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Information Guide for General Purpose Industrial AC Small and Medium Squirrel-Cage Induction Motor Standards

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FOREWORD

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INFORMATION GUIDE FOR GENERAL PURPOSE INDUSTRIAL AC SMALL AND MEDIUM SQUIRREL-CAGE INDUCTION MOTOR STANDARDS

1. PURPOSE

This is a condensation of the standards on motors included in NEMA Standards Publication *Motors and Generators*, MG1-1998 through Revision 2. Some standards are reprinted in their entirety while others have been combined or abbreviated. The numbers placed at the end of many of the paragraphs in this condensation (e.g. MG1 Part 6) refer to the complete standard in MG1.

2. SCOPE

The standards in this guide cover alternating-current squirrel-cage motors up to and including the ratings built in frames corresponding to the continuous open-type ratings given in Table 1.

3. DEFINITIONS

ambient temperature: The temperature of the surrounding air which comes into contact with the heated parts of the apparatus. [MG1-1.56]

capacitor motor: A single-phase induction motor with main winding arranged for direct connection to power source and auxiliary winding connected in series with a capacitor. There are three types of capacitor motors: capacitor start, in which capacitor phase is in circuit only during starting; permanent-split capacitor which has the same capacitance for both starting and running; two-value capacitor motor in which there are different values of effective capacitance for starting and running. [MG1-1.20.3.3]

current:

locked-rotor current: The steady-state current taken from the line, with the rotor locked and with rated voltage and rated frequency applied to the motor. [MG1-1.53]

no-load current: The current flowing through a line terminal of a winding when rated voltage is applied at a rated frequency with no connected load. [MG1-1.54]

design letters: Identifies specific performance requirements for starting and operating characteristics. See Table 8. [MG1-1.19.1]

dimensions: Dimension are indicated by the NEMA letters given in Table 19. [MG1-4.1]

dripproof motor: An open motor 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. [MG1-1.25.1]

dripproof guarded motor**:** A dripproof motor whose ventilating openings are guarded. [MG1-1.25.5]

energy efficient polyphase squirrel-cage induction motor – An induction motor having an efficiency in accordance with 9.21.3. [MG1-1.41.2]

frame number: The frame number for small motors is the "D" dimension in inches multiplied by 16. The frame number for medium motors consists of three or four digits. The first two digits are equal to four times the "D" dimension in inches. When this product is not a whole number, the first two digits of the frame number are the next higher whole number. The third and, when required, fourth digit of the frame number is obtained from the value of the "2F" dimension in inches as shown in the columns headed 1 to 15, inclusive, in the Table 20. [MG1-4.2]

general-purpose motor: A squirrel-cage induction motor, rated 500 horsepower and less, open or enclosed construction. It is designed in standard ratings with standard operating characteristics and mechanical construction for use under usual service conditions without restriction to a particular application or type of application. [MG1-1.6]

guarded motor: An open motor 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 openings in the motor enclosure shall be such that (1) a probe such as that illustrated in Figure 1, when inserted through the openings, will not touch an uninsulated live metal part or a hazardous rotating part and (2) a probe such as that illustrated in Figure 2, when inserted through the openings, will not touch film coated wire. [MG1-1.25.4]

high-potential tests: High-potential tests are tests which consist of the application of a voltage higher than the rated voltage for a specified time for the purpose of determining the adequacy against breakdown of insulating materials and spacings under normal conditions. [MG1 Part 3]

IC code: Acronym for "International Cooling." See Clause 5 Methods of Cooling. [MG1 Part 6]

IP code: Acronym for "International Protection." See Clause 4 Classification of Degrees of Protection. [MG1 Part 5]

medium (integral) motor**:** An alternating-current medium motor is (1) built in a three-or four-digit frame series (or equivalent for motors without feet); and (2) having a continuous rating up to and including the information in Table 2. [MG1-1.4.1]

NEMA Premium™ efficiency electric motor - A continuous rated, single-speed, polyphase, squirrel-cage induction motor of 2, 4, or 6 pole design meeting the performance requirements of Design A or Design B and having a nominal full load efficiency not less than that shown in 9.21.4. [MG1-1.16]

open motor: One having ventilating openings which permit passage of external cooling air over and around the windings of the motor. [MG1-1.25]

service factor: A multiplier which, when applied to the rated horsepower, indicates a permissible horsepower loading which may be carried under the conditions specified for the service factor. [MG1-1.42]

small (fractional) motor: A small motor is either (1) built in a two digit frame number series (or equivalent for motors without feet); or (2) a motor built in a frame smaller than that frame of a medium motor which has a continuous rating at 1700-1800 rpm of 1 horsepower; or (3) a motor rated less than 1/3 horsepower and less than 800 rpm. [MG1-1.3]

squirrel-cage induction motor: An alternating-current motor composed of a primary winding connected to a power source and a squirrel-cage secondary winding which carries induced current. [MG1-1.18.1.1]

starting capacitance for a capacitor motor: The total effective capacitance in series with the starting winding under locked-rotor conditions. [MG1-1.58]

temperature tests: Tests taken to determine the temperature rise of certain parts of the motor above the ambient temperature, when running under a specified load. [MG1-1.55]

torque:

breakdown torque: The maximum torque developed by the motor with rated voltage applied at rated frequency, without an abrupt drop in speed. [MG1-1.50]

locked-rotor torque: The minimum torque developed by the motor at rest for all angular positions of the rotor, with rated voltage applied at rated frequency. [MG1-1.47]

pull-up torque: The minimum torque developed by the motor during the period of acceleration from rest to the speed at which breakdown torque occurs. For motors which do not have a definite breakdown torque, the pull-up torque is the minimum torque developed up to rated speed. [MG1-1.48]

totally enclosed motor: A motor enclosed to prevent the free exchange of air between the inside and the outside of the case but not sufficiently enclosed to be termed air-tight. [MG1-1.26]

totally enclosed fan-cooled motor: A totally enclosed motor equipped for exterior cooling by means of a fan or fans integral with the motor but external to the enclosing parts. [MG1-1.26.2]

totally enclosed fan-cooled guarded motor: A totally enclosed fan-cooled motor in which all openings giving direct access to the fan are limited in size by the design of the structural parts or by screens, grills, expanded metal, etc., to prevent accidental contact with the fan. Such openings shall not permit the passage of a cylindrical rod 0.75 inch in diameter, and a probe such as that shown in Figure 1 and Figure 2 shall not contact the blades, spokes, or other irregular surfaces of the fan. [MG1-1.26.3]

totally enclosed nonventilated motor: A totally enclosed motor which is not equipped for cooling by means external to the enclosing parts. [MG1-1.26.1]

voltage unbalance: The voltage unbalance in percent may be defined as follows:

percent voltage unbalance = 100 x maximum voltage deviation from average voltage ÷ average voltage

Example—With voltages of 460, 467, and 450, the average is 459, the maximum deviation from average is 9, and the percent unbalance = 100 x 9/459 = 1.96 percent. [MG1-14.36.2]

