Plus or minus 10 percent of rated voltage with rated frequency;
b. Plus or minus 5 percent of rated frequency with rated voltage; and
c. A combined variation in voltage and frequency of 10 percent (sum of absolute values) of the rated values, provided the frequency variation does not exceed plus or minus 5 percent of rated frequency.

Performance within these voltage and frequency variations will not necessarily be in accordance with the standards established for operation at rated voltage and frequency.

3.7.2.2 STARTING

The limiting values of voltage and frequency under which a motor will successfully start and synchronize depend upon the margin between the locked-rotor and pull-in torques of the motor at rated voltage and frequency and the corresponding

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requirements of the load under starting conditions. Since the locked-rotor and pull-in torques of a motor are approximately proportional to the square of the voltage and inversely proportional to the square of the frequency, it is generally desirable to determine what voltage and frequency variation will actually occur at each installation, taking into account any voltage drop resulting from the starting current drawn by the motor. This information and the torque requirements of the driven machine determine the values of locked-rotor and pull-in torque at rated voltage and frequency that are adequate for the application.

3.7.2.3 OPERATION FROM VARIABLE-FREQUENCY POWER SUPPLIES

Synchronous motors to be operated from solid-state or other types of variable-frequency power supplies for adjustable-speed-drive applications, may require individual consideration to provide satisfactory performance. Especially for operation below rated speed, it may be necessary to reduce the motor torque load below the rated full-load torque to avoid overheating the motor. The motor manufacturer should be consulted before selecting a motor for such application.

3.7.3 Synchronous Generators

Synchronous generators will operate successfully at rated kVA, frequency, and power factor with a variation in the output voltage up to plus or minus 5 percent of rated voltage.

Performance within these voltage variations will not necessarily be in accordance with the standards established for operation at rated voltage.

3.7.4 Direct-current Motors

Direct-current motors will operate successfully using the power supply selected for the basis of rating up to and including 110 percent of rated direct-current armature voltage provided the highest rated speed is not exceeded. Direct-current motors rated for operation from a rectifier power supply will operate successfully with a variation of plus or minus 10 percent of rated alternating-current line voltage.

Performance within this voltage variation will not necessarily be in accordance with the standards established for operation at rated voltage. For operation below base speed, see 3.10.

3.8 USUAL SERVICE CONDITIONS

Usual service conditions are as follows:

1. An ambient temperature in the range of 0°C to 40°C or, when water cooling is used, in the range of 10°C to 40°C;
2. Exposure to an altitude which does not exceed 3300 feet (1000 meters);
3. Installation on a rigid mounting surface; and
4. Installation in areas or supplementary enclosures which do not seriously interfere with the ventilation of the machine.

3.9 UNUSUAL SERVICE CONDITIONS

The manufacturer should be consulted if any unusual service conditions exist which may affect the construction or operation of the machine. Among such conditions are:

1. Exposure to:
    a. Combustible, explosive, abrasive, or conducting dusts;
    b. Lint or very dirty operating conditions where the accumulation of dirt will interfere with normal ventilation;
    c. Chemical fumes, flammable or explosive gases;
    d. Nuclear radiation;
    e. Steam, salt-laden air, or oil vapor;
    f. Damp or very dry locations, radiant heat, vermin infestation, or atmospheres conducive to the growth of fungus;
    g. Abnormal shock, vibration, or mechanical loading from external sources; and
    h. Abnormal axial or side thrust imposed on the motor shaft.
2. Operation where:
    a. There is excessive departure from rated voltage or frequency, or both (see 3.7);
    b. The deviation factor of the alternating-current supply voltage exceeds 10 percent;
    c. The alternating-current supply voltage is unbalanced by more than 1 percent; and
    d. Low noise levels are required.
3. Operation at speeds above the highest rated speed.
4. Operation in a poorly ventilated room, in a pit, or in an inclined position.
5. Operation where subjected to:
    a. Torsional impact load;
    b. Repetitive abnormal overloads; and
    c. Reversing or electric braking.
6. Operation of machine at standstill with any winding continuously energized or of short-time rated machine with any winding continuously energized.
7. Operation of direct-current machine where the average armature current is less than 50 percent of the rated full-load amperes over a 24-hour period, or continuous operation at armature current less than 50 percent of rated current for more than 4 hours.

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3.10 SPEED LIMITATION

3.10.1 Operation Below Rated or Base Speed

When a machine is operated below rated speed (base speed in the case of direct-current motors), it may be necessary to reduce its loading in order to avoid overheating. Overheating may result from reduced ventilation, changes in power supply characteristics, or changes in the characteristics of the machine. The manufacturer of the driven or driving equipment or the manufacturer of the machine, or both, should be consulted for further information regarding applications where operation below rated or base speed is contemplated. This further information should be considered by the user, his consultants, or others most familiar with the details of the application involved when making the final decision.

Authorized Engineering Information 11-16-1989.

3.10.2 Operation Above Highest Rated Speed

Series motors and direct-current compound-wound and shunt-wound motors are subject to dangerous overspeeding under certain conditions of misoperation.

A series motor with no load (or light load) connected to it will increase in speed very rapidly, and the armature may be thrown apart by centrifugal force. Series motors should therefore be positively connected to the driven load in a manner which will not allow the motor to become disconnected accidentally from the driven load.

Dangerous overspeeding of a direct-current compound-wound or shunt-wound motor may occur if the shunt field circuit becomes deenergized. Unless the speed is inherently limited by the application of the motor, these motors should be protected against dangerous overspeed by overspeed devices, field loss relays, or other means.

Authorized Engineering Information 7-17-1968.

3.11 OPERATION OF DIRECT-CURRENT MOTORS ON RECTIFIED ALTERNATING CURRENT

3.11.1 General

When a direct-current motor is operated from a rectified alternating-current supply, its performance may differ materially from that of the same motor when operated from a low-ripple direct-current source of supply, such as a generator or a battery. The pulsating voltage and current wave forms may increase temperature rise and noise and adversely affect commutation and efficiency. Because of these effects, it may be necessary that direct-current motors be designed or specifically selected to operate on the particular type of rectifier to be used.

Authorized Engineering Information 11-16-1989.

3.11.2 Motors Built in Frames Having a Continuous Dripproof Rating or Equivalent Capacity, Up to and Including 1.25 Horsepower per RPM, Open Type

Standards for these motors, as contained in Parts 10, 11, 12, and 14 of NEMA Publication MG 1, set forth a basis of rating direct-current motors intended for use with rectifier power supplies. These ratings are based upon tests of the motors using a test power supply.

Small motors are identified on the nameplate by means of a rated form factor, whereas medium motors are identified on the nameplate by a single letter or a combination of digits and letters designating a particular type of rectifier power supply.

All direct-current motors intended for use on rectifier power supplies may be used on low-ripple power supplies such as a direct-current generator or battery. In addition, motors identified by a rated form factor or a single identifying letter may be used on a power supply having a lower form factor or on a power supply designated or identified by a lower letter of the alphabet. For example, a motor rated on the basis of an E power supply may be used on a C or D power supply.

For operation of direct-current motors on power supplies other than those used to establish the basis of rating (except as noted above), the combination of the power supply and the motor should be considered in combination with the motor manufacturer.

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3.11.3 Motors Built in Frames Larger than Those Having a Continuous Dripproof Rating, or Equivalent Capacity, of 1.25 Horsepower per RPM, Open Type

Standards for these motors, as contained in Part 23 of NEMA Publication MG 1, are based on operation from a low-ripple power supply. The power supply and series inductance (including motor armature) selected should be such that the magnitude of the ripple current (peak-to-peak), expressed in percent of rated load current, does not exceed 6 percent at rated load, rated armature voltage, and rated base speed. For operation on other power supplies, the combination of the power supply and the motor should be considered in consultation with the motor manufacturer.

Authorized Engineering Information 11-16-1989.

3.11.4 Bearing Currents

When a direct-current motor is operated from some unfiltered rectifier power supplies, bearing currents may result. Ripple currents, transmitted by capacitive coupling between the rotor winding and the core, may flow through the ground path to the transformer secondary. While these currents are small in magnitude, they may cause damage to either antifriction or sleeve bearings under certain circumstances. It is recommended that the manufacturer be consulted to determine whether bearing currents may be a problem and, if so, what measures can be taken to minimize them.

Authorized Engineering Information 11-16-1972.

3.12 SHAFT LOADING

Hazard can be created by overstressing the motor or generator shaft by such means as misalignment of couplings, overtightening belts, and so forth, or by using V-belt sheaves, gear pinions, or chain sprockets smaller in diameter than provided for in the design of the machine. In coupling to the motor or generator shaft, the practices outlined in Part 14 of NEMA Publication MG 1 should be followed, or the machine manufacturer should be consulted.