4. CLASSIFICATION OF DEGREES OF PROTECTION PROVIDED FOR ENCLOSURES FOR ROTATING MOTORS

The designation used for the degree of protection consists of the letters IP followed by two characteristic numerals signifying conformity with the conditions indicated in Table 3. [MG1-5.3]

4.1 Single Characteristic Numeral

When it is required to indicate degree of protection by only one characteristic numeral, the omitted numeral shall be replaced by the letter X. For example, IPX5 or IP2X. [MG1-5.3.1]

4.2 Supplementary Letters

Additional information may be indicated by a supplementary letter following the second characteristic numeral. If more than one letter is used, the alphabetic sequence shall apply. [MG1-5.3.2]

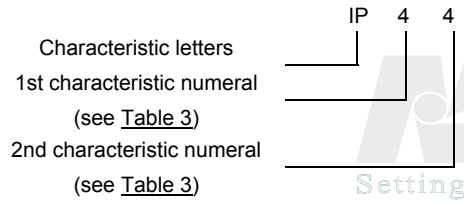
4.3 Letters Following Numerals

In special application (such as motors with open circuit cooling for ship deck installation with air inlet and outlet openings closed during standstill) numerals may be followed by a letter indicating whether the protection against harmful effects due to ingress of water was verified or tested for the machine not running (letter S) or the machine running (letter M). In this case the degree of protection in either state of the machine shall be indicated, for example IP55S/IP20M. The absence of the letters S and M shall imply that the intended degree of protection will be provided under all normal conditions of use. [MG1-5.3.2.1]

4.4 Letters Placed Immediately After the Letters IP

For open internally air-cooled motors suitable under specific weather conditions and provided with additional protective features or processes, such as those required for open water-protected motors, the letter W may be used. [MG1-5.3.2.2]

Example of Designation



4.5 Degrees of Protection—First Characteristic Numeral

The first characteristic numeral indicates the degree of protection provided by the enclosure with respect to persons and also to the parts of the machine inside the enclosure. Table 3 gives brief details of objects which will be excluded from the enclosure for each of the degrees of protection represented by the first characteristic numeral. [MG1-5.4.1]

The term “excluded” implies that a part of the body, or a tool or wire held by a person, either will not enter the machine or, if it enters, that adequate clearance will be maintained between it and the live or dangerous moving parts (smooth rotating shafts and the like are not considered dangerous). Table 3 also indicates the minimum size of foreign objects which will be excluded. [MG1-5.4.1]

Compliance of an enclosure with an indicated degree of protection implies that the enclosure will also comply with all lower degrees of protection. In consequence, the tests establishing these lower degrees of protection are not required, except in cases of doubt. [MG1-5.4.2]

4.6 Degrees of Protection—Second Characteristic Numeral

The second characteristic numeral indicates the degree of protection provided by the enclosure with respect to harmful effect due to ingress of water. Table 3 gives brief details of the type of protection provided by the enclosure for each of the degrees of protection represented by the second characteristic numeral.

A machine is weather-protected when its design reduces the ingress of rain, snow, and airborne particles, under specified conditions, to an amount consistent with correct operation. This degree of protection is designated by the letter W placed after the two characteristic numerals. [MG1-5.5.1]

5. METHODS OF COOLING

The designation used for the method of cooling consists of the letters IC, followed by numerals and letters representing the circuit arrangement, the coolant and the method of movement of the coolant. A complete designation and a simplified designation are defined. The complete designation system is intended for use mainly when the simplified system is not applicable. [MG1-6.1]

5.1 Arrangement of the IC Code

The designation system is demonstrated in Table 4. The simplified designations should preferably be used, that is, the complete designation system is intended for use mainly when the simplified system is not applicable.

6. MECHANICAL VIBRATION—MEASUREMENT, EVALUATION, AND LIMITS OF AC MEDIUM MOTORS

This standard is applicable to polyphase alternating current motors tested with sinusoidal power. The standard is not applicable to motors mounted in situ, single-phase motors, or three-phase motors operated on single-phase systems. [MG1-7.1]

The criterion for bearing housing vibration is the peak value of unfiltered vibration velocity in the vertical, horizontal and axial directions. Unfiltered vibration limits for standard motors, when tested on resilient mounts, are shown in Table 5. [MG1-7.4.1]

7. SMALL (FRACTIONAL) AND MEDIUM (INTEGRAL) MOTORS RATINGS

7.1 Voltages

Single-phase motors	Polyphase motors
60 hertz—115, 200, and 230 volts	60 hertz—115[1], 200, 230, 460, and 575 volts
50 hertz—110 and 220 volts	50 hertz—220 and 380 volts

Notes:1. It is not practical to build motors of all horsepower ratings for all the standard voltages. [MG1-10.30]

2. Operation of a motor rated 230 volts on a 208-volt system is not recommended. Such operation will generally result in excessive overheating and serious reduction in torques. Induction motors intended for operation on 208-volt systems should be rated for 200 volts. [MG1-14.35]

[1] Applies only to motors rated 15 horsepower and smaller.

7.2 Frequencies

The frequency shall be 50 and 60 hertz. [MG1-10.31]

7.3 Horsepower and Speed Ratings

7.3.1 Small Induction Motors

The horsepower and speed ratings for small induction motors are shown in Table 6. [MG1-10.32.1]

7.3.2 Single-Phase Medium Motors

The horsepower and synchronous speed ratings of single-phase medium motors rated 115, 200 and 230 volts are shown in Table 7. [MG1-10.32.3]

7.3.3 Polyphase Medium Induction Motors

The horsepower and synchronous speed ratings of polyphase medium induction motors are shown in Table 8. [MG1-10.32.4]

7.3.4 Basis of Single-Phase Horsepower Rating

The horsepower rating of a small or medium single-phase induction motor is based upon the breakdown torque. The value of breakdown torque to be expected by the user for any horsepower and speed shall fall within the range given in Table 9 and Table 10. [MG1-10.34.1]

7.4 Horsepower Ratings of Multispeed Motors

7.4.1 Constant Horsepower

The horsepower rating for each rated speed shall be selected from Table 6 and Table 7. [MG1-10.33.1]

7.4.2 Constant Torque

The horsepower rating for the highest rated speed is selected from Table 6 or Table 7. The horsepower rating for each lower speed shall be determined by multiplying the horsepower rating at the highest speed by the ratio of the lower synchronous speed to the highest synchronous speed. [MG1-10.33.2]

7.4.3 Variable Torque

The horsepower ratings at the highest rated speed is selected from Table 6 or Table 7.. The horsepower rating for each lower speed shall be determined by multiplying the horsepower rating at the highest speed by the square of the ratio of the lower synchronous speed to the highest synchronous speed. [MG1-10.33.3]

7.5 Rating of 60-Hertz Motors Operated on 50-Hertz Power

General-purpose alternating-current polyphase 2-, 4-, 6- and 8-pole, 60-hertz medium induction motors, although not designed to operate at their 60-hertz ratings on 50-hertz circuits, can be operated satisfactorily at 50-hertz if voltage and horsepower ratings are appropriately reduced (see MG1 Part 14). [MG1-14.34]

7.6 Time Ratings for Single-Phase and Polyphase Induction Motors

The time rating for single-phase and polyphase induction motors shall be 5, 15, 30 and 60 minutes or continuous.