Authorized Engineering Information 11-16-1989.

3.13 TRANSIENT TORQUES

Machines are inherently capable of developing transient torques considerably in excess of their rated torque when exposed to any of the following conditions:

1. Bus transfer;
2. Out-of-phase synchronizing;
3. Plugging;
4. Speed transfer or regenerative braking, or both, of multispeed motors; or
5. External short circuits.

The magnitude of these transient torques ranges from approximately 5 to 20 times rated torque as a function of the machine, operating conditions, switching times, system inertia, and so forth.

To avoid the possibility of damaging the external equipment (that is, shafts, couplings, gears, and so forth), the peak magnitude of the transient torques likely to be encountered should be considered in the design of the system. The machine manufacturer should be consulted regarding the peak magnitude of the transient air-gap torque, and this information should be considered by the manufacturer of the driven or driving equipment, the user, his consultants, or others most familiar with the details of the application involved when making the final decision.

MG 1-20.85 and 21.86 of NEMA Publication MG 1 provide basic application information relative to bus transfer or reclosing. The 1.33 maximum per unit volts per Hertz specified in MG 1-20.85 for bus transfer or reclosing is also applicable to out-of-phase synchronizing of synchronous generators.

Authorized Engineering Information 11-16-1989.

3.14 TORSIONAL VIBRATION

Overstressed shafts or couplings and other hazards can result from equipment which subjects machines to excessive torsional vibration. Unlike lateral vibrations that can be readily sensed by touch and measured with relatively common instruments, torsional vibrations with considerable amplitudes can exist and be undetectable except by special, relatively uncommon instruments. Since torsional vibrations are so difficult to detect and measure, it is particularly important that torsional stresses be considered when machines are to drive or be driven by equipment producing periodic torque pulses, such as reciprocating engines, chippers, hammer mills, and so forth.

While the factors which affect torsional vibration are primarily contained in the design of the equipment external to the motor, the design of the machine rotor to which the external equipment is mechanically connected should also be considered. When the manufacturer of the external equipment makes a torsional analysis of the complete assembly, the machine manufacturer should be consulted for the rotor design data which affects torsional vibration.

Authorized Engineering Information 11-16-1989.

3.15 TORQUE PULSATIONS DURING STARTING OF SYNCHRONOUS MOTORS

When operated at other than synchronous speed, all salient-pole synchronous motors develop a pulsating torque superimposed on the average torque. During starting and acceleration (with no field excitation applied), the frequency of the torque pulsations is at any instant equal to the per-unit slip times 2 times the line frequency. Thus, for a 60-hertz motor, the frequency of the torque pulsation varies from 120 hertz at zero speed to zero hertz at synchronous speed.

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Any system consisting of inertias connected by shafting has one or more natural torsional frequencies. During acceleration by a salient-pole synchronous motor, any torsional natural frequency at or below 2 times line frequency will be transiently excited.

When it is desired to investigate the magnitudes of the torques which are transiently imposed upon the shafting during starting, the instantaneous torque pulsations should be considered in addition to the average torque.

Authorized Engineering Information 11-16-1972.

3.16 SAFETY IN MACHINE INSTALLATIONS

3.16.1 Installation and Protection

All machines covered by this publication should be installed and protected in accordance with the applicable provisions of national codes and sound local practices.

Authorized Engineering Information 11-16-1989.

3.16.2 Grounding

The frames and other metal exteriors of machines (except for insulated pedestal bearings) usually should be grounded to limit their potential to ground in the event of accidental connection or contact between live electrical parts and the metal exteriors. See the *National Electrical Code*, Article 430, Part L, for information on grounding of motors; Article 445-1 for grounding of generators; and Article 250 for general information on grounding. In making the ground connection, the installer should make certain that there is a solid and permanent metallic connection between the ground point, the machine terminal housing, and the machine frame. A common method of providing a ground is through a grounded metallic conduit system.

Motors with resilient cushion rings are usually supplied with a bonding conductor across the resilient member (see 3.9). Some motors are supplied with the bonding conductor on the concealed side of the cushion ring to protect the bond from damage. Motors with bonded cushion rings should usually be grounded at the time of installation. When motors with bonded cushion rings are used in multimotor installations employing group fusing or group protection, the bonding of the cushion ring should be checked (see 3.9) to determine that it is adequate for the rating of the branch circuit overcurrent protective device being used.

There are applications where grounding the exterior parts of a machine may result in greater hazard by increasing the possibility of a person in the area simultaneously contacting ground and some other nearby live electrical part or other ungrounded electrical equipment. In portable equipment, it is difficult to be sure that a positive ground connection is maintained as the equipment is moved, and providing a grounding conductor may lead to a false sense of security. When careful consideration of the hazards involved in a particular application indicates the machine frames should not be grounded or when unusual operating conditions dictate that a grounded frame cannot be used, the installer should make sure the machine is permanently and effectively insulated from ground. In those installations where the machine frame is insulated from ground, it is recommended that appropriate warning labels or signs be placed on or in the area of the equipment by the installer.

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3.16.3 Wiring Connections

The connection of the machine to the power supply should be made by qualified personnel in accordance with the diagram or other instructions furnished by the machine manufacturer. Where the machine has provision for use on different values of voltage by alteration of the connections, care should be taken to ensure that the connections made are correct for the voltage supplied to the machine.

If a machine having a cord and attachment plug cap is required to be reconnected for operation on a different voltage, it is recommended that the changes be made by a qualified electrician. Care should be taken to ensure that the attachment plug cap is replaced with one of a type suitable for the voltage for which the machine is reconnected and that all of the instructions of the machine manufacturer are followed, since improper connections could result in the machine becoming a shock hazard.

Authorized Engineering Information 9-7-1977.

3.16.4 Flammable Materials

Sparking of brushes on commutator or collector rings may be expected during normal operation. In addition, open-type machines may eject flame or molten metal, or both, in the event of an insulation failure, commutator flashover, or arc-over of collector rings. Therefore, consideration should be given to the avoidance or protection of flammable or combustible materials in the area of open-type machines.

Authorized Engineering Information 11-16-1989.

3.16.5 Rotating Parts

Except for openings in machine enclosures (see 1.1.1), the guarding of rotating parts such as couplings, pulleys, and unused shaft extensions, should be in accordance with ANSI B15.1. This is particularly important where the parts have surface irregularities such as keys, keyways, or set screws. Some satisfactory methods of guarding are:

1. Covering the machine and associated rotating parts with structural or decorative parts of the driven or driving equipment.
2. Providing covers for the rotating parts. The openings in or at the edges of such covers should not be more than ½ inch wide (¾ inch if the rotating parts are more than 5.5 inches from the opening) in the direction (usually above and to the side) from which contact is to be expected. In other directions where other stationary parts, such as a sub-base, provide partial guarding, somewhat wider openings may be

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used. Covers should be sufficiently rigid to maintain adequate guarding in normal service.

NOTE: Where the torques involved are small and the rotating parts of the motor are of small diameter without sharp edges, guarding is not ordinarily necessary. Such motors are usually rated ½ horsepower or less.

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3.16.6 Maximum Speed of Drive Components

The maximum speed of drive components should not exceed the values recommended by the component manufacturer or the values specified in the industry standards to which the component manufacturer indicates conformance. Speeds above the maximum recommended speed may result in damage to the equipment or injury to personnel.

Authorized Engineering Information 11-16-1989.

3.16.7 Lifting of Machines

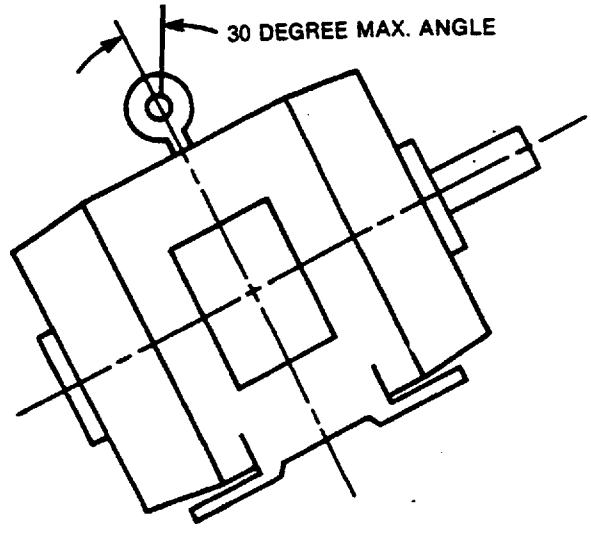
The lifting of machines and related equipment is a potentially hazardous operation requiring care and knowledge of proper lifting techniques to assure safety of personnel and to prevent damage to the equipment. Any instructions or guidelines given by the machine manufacturer on machine labels, instruction sheets, or drawings should be followed carefully.