All short-time ratings are based upon a corresponding short-time load test which shall commence only when the winding and other parts of the machine are within 5°C of the ambient temperature at the time of the starting of the test. [MG1-10.36]

7.7 Code Letters (for Locked-Rotor kVA)—Nameplate Marking

The nameplate of an alternating-current motor rated 1/2 horsepower and larger may be marked with the caption "Code" followed by a letter selected from the table below to show the locked-rotor kVA per horsepower.

The letter designations for locked-rotor kVA per horsepower as measured at full voltage and rated frequency are as shown in Table 12. [MG1-10.37]

Broad- or dual-voltage motors which have a different locked-rotor kVA per horsepower on the different voltages shall be marked with the code letter for the voltage giving the highest locked-rotor kVA per horsepower.

Motors with 60- and 50-hertz ratings shall be marked with a code letter designating the locked-rotor kVA per horsepower on 60-hertz. [MG1-10.37.6]

7.8 Nameplate Temperature Ratings for Alternating-Current Small Motors

Alternating-current small motors shall be rated on the basis of a maximum ambient temperature and the insulation system class.

The rated value of the maximum ambient temperature shall be 40°C unless otherwise specified, and the insulation system shall be Class A, B, F, or H. [MG1-10.38]

7.9 Nameplate Marking for Small Single-Phase and Polyphase Motors

The following information shall be given on all nameplates. For motors with dual ratings see 7.9.1 [MG1-10.39.1]

a) Manufacturer's type and frame designation
b) horsepower output
c) Time rating
d) Maximum ambient temperature for which motor is designed
e) Insulation system designation. (If stator and rotor use different classes of insulation systems, both insulation system designations shall be given on the nameplate, that for the stator being given first.)
f) Rpm at full load
g) Frequency
h) Number of phases
i) Full-load amperes
j) Voltage
k) Code letter for locked-rotor kVA or locked-rotor amperes for motors 1/2 horsepower or larger
l) For motors equipped with thermal protectors, the words "thermally protected" and for motors rated more than 1 horsepower, a type number.

7.9.1 Dual Voltage, Dual Frequency, and Dual Speed Motors

[MG1-10.39.5]

a) Broad Voltage (no reconnection of motor leads)
   Use dash between voltages (i.e., 200-300)

b) Dual Voltage (reconnection of motor leads)
   Use slash between voltages (i.e., 230/460)
   Use slash between amperes (i.e., 4.6/2.3)

c) Dual Frequency and Single Voltage
   Use ampersand (&) between values for each frequency
   Hz (i.e., 60&50)
   Volt (i.e., 115&110)
   Rpm (i.e., 1725&1450)
   Amp (i.e., 5.0&6.0)

Note: If spacing in standard location on nameplate is not adequate, the values of alternative frequency and associated volts, rpm, and amps shall be permitted to be specified at a different location on the nameplate.

d) Dual Frequency and Dual Voltage

Use slash between voltages for one frequency and ampersand (&) between values for each frequency.

Hz (i.e., 60&50)
Volt (i.e., 115/230&110/220)
Rpm (i.e., 1725&1450)
Amp (i.e., 5.0/2.5&6.0/3.0)

Note: If spacing in standard location on nameplate is not adequate, the values of alternative frequency and associated volts, rpm, and amps shall be permitted to be specified at a different location on the nameplate.

e) Dual Pole-Changing, Single Frequency and Single voltage

Use slash between values of hp, rpm and amps
Hp (i.e., 1/4 / 1/12)
Rpm (i.e., 1725/1140)
Amp (i.e., 4.2/2.6)

Note: Horsepowers shall be permitted to be designated in decimals rather than fractions for clarity.

7.10 Nameplate Marking for Medium Single-Phase and Polyphase Induction Motors

The following information shall be given on all nameplates of medium single-phase and polyphase induction motors. For motors with broad range or dual voltage, see the above information. [MG1-10.40.1]

a) Manufacturer's type and frame designation
b) Horsepower output
c) Time rating
d) Maximum ambient temperature for which motor is designed. (As an alternative to items d. and e., the temperature rise by resistance shall be permitted to be given.)
e) Insulation system designation
f) Rpm at full load
g) Frequency
h) Number of phases
i) Rated-load amperes
j) Voltage
k) Code letter for locked-rotor kVA or locked-rotor amperes for motors 1/2 horsepower or larger
l) Design letter for medium motors
m) NEMA nominal efficiency, when required
n) Service factor, if other than 1.0
o) Service factor amps when service factor exceeds 1.15
p) For motors equipped with thermal protectors, the words "thermally protected" if the motor provides all the protection described 9.19
q) For motors rated above 1 horsepower equipped with over-temperature devices or systems, the words 'OVER TEMP PROT-" followed by a type number. (See 9.20)

7.11 Additional Nameplate Information for All Motors

Some examples of additional nameplate information [MG1-10.39.6]

a) Enclosure or IP code
b) Manufacturer's name, mark, or logo
c) Manufacturer's plant location
d) Serial number or date of manufacture
e) Method of cooling or IC code

8. DIMENSIONS—AC SMALL (FRACTIONAL) AND MEDIUM (INTEGRAL) MOTORS

8.1 System for Designating Frames

The system for designating frames of motors consist of a series of numbers in combination with letters, defined as follows: [MG1-4.2]

8.1.1 Small Motors

The frame number for small motors is the D dimension in inches multiplied by 16. The letters C, H, Y and Z immediately follow the frame number to denote variations, for general purpose motors, as follows: [MG1-4.2.2]

C –Type C face-mounting
H – Indicates a frame having an F dimension larger than that of the same frame without the suffix letter H
Y – Special mounting dimensions (dimensional diagram must be obtained from the manufacturer)
Z – All mounting dimensions are standard except the shaft extension

Note:Other letters are also used to denote other motor types.

8.1.2 Medium Motors

The system for numbering the frames of medium motors is as follows (See also Table 13, Figure 3, Figure 4, Figure 5, and Figure 6.): [MG1-4.2]

a) The first two digits of the frame number are equal to four times the D dimension in inches. When this product is not a whole number, the first two digits of the frame number is the next higher whole number.
b) The third and, when required, the fourth digit of the frame number is obtained from the value of 2F in inches by referring to the columns headed 1 to 15, inclusive, in Table 13.

The letters C, CH, D, R, S, T, U, V, Y, or Z immediately following the frame number are used to denote variations as follows:

C – Type C face mounting on drive end. (When the face mounting is at the end opposite the drive, the prefix F shall be used, making the suffix letters FC.)