Generally, where lifting means has been provided on the machine by the manufacturer, such lifting means (that is, eyebolts, lifting lugs, and so forth) are so located that when the machine is suspended in the intended manner, the resultant angle of lifting from the design lifting direction will not be greater than 30 degrees for machines with single lifting means or 45 degrees for machines with multiple lifting means. In all cases, care should be taken to assure lifting in the direction intended in the design of the lifting means (see Figures 3-1 and 3-2). With multiple lifting means, a spreader bar or a supporting sling, or both, is recommended to reduce the lifting angle or prevent damage to top mounted protective or ventilating enclosures.

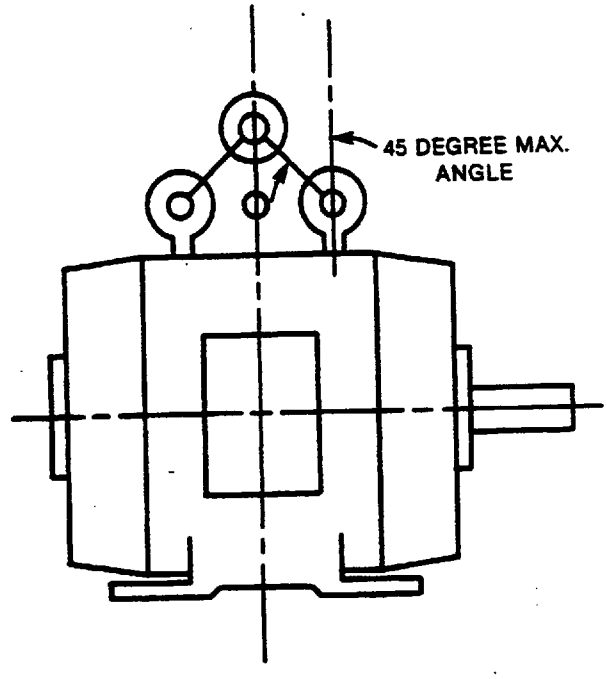
For unusual conditions, such as side-wall and ceiling mounting of horizontal motors and installation of vertical motors shipped in a horizontal position, special precautions should be taken and it is recommended that an experienced rigger be employed.

Precautions should be taken to prevent hazardous overloads due to acceleration, deceleration, or shock forces. Additional care should also be used when lifting or handling at temperatures below 0°C because the ductility of the lifting means is reduced.

In the case of assemblies on a common base, any lifting means provided on the machine should not be used to lift the assembly and base, but rather the assembly should be lifted by a sling around the base or by other lifting means provided on the base. It is recommended that a spreader bar be used when lifting assemblies on a common base.



SINGLE LIFTING DEVICE (TYPICAL)
Figure 3-1



MULTIPLE LIFTING DEVICES (TYPICAL)
Figure 3-2

LIFTING MACHINE ALONE

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Unless specifically allowed by the manufacturer's instruction manual or drawings, or both, the lifting means provided for lifting a machine should not be used to lift the machine plus additional equipment such as gears, pumps, compressors, or other driven equipment.

***Exception*:** For machines built in 34-inch diameter[1] (680 frame) and smaller, the following guide may be used.

If care is taken to minimize shock loading, and a spreader bar or supporting sling (securely anchored), or both, is used to assure a lifting force parallel with the designed lifting direction (lifting angle of zero degrees) and equally distributed over multiple lifting points, connected loads not exceeding 100 percent of the machine weight can normally be safely handled with the machine lifting device (see Figures 3-3, 3-4, and 3-5).

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[1] This is a diameter measured in the plane of laminations of the circle circumscribing the stator frame, excluding lugs, fins, boxes, and so forth, used solely for machine cooling, mounting, assembly, or connection.

3.16.8 Surface Temperatures

The surface temperature of machines varies with enclosure type, cooling method, insulation class, and operating conditions. Exposed surfaces may reach temperatures which could cause discomfort or injury to personnel accidentally coming in contact with the hot surfaces. For this reason during machine installation consideration should be given to the possible need to protect against accidental contact with hot machine surfaces.