CH – Type C face-mounting dimensions are different from those for the frame designation having the suffix letter C. The letters CH are to be considered as one suffix and shall not be separated.)

D – Type D flange-mounting on drive end. (When the flange mounting is at the end opposite the drive, the prefix F shall be used, making the suffix letters FD.)

R – Drive end tapered shaft extension having dimensions in accordance with 9.5.

S – Standard short shaft for direct connection (see Table 20, Table 21, Table 22, Table 23, and Table 24).

T – Included as part of a frame designation for which standard dimensions have been established (see Table 20, Table 21, Table 22, Table 23, and Table 24).

U – Previously used as part of a frame designation for which standard dimensions had been established (no longer included in MG1).

V – Vertical mounting only.

Y – Special mounting dimensions (dimensional diagram must be obtained from the manufacturer.)

Z – All mounting dimensions are standard except the shaft extension(s). Also used to designate motor with double shaft extension.

8.2 Frame Assignments

Frame assignments for alternating current single-phase, Design L, horizontal and vertical, open type motors are given in Table 14. Frame assignments for alternating current, polyphase, squirrel-cage, Designs A, B, and C, horizontal and vertical motors, open type and totally enclosed fan-cooled type are given in Table 15, Table 16, Table 17, and Table 18. [MG1, Part 13]

8.3 Lettering of Dimension Sheets

Dimensions on dimension sheets shall be lettered in accordance with Table 19. [MG1-4.1]

8.4 Tolerances for Shaft Runout

The tolerance for the permissible shaft runout, when measured at the end of the shaft extension, shall be: [MG1-4.9.7]

a) For 0.1875 to 1.625-inch diameter shafts, inclusive—0.002-inch indicator reading.
b) For over 1.625 to 6.500-inch diameter shafts, inclusive—0.003-inch indicator reading.

Note: Standards have not been established for shaft runouts where the shaft extension length exceeds the standard. However, runouts for shafts longer than standard are usually greater than those indicated above.

8.5 Grounding Means for Field Wiring

When motors 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 to, with accessibility from, the terminal housing. [MG1-4.20]

9. TESTS AND PERFORMANCE—AC SMALL AND MEDIUM MOTORS

9.1 Routine Tests for Polyphase Medium Induction Motors

The method of testing polyphase induction motors shall be in accordance with IEEE Std 112.

Typical tests which may be made on motors completely assembled in the factory and furnished with shaft and complete set of bearings are as follows: [MG1-12.55]

a) Measurement of winding resistance
b) No-load readings of current and speed at normal voltage and frequency. On 50 hertz motors, these readings may be taken at 60 hertz.
c) Current input at rated frequency with rotor at stand-still for squirrel-cage motors. This may be taken single-phase or polyphase at rated or reduced voltage. (When this test is made single-phase, the polyphase values of a duplicate machine should be given in any report.) On 50 hertz motors, these readings may be taken at 60 hertz.
d) High-potential test

9.2 High-potential test voltages for induction motors.

[MG1-12. 3]

Category	Effective Test Voltage	Duration
A. At-the-factory tests		
1. Motors rated 1/2 horsepower or less and 250 volts or less	1000 volts	1 minute
2. Motors rated 1/2 horsepower or less and greater than 250 volts	1000 volts + 2 times the rated voltage of the motor	1 minute
3. Motors rated larger than 1/2 horsepower	1000 volts + 2 times the rated voltage of the motor	1 minute
B. After-factory tests		
1. Initial test at destination of a new stator	Use factory test voltages (A)	
2. Test of an assembled group of motors and apparatus	Use factory test value of the lowest of the group test value (A) times .85	
3. Additional tests made after installation	Use factory test values (A times .75)	

9.3 Test Methods

Tests to determine performance characteristics shall be made in accordance with the following: [MG1-12.30]

a) For single-phase motors—IEEE Std 114
b) For polyphase induction motors—IEEE Std 112

9.4 Performance Characteristics

When performance characteristics are provided, they should be expressed as follows: [MG1-12.31]

a) Current in amperes or percent of rated current.
b) Torque in pound-feet, pound-inches, ounce-feet, ounce-inches, or percent of full-load torque.
c) Output in horsepower or percent of rated horsepower.
d) Speed in revolutions per minute or percent of synchronous speed.
e) Efficiency in percent.
f) Power factor in percent.
g) Voltage in volts or percent of rated voltage.
h) Input power in watts or kilowatts.

Note: If SI units are used, they should be in accordance with ISO Publication No. R.-1000.

9.5 Torque Characteristics of Single-Phase General-Purpose Induction Motors

9.5.1 Breakdown Torque of Single-Phase Motors

The breakdown torque of single-phase general-purpose small and medium induction motors shall be the higher figure in each torque range as given in Table 9, subject to tolerances in manufacturing and other conditions (MG1-10.34) [MG1-12.32.1].

9.5.2 Locked-Rotor Torque of Single-Phase Small Motors

The locked-rotor torque of single-phase general-purpose small motors, with rated voltage and frequency applied, shall be not less than shown in Table 27. [MG1-12.32.2]

9.5.3 Locked-Rotor Torque of Single-Phase Medium Motors

The locked-rotor torque of single-phase general-purpose medium motors, with rated voltage and frequency applied, shall be not less than shown in Table 28. [MG1-12.32.3]

9.5.4 Pull-Up Torque of Single-Phase Medium Motors

The pull-up torque of single-phase general-purpose alternating-current medium motors, with rated voltage and frequency applied, shall be not less than the rated load torque. [MG1-12.32.4]

9.6 Locked-Rotor Current Characteristics of Single-Phase and Polyphase General-Purpose Induction Motors

9.6.1 Locked-Rotor Current of Single-Phase Small Motors, Designs N and O

The locked-rotor current of 60-Hertz, single-phase motors shall not exceed the values given in Table 29. [MG1-12.33.1]

The locked-rotor currents of single-phase general-purpose motors shall not exceed the values for Design N motors.

9.6.2 Locked-Rotor Current of Single-Phase Medium Motors, Designs L and M

The locked-rotor current of single-phase, 60-Hertz, Design L and M motors of all types, when measured with rated voltage and frequency impressed and with the rotor locked, shall not exceed the values shown in Table 30. [MG1-12.34]

9.6.3 Locked-Rotor Current of 3-Phase 60-Hertz Small and Medium Squirrel-Cage Induction Motors Rated at 230 Volts

The locked-rotor current of single-speed, 3-phase, constant-speed induction motors rated 230 volts, when measured with rated voltage and frequency impressed and with rotor locked, shall not exceed the values listed in Table 31. [MG1-12.35.1]

The values in the above table are rms symmetrical values, i.e., average of the three phases. There will be a one-half cycle instantaneous peak value which may range from 1.8 to 2.8 times the above values as a function of the motor design and switching angle. This is based upon an ambient temperature of 25°C. [MG1-12.36]

9.7 Torque Characteristics of Polyphase General-Purpose Induction Motors

9.7.1 Breakdown Torque Characteristics of Polyphase Small Motors

The breakdown torque of a general-purpose polyphase squirrel-cage small motor, with rated voltage and frequency applied, shall be not less than 140 percent of the breakdown torque of a single-phase general purpose small motor of the same horsepower and speed rating given in 9.5. [MG1-12.37]

Note: The speed at breakdown torque is ordinarily much lower in small polyphase motors than in small single-phase motors. Higher breakdown torques are required for polyphase motors so that polyphase and single-phase motors will have interchangeable running characteristics, rating for rating, when applied to normal single-phase motor loads.

9.7.2 Locked-Rotor Torque of Single-Speed Polyphase Squirrel-Cage Medium Motors with Continuous Rating

The locked-rotor torque of Design A, B, and C single-speed polyphase squirrel-cage medium motors, with rated voltage and frequency applied, shall be not less than the values shown in Table 32 and Table 33 which are expressed in percent of full-load torque. [MG1-12.38]

The locked-rotor torque of Design D, 60- and 50-hertz, 4-, 6-, and 8-pole, single-speed polyphase squirrel-cage medium motors rated 150 horsepower and smaller, with rated voltage and frequency applied, shall be not less than 275 percent, expressed in percent of full-load torque. [MG1-12.38.3]

9.7.3 Breakdown Torque of Single-Speed Polyphase Squirrel-Cage Medium Motors with Continuous Ratings

The breakdown torque of Design A, B, and C 60- and 50-hertz, single-speed polyphase squirrel-cage medium motors, with rated voltage and frequency applied, shall be not less than the values shown in Table 34 and Table 35 which are expressed in percent of full-load torque. [MG1-12.39]

9.7.4 Pull-Up Torque of Single-Speed Polyphase Squirrel-Cage Medium Motors with Continuous Ratings

The pull-up torque of Design A, B, and C 60- and 50-hertz, single-speed, polyphase squirrel-cage medium motors, with rated voltage and frequency applied, shall be not less than the values shown in Table 36 and Table 37 which are expressed in percent of full-load torque. [MG1-12.40]

9.8 Temperature Rise for Small and Medium Single-Phase and Polyphase Induction Motors

The temperature rise, above the temperature of the cooling medium, for each of the various parts of the motor shall not exceed the values given in Table 38 when tested in accordance with the rating. The temperature rise for motors having a service factor greater than 1.0 shall not exceed the values given in Table 38 when tested at the service factor load. Temperatures shall be determined in accordance with the following: [MG1-12.42.1 and 1-12.43]

a) For single-phase motors—IEEE Std 114
b) For polyphase induction motors—IEEE Std 112

9.9 Variations from Rated Voltage and Rated Frequency

9.9.1 Running

Alternating-current motors shall 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 for induction motors.
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. [MG1-12.44.1]

9.9.2 Starting

Medium motors shall start and accelerate to running speed a load which has a torque characteristic and an inertia value not exceeding that listed in 9.18, with the voltage and frequency variations specified in 9.9.1.

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. [MG1-12.44.2]

9.10 Voltage Unbalance

Alternating-current polyphase motors shall operate successfully under running conditions at rated load when the voltage unbalance at the motor terminals does not exceed 1 percent. Performance will not necessarily be the same as when the motor is operating with a balanced voltage at the motor terminals. [MG1-12.45]

Unbalanced currents resulting from unequal line voltages applied to an induction motor produces an elevated temperature rise compared to a motor operating with balanced voltages. Should voltages be unbalanced, the motor horsepower rating should be derated in accordance with MG1 Part 14. (See Figure 7.) [MG1-14.36]

9.11 Variation from Rated Speed

The variation from the nameplate or published data speed of alternating-current, single-phase and polyphase, medium motors shall not exceed 20 percent of the difference between synchronous speed and rated speed when measured at rated voltage, frequency, and load and with an ambient temperature of 25°C. [MG1-12.46]

9.12 Variation from Nameplate Amperes—Alternating-Current Medium Motors

When operated at rated voltage, rated frequency, and rated horsepower output, the input in amperes shall not vary from the nameplate value by more than 10 percent. [MG1-12.47]

9.13 Occasional Excess Current

Polyphase motors having outputs not exceeding 500 horsepower and rated voltages not exceeding 1kV shall be capable of withstanding a current equal to 1.5 times the full load rated current for not less than two minutes when the motor is initially at normal operating temperature.

Repeated overloads resulting in prolonged operation at winding temperatures above the maximum values given in 9.8 will result in reduced insulation life. [MG1-12.48]

9.14 Stall Time

Polyphase motors having outputs not exceeding 500 horsepower and rated voltage not exceeding 1kV shall be capable of withstanding locked-rotor current for not less than 12 seconds when the motor is initially at normal operating temperatures.

Motors specially designed for inertia loads greater than those in Table 45 shall be marked on the nameplate with the permissible stall time in seconds (see 7.10). [MG1-12.49]

9.15 Service Factor of Alternating-Current Motors

9.15.1 General-Purpose Alternating-Current Motors of the Open Type

When operated at rated voltage and frequency, general purpose alternating-current motors of the open type shall have a service factor in accordance with Table 39. [MG1-12.51.1 and MG1-14.37]

When an induction motor is operated at any service factor greater than 1.0, it may have efficiency, power factor, and speed different from those at rated load. Locked-rotor torque and current and breakdown torque will remain unchanged. A motor operating continuously at any service factor greater than 1.0 will have a reduced life expectancy compared to operating at its rated nameplate horsepower. [MG1-14.37]

In those applications requiring an overload capacity, the use of a higher horsepower rating is recommended to avoid exceeding the temperature rises for the class of insulation system used and to provide adequate torque capacity [MG1-12.51.2]

9.16 Overspeeds for Squirrel-Cage Motors

Squirrel-cage induction motors, except crane motors, shall be so constructed that, in an emergency not to exceed 2 minutes, they will withstand without mechanical damage overspeeds above synchronous speed in accordance with Table 40. [MG1-12.52.1]

9.16.1 General Purpose Squirrel-Cage Induction Motors

General purpose squirrel-cage induction motors for the ratings specified in Table 41, except those described in 9.16.2 and horsepower per frame assignments in accordance with Table 14, Table 15, Table 16, Table 17, and Table 18 shall be mechanically constructed so as to be capable of operating continuously at the rated load at speeds not less than the speed indicated in Table 41. Those motors for which this speed is greater than synchronous speed at 60 Hz shall be capable of withstanding overspeeds, not to exceed 2 minutes, of 10 percent above the speed indicated in Table 41 without mechanical damage. For motors where the speed in Table 41 is equal to synchronous speed at 60 Hz, the overspeed limits in 9.16 shall apply. [MG1-12.52.2]

Table 41 does not apply to motors used in belted applications. For belted applications consult the motor manufacturer.