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3.16.9 Hold Down Bolt Sizes

The bolt holes in machine feet and flanges have been selected to accept bolts which will hold the machine securely in place. The largest bolt diameter which will fit the nominal hole should be used to mount the machine. The length of the bolt should be such that the minimal thread engagement based on steel (or equivalent) is equal to the bolt diameter after allowing for washers under the head of the bolt and any shims under the feet.

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3.16.10 Power Factor Correction

When power factor correction capacitors are used, the total corrective kvar placed on the load side of the motor controller should not exceed the value required to raise the no-load power factor of the motor to unity. Corrective kvar in excess of this value may cause overexcitation resulting in high transient voltages, currents, and torques that can increase safety hazards to personnel and can cause possible damage to the motor or to the driven equipment.

The use of capacitors for power factor correction, switched at the motor terminals, is not recommended for elevator motors, multi-speed motors, motors used on plugging or jogging applications, motors subject to high speed bus transfer, and motors used with open transition wye-delta or auto-transformer starting. For such applications the motor manufacturer should be consulted before installing power factor corrective capacitors switched at the motor terminals.

Authorized Engineering Information 9-7-1977.

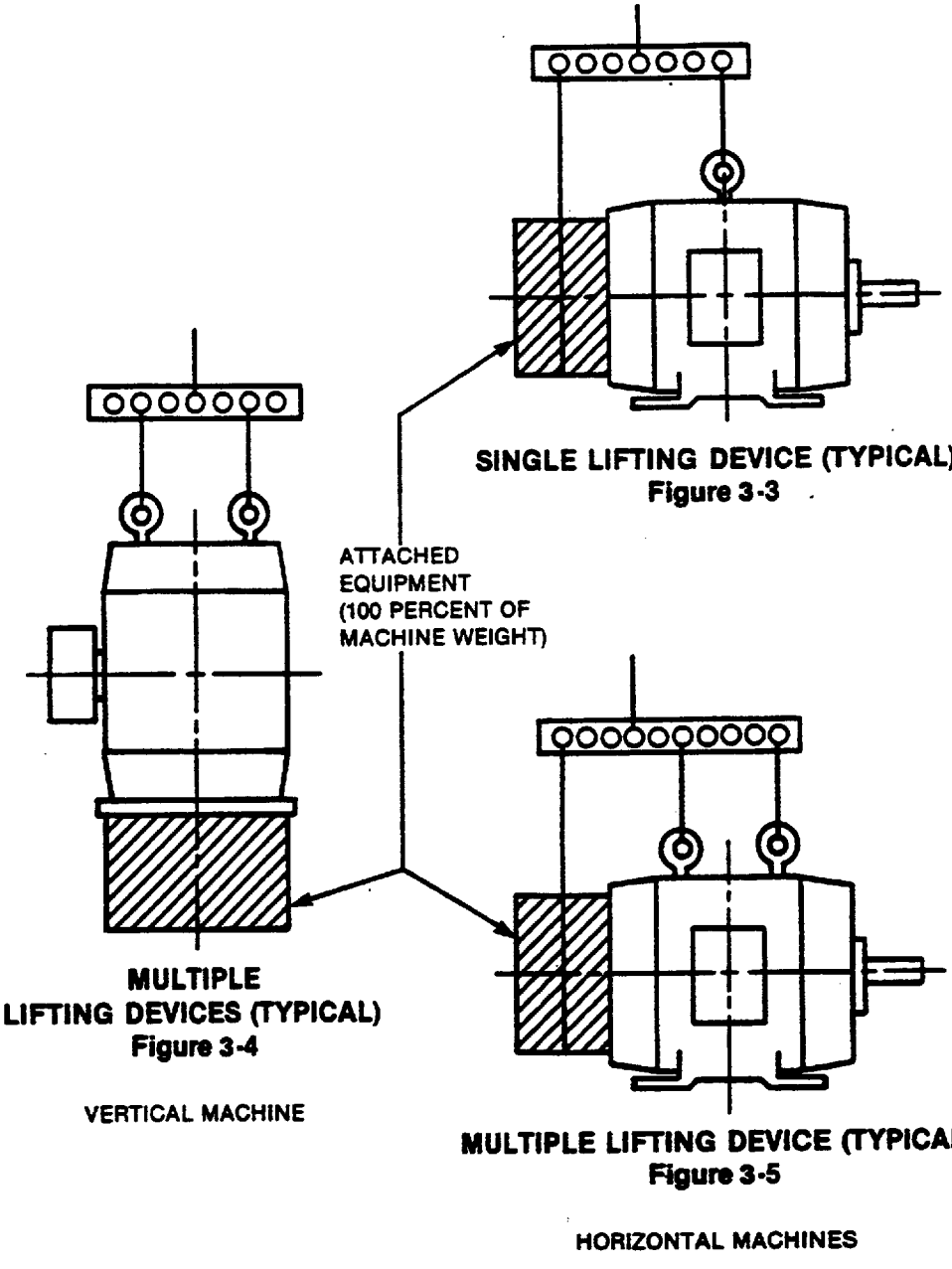
3.17 SAFETY IN MACHINE USE

3.17.1 Loading

There is no single, applicable standard for safe loading of a machine. The principle effect of overloading a machine is an increase in operating temperature. While it should be recognized that operation at a higher temperature does accelerate the deterioration of the insulation, no ordinarily attainable temperature normally results in an immediate hazard (*Caution*—see 3.5) if adequate overload protective equipment is properly selected and applied.

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SINGLE LIFTING DEVICE (TYPICAL)
Figure 3-3

MULTIPLE
LIFTING DEVICES (TYPICAL)
Figure 3-4

VERTICAL MACHINE

MULTIPLE LIFTING DEVICE (TYPICAL)
Figure 3-5

HORIZONTAL MACHINES

LIFTING MACHINE HAVING ATTACHED EQUIPMENT

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3.17.2 Automatic Reset Thermal Protectors

Motors with automatic reset thermal protectors should not be used when unexpected starting of the equipment might result in injury to the operator or malfunctioning of the equipment. Examples of such equipment are bench saws and food choppers.

Authorized Engineering Information 11-16-1972.

3.17.3 Maintenance

A well planned and executed maintenance schedule is essential to the satisfactory operation of electrical equipment. The kind and frequency of the maintenance operation will vary with the kind and size of the equipment as well as with the nature of the operating conditions.