9.16.2 General-Purpose Design A and B Direct-Coupled Squirrel-Cage Induction Motors

General-purpose Design A and B (TS shaft for motors above the 250 frame size) squirrel-cage induction motors for the ratings specified in Table 42 and horsepower per frame assignments in accordance with Table 15 and Table 16 be mechanically constructed so as to be capable of operating continuously at the rated load at speeds not less than the speed indicated in Table 42 when directly coupled. Those motors for which this speed is greater than the synchronous speed at 60 Hz shall be capable of withstanding overspeeds, not to exceed 2 minutes, of 10 percent above the speed indicated in Table 42 without mechanical damage. For motors where the speed in Table 42 is equal to synchronous speed at 60 Hz, the overspeed limits in 9.16 shall apply. [MG1-12.52.3]

Table 42 does not apply to motors used in belted applications. For belted applications consult the motor manufacturer.

9.17 Machine Sound (Medium Induction Motors)

9.17.1 General

Acoustic quantities can be expressed in sound pressure terms or sound power terms. The use of a sound power level, which can be specified independently of the measurement surface and environmental conditions, avoids the complications associated with sound pressure levels which require additional data to be specified. Sound power levels provide a measure of radiated energy and have advantages in acoustic analysis and design. [MG1-9.2]

9.17.2 Sound Measurement

Sound level measurements and calculation of sound power level produced by the motor shall be in accordance with either ANSI S12.12, S12.31, S12.33, S12.34, or S12.35, unless otherwise specified. [MG1-9.4.1]

The standard load condition shall be no-load. [MG1-9.5.2]

It should be recognized that decibel readings are not exact and are subject to many external influences. For further information see NEMA Standards Publication *Sound Level Prediction for Installed Rotating Electrical* Motors, MG 3-1990.

9.17.3 Sound Power Levels of Polyphase Squirrel-Cage Induction Motors at No Load

When a motor is tested under the conditions specified in MG1-9.5.2, the sound power level of the TEFC, ODP, and WPII motors shall not exceed the relevant value(s) specified in Table 43 when operating at no-load. [MG1-9.6.2]

9.17.4 Sound Power Levels of Polyphase Squirrel-Cage Induction Motors at Rated Load

When a single-speed, three-phase, squirrel-cage, induction motor of ODP, TEFC or WPII construction, with outputs from 0.5 HP through 500 HP is tested under rated load the sound power level should not exceed the sum of the values specified in Table 43 and Table 44. [MG1-9.6.3]

NOTES

1 The limits of the tables recognize class 2 accuracy grade levels of measurement uncertainty and production variations.

2 Sound power levels under load conditions are normally higher than those at no-load. Generally, if ventilation noise is predominant the change may be small, but if the electromagnetic noise is predominant the change may be significant.

9.18 Number of Starts

Squirrel-cage induction motors having horsepower ratings given in Table 8 and performance characteristics in accordance with MG1 Part 12[1] shall be capable of accelerating without injurious heating load Wk^2 referred to the motor shaft equal to or less than the values listed in Table 45 under the following conditions:

a) Applied voltage and frequency in accordance with 9.9.
b) During the accelerating period, the connected load torque is equal to or less than a torque which varies as the square of the speed and is equal to 100 percent of rated-load torque at rated speed.
c) Two starts in succession (coasting to rest between starts) with the motor initially at the ambient temperature or one start with the motor initially at a temperature not exceeding its rated load operating temperature.

If the starting conditions are other than those stated above, the motor manufacturer should be consulted.

[1] Locked-rotor torque in accordance with the paragraph on *Locked-Rotor Torque of Single-Speed Polyphase Squirrel-Cage Medium Motors with Continuous Rating* (9.7.2), breakdown torque in accordance with the paragraph on *Breakdown Torque of Single-Speed Polyphase Squirrel-Cage Medium Motors with Continuous Rating* (9.7.3), Class A or B insulation system with temperature rise in accordance with the paragraph titled *Temperature Rise for Medium Single-Phase and Polyphase Induction Motors* (9.8), and service factor in accordance with the paragraph titled *Service Factor of Alternating-Current Motors* (9.15).

When additional starts are required, it is recommended that none be made until all conditions affecting operation have been thoroughly investigated and the apparatus examined for evidence of excessive heating. It should be recognized that the number of starts should be kept to a minimum since the life of the motor is affected by the number of starts. [MG1-12.54]

9.19 Thermal Protection of Medium Motors

The protector in a thermally-protected motor shall limit the winding temperature and the ultimate trip current as follows: [MG1-12.56]

9.19.1 Winding Temperature

9.19.1.1 Running Load

When a motor marked “Thermally Protected” is running at the maximum continuous load which it can carry without causing the protector to open the circuit, the temperature of the windings shall not exceed that in Table 46.

Tests shall be conducted at any ambient temperature within the range of 10°C to 40°C.

The temperature of the windings shall be measured by the resistance method except that, for motors rated 15 horsepower and smaller, the temperature shall alternatively be permitted to be measured by the thermocouple method.

Short-time rated motors and motors for intermittent duty shall be permitted to be run at no load and reduced voltage, if necessary, for a continuous running test to verify that the protector limits the temperatures to those given in the foregoing table. [MG1-12.56.1.1]

9.19.1.2 Locked-Rotor

When a motor marked “Thermally Protected” is under locked-rotor conditions, the thermal protector shall cycle to limit the winding temperature to the values given in Table 47.

The test for motors with automatic-reset thermal protectors shall be run until temperature peaks are constant or for 72 hours, whichever is shorter.

The test for motors with manual-reset thermal protectors shall be 10 cycles, the protector being reclosed as quickly as possible after it opens. If ten cycles are completed in less than 1 hour, only the “during first hour” limits given in Table 47 apply. [MG1-12.56.1.2]

9.19.1.3 Trip Current

A motor rated more than 1 horsepower and marked “Thermally Protected” shall have an ultimate trip current, based on a 40°C ambient temperature, not in excess of the percentages of motor full-load currents in Table 48.

Dual-voltage motors shall comply with the ultimate trip current requirements for both voltages. [MG1-12.56.2]

9.20 Overtemperature Protection of Medium Motors Not Meeting The Definition of “Thermally Protected”

Motors rated above 1 horsepower and marked “OVER TEMP PROT-” are provided with winding overtemperature protection devices or systems which do not meet the definition of “Thermally Protected.”

The motors marked “OVER TEMP PROT-” shall be followed by the numeral 1, 2, or 3 stamped in the blank space to indicate the type of winding overtemperature protection provided. For each type, the winding overtemperature protector shall limit the temperature of the winding as follows. [MG1-12.57]

9.20.1 Type 1—Winding Running and Locked Rotor Overtemperature Protection

9.20.1.1 Winding Running Temperature

When the motor is marked “OVER TEMP PROT-1” and is running at the maximum continuous load which it can carry without causing the winding overtemperature protector to operate, the temperature of the windings shall not exceed the temperature shown in Table 46.

The temperature of the windings shall be measured by the resistance method except that, for motors rated 15 horsepower and smaller, the temperature shall be permitted to be measured by the thermocouple method. [MG1-12.57.1.1]

9.20.1.2 Winding Locked-Rotor Temperature

In addition, when the motor is marked "OVER TEMP PROT 1" and is under locked-rotor conditions, the winding overtemperature protector shall limit the temperature of the windings to the values shown in Table 47. [MG1-12.57.1.2]

9.20.2 Type 2—Winding Running Overtemperature Protection

When the motor is marked "OVER TEMP PROT 2" and is running at the maximum continuous load which it can carry without causing the winding overtemperature protector to operate, the temperature of the windings shall not exceed the temperature shown in Table 46.

When the motor is so marked, locked-rotor protection is not provided by the winding overtemperature protector. [MG1-12.57.2]

9.20.3 Type 3—Winding Overtemperature Protection, Nonspecific Type

When the motor is marked "OVER TEMP PROT 3," the motor manufacturer shall be consulted for details of protected conditions or winding temperatures, or both. [MG1-12.57.3]

9.21 Efficiency

9.21.1 Determination of Motor Efficiency and Losses

Efficiency and losses shall be determined in accordance with IEEE Std 112 or Canadian Standards Association Standard C390. The efficiency shall be determined at rated output, voltage, and frequency.

Unless otherwise specified, horizontal polyphase, squirrel-cage medium motors rated 1 to 500 horsepower shall be tested by dynamometer (Method B)[1] as described in Section 6.4 of IEEE Std 112. Motor efficiency shall be calculated using Form B of IEEE Std 112 or the equivalent C390 calculation procedure. Vertical motors of this horsepower range shall also be tested by Method B if bearing construction permits; otherwise they shall be tested by segregated losses (Method E)[2] as described in Section 6.6 of IEEE Std 112, including direct measurement of stray-loss load.

The following losses shall be included in determining the efficiency.

a) Stator I^2R
b) Rotor I^2R
c) Core loss
d) Stray load loss
e) Friction and windage loss[3]

Power required for auxiliary items, such as external pumps or fans, that are necessary for the operation of the motor shall be stated separately.

In determining I^2R losses at all loads, the resistance of each winding shall be corrected to a temperature equal to an ambient temperature of 25°C plus the observed rated load temperature rise measured by resistance. When the rated load temperature rise has not been measured, the resistance of the winding shall be corrected to that in Table 49 for the class of insulation system. If the rated temperature rise is specified as that of a lower class of insulation system, the temperature for resistance correction shall be that of the lowest insulation class. [MG1-12.58.1]

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[1] CSA Std C390 Method 1.

[2] CSA Std C390 Method 2.

[3] In the case of motors which are furnished with thrust bearings, only that portion of the thrust bearing loss produced by the motor itself shall be included in the efficiency calculation. Alternatively, a calculated value of efficiency, including bearing loss due to external thrust load, shall be permitted to be specified. In the case of motors which are furnished with less than a full set of bearings, friction and windage losses which are representative of the actual installation shall be determined by (1) calculation or (2) experience with shop test bearings and shall be included in the efficiency calculations.

9.21.2 Efficiency of Polyphase Squirrel-Cage Medium Motors with Continuous Ratings

The full-load efficiency of Design A and B single-speed polyphase squirrel-cage medium motors in the range of 1 through 350 horsepower for frames assigned in accordance with Table 15 or Table 16, above 350 horsepower up to and including 500 horsepower, and equivalent Design C ratings shall be identified on the nameplate by a nominal efficiency selected from the Nominal Efficiency column in Table 50 which shall be not greater than the average efficiency of a large population of motors of the same design.

The efficiency shall be identified on the nameplate by the caption "NEMA Nominal Efficiency" or "NEMA Nom. Eff."

The full-load efficiency, when operating at rated voltage and frequency, shall be not less than the minimum value indicated in Column B of Table 50 associated with the nominal value in Column A.

Variations in materials, manufacturing processes, and tests result in motor-to-motor efficiency variations for a given motor design; the full-load efficiency for a large population of motors of a single design is not a unique efficiency but rather a band of efficiency. Therefore, Table 50 has been established to indicate a logical series of nominal motor efficiencies and the minimum associated with each nominal. The nominal efficiency represents a value which should be used to compute the energy consumption of a motor or group of motors. [MG1-12.58.2]

9.21.3 Efficiency Levels of Energy Efficient Polyphase Squirrel-Cage Induction Motors

The nominal full-load efficiency of polyphase squirrel-cage induction motors rated 600 volts or less determined in accordance with 9.21.1, identified on the nameplate in accordance with 9.21.2, and having a corresponding minimum efficiency in accordance with Column B of Table 50, shall equal or exceed the values listed in Table 51 for the motor to be classified as "energy efficient." [MG1-12.59]

9.21.4 Efficiency Levels Of Nema Premium™ Efficiency Electric Motors

9.21.4.1 Motors Rated 600 Volts or Less (Random Wound)

The nominal full-load efficiency of random wound NEMA Premium™ Efficiency electric motors rated 600 volts or less determined in accordance with 9.21.1, identified on the nameplate in accordance with 9.21.2, and having a corresponding minimum efficiency in accordance with Column B of Table 50, shall equal or exceed the values listed in Table 52. [MG1-12.60.2]

9.21.4.2 Motors Rated Medium Voltage, 5000 Volts or Less (Form Wound)

The nominal full-load efficiency of form wound NEMA Premium™ Efficiency electric motors rated at a medium voltage of 5000 volts or less determined in accordance with 9.21.1, identified on the nameplate in accordance with 9.21.2, and having a corresponding minimum efficiency in accordance with Column B of Table 50, shall equal or exceed the values listed in Table 53. [MG1-12.60.1]

9.21.5 Typical Variations of Efficiency with Load

The efficiency of polyphase induction motors varies from zero at no load to a maximum value near rated load and then decreases as load increases. The efficiency versus load curves in Figure 8 illustrate the typical profile of efficiency variation for various motor ratings. Actual values of motor efficiencies at various load levels can be obtained from the motor manufacturer. [MG1-14.47]

10. APPLICATION DATA—AC SMALL AND MEDIUM MOTORS

10.1 Service Conditions

The following service conditions are defined as "usual":

a) An ambient temperature in the range of -15°C to 40°C or, when water cooling is used, 5°C to 40°C.
b) Exposure to an altitude not exceeding 3300 feet (1000 meters).
c) Installation on a rigid mounting surface.
d) Installation in areas or supplementary enclosures which do not seriously interfere with the ventilation of the machine.

e) Voltage variation within 10% of rated voltage at rated frequency (see 9.9).
f) Frequency variation within 5% of rated frequency (see 9.9).
g) Unbalance of the voltages of the alternating-current supply does not exceed 1% (see 9.10).
h) V-belt drive in accordance with MG1 Part 14.
i) Flat-belt, chain, and gear drives in accordance with MG1 Part 14.