It is not possible to establish a single maintenance program to serve all classes of equipment within the scope of this publication. The user should establish a maintenance program giving due consideration to the installation and application of the equipment as well as to the maintenance instructions and recommendations of the machine manufacturer.

The following factors should be considered when formulating a maintenance program:

1. Maintenance should be performed by qualified personnel.
2. The equipment should be so located as to permit the performance of all maintenance operations without hazard to the worker.
3. Whenever possible, maintenance should be performed with the equipment not in operation and disconnected from the line. In particular, the alternating-current primary power source for a direct-current or alternating-current motor used on an adjustable-voltage or adjustable-frequency electronic power supply, or with an electronic controller, should be completely disconnected from the line. All hazardous energy sources should be locked out and/or tagged if workers may be exposed to injury by reenergization.
4. A general inspection of mechanical integrity, that is, fracture, loose bolts, missing parts, and so forth, should be made.
5. Vibration and noise should be observed. A change in the magnitude or frequency of the vibration or noise, or both, indicates a need for attention.
6. Ventilation passages should be kept open. If the equipment depends upon auxiliary cooling, that is, air, water, oil, and so forth, periodic inspections should be made of these systems.
7. Periodic inspection or tests, or both, of the insulation system, when recommended by the machine manufacturer, should be made.
8. Brushes, slip rings, and commutators should be frequently inspected and serviced as required.
9. Lubrication procedures given in the machine manufacturer's instructions should be followed.
10. The means employed for grounding the machine or insulating the machine from ground should be checked to assure its integrity.
11. Flexible cords and connectors should be examined to determine that the cords are free from abrasion, cracks, and exposed strands and that the connectors have unbroken bodies so that live parts are not exposed.

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3.17.4 Repair

When a machine is repaired, it is important that any replacement part be of a quality equal to or better than that of the original part. For example, any replacement shaft should be of as high quality steel and have as good heat treatment as the shaft being replaced; insulation should be replaced by insulating materials of at least the same, or higher, temperature rating. Care should be taken to avoid the use of parts which no longer are compatible with other changes in the machine. Also, replacement parts should be inspected for deterioration due to shelf life and for signs of rework or wear which may involve factors critical to safety.

Repaired machines should conform to the provisions of Section 1 and 2 of this publication except that if a winding is only repaired or partially replaced, the applied high-potential test voltage should be 70 percent of the specified value.

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