The manufacturer should be consulted if any unusual service conditions exist which may affect the construction or operation of the machine. [MG1-14.2]

Examples of typical applications for general purpose small and medium ac squirrel –cage induction motors are shown in Table 11.

11. APPLICATION CONSIDERATIONS FOR CONSTANT SPEED DESIGN A AND B INDUCTION MOTORS USED ON A SINUSOIDAL BUS WITH HARMONIC CONTENT

11.1 Efficiency

Efficiency will be reduced when a motor is operated on a bus with harmonic content. The harmonics present will increase the electrical losses which decrease efficiency. This increase in losses will also result in an increase in motor temperature, which further reduces efficiency. [MG1-30. 1.1]

11.2 Derating for Harmonic Content

Harmonic currents are introduced when the line voltages applied to a polyphase induction motor include voltage components at frequencies other than nominal (fundamental) frequency of the supply. Consequently, the temperature rise of the motor operating at a particular load and per unit voltage harmonic factor will be greater than that for the motor operating under the same conditions with only voltage at the fundamental frequency applied.

When a motor is operated at its rated conditions and the voltage applied to the motor consists of components at frequencies other than the nominal frequency, the rated horsepower of the motor should be multiplied by the factor shown in Figure 9 to reduce the possibility of damage to the motor. This curve is developed under the assumption that only harmonics equal to odd multiples (except those divisible by three) of the fundamental frequency are present. It is assumed that any voltage unbalance or any even harmonics, or both, present in the voltage are negligible. This derating curve is not intended to apply when the motor is operated at other than its rated frequency nor when operated from a variable voltage or a variable frequency power supply, or both. [MG1-30. 1.2]

11.2.1 Harmonic Voltage Factor (HVF) Defined

The harmonic voltage factor (HVF) is defined as follows:

$$\sqrt{\sum_{n=5}^{n=\infty} \frac{V_n^2}{n}}$$

Where:

n = order of odd harmonic, not including those divisible by three

V_n = the per-unit magnitude of the voltage at the n^{th} harmonic frequency

Example: With per-unit voltages of 0.10, 0.07, 0.045, and 0.036 occurring at the 5, 7, 11, and 13th harmonics, respectively, the value of the HVF is:

$$\sqrt{\frac{0.10^2}{5} + \frac{0.07^2}{7} + \frac{0.045^2}{11} + \frac{0.036^2}{13}} = 0.0546$$

[MG1-30.1.2.1]

11.3 Power Factor Correction

The proper application of power capacitors to a bus with harmonic currents requires an analysis of the power system to avoid potential harmonic resonance of the power capacitors in combination with transformer and circuit inductance. For power distribution systems which have several motors connected to a bus, power capacitors connected to the bus rather than switched with individual motors are recommended to minimize potentially resonant combinations of capacitance and inductance, and to simplify the application of any tuning filters that may be required. This requires that such bus-connected capacitor banks be sized so that proper bus voltage limits are maintained. [MG1-30.1.3] (See MG1 Part 14.)

12. APPLICATION CONSIDERATIONS FOR GENERAL PURPOSE DESIGN A AND B INDUCTION MOTORS USED WITH ADJUSTABLE-VOLTAGE OR ADJUSTABLE-FREQUENCY CONTROLS OR BOTH

12.1 Torque

12.1.1 Motor Torque During Operation Below Base Speed

To develop constant torque below base speed by maintaining constant air-gap flux the motor input voltage should be varied to maintain approximately rated volts per hertz. At frequencies below approximately 30 hertz an increase in the volts per hertz ratio (boost voltage) may be required to maintain air-gap flux (i.e., constant torque). For applications that require less than rated torque below base speed, system economics may be improved by operation at a reduced volts per hertz ratio. [MG1-30. 2.2.2.1]

12.1.2 Torque Derating at Reduced Speeds

Induction motors to be operated in adjustable-speed drive applications should be derated as a result of the reduction in cooling of the motor resulting from the reduction in operating speed and the effect of the additional losses introduced by harmonics in the power source. The effect of derating must be evaluated on an application-by-application basis. [MG1-30.2.2.2.2 and MG1-30.2.2.2.3]

12.1.3 Motor Torque During Operation Above Base Speed

Above base speed, a motor input voltage having a fundamental component equal to rated motor voltage (which may be limited by the control and its input power) as frequency increases will result in constant horsepower operation (torque reducing with reduced volts per hertz). The maximum (breakdown) torque capability of the motor within this speed range will limit the maximum frequency (and speed) at which constant horsepower operation is possible.

General purpose motors are capable of constant horsepower above base speed up to 90 Hz. The maximum frequency of 90 hertz is established based on the approximate peak torque capability of greater than 175 percent for NEMA Design A and B motors assuming operation at a constant level of voltage equal to rated voltage from 60 to 90 hertz. For the capability of motors for which the minimum breakdown torque is less than 175 percent, consult the motor manufacturer.

For operation above 90 hertz at a required horsepower level, it may be necessary to utilize a motor with a greater horsepower rating at 60 hertz.

However, the maximum speed at which a motor can safely operate may be limited to some speed below the maximum speed related to its load carrying capability because of mechanical considerations. (See 12.4.) [MG1-30. 2.2.2.4]

12.2 Current

12.2.1 Running Current

Controls are generally rated in terms of a continuous output current capability, a short term output current , and a peak output current. To properly choose the size of control required in an application, consideration should be given to the peak and transient values in addition to the rms value of motor current, and the manner in which the system is to be operated. Because some level of current will exist at each of the harmonic frequencies characteristic of the particular type of control, the total rms sum of current required at full load may be from 5 percent to 10 percent greater than that level of current

corresponding to operation on a sinusoidal power source. The magnitude of the peak values of the current waveform may vary from 1.3 to 2.5 times the rms value of the current, depending on the type of control considered and the motor characteristics. An additional margin from 10 percent to 50 percent in the current rating of the control should be considered to allow for possible overload conditions on the motor so as not to trip the control on such short time overcurrent demand. When the motor and control are used in a system where sudden changes in load torque or frequency might occur, the control should be sized based on the peak value of the transient current which results from the sudden change. Also, when changing from one operating speed to another, if the rate of change in frequency is greater than the possible rate of change in motor speed and if the slip increases beyond the value of slip at rated load, then the amount of rms current or peak current required from the control may exceed that of the steady state requirements. [MG1-30. 2.2.4.1]

12.2.2 Starting Current

In a stall condition, the amount of current drawn by an induction motor is primarily determined by the magnitude and frequency of the applied voltage and the impedance of the motor. Under variable frequency control, motors are normally started by applying voltage to the motor at a low frequency (less than 3 hertz). The current drawn by the motor under this condition is mainly a function of the equivalent stator and rotor resistances since the reactive impedance is small because of the low frequency. In order to provide sufficient starting torque, it is necessary to provide an increase in voltage (voltage boost) at low frequencies in order to overcome this resistive drop in the motor. This voltage boost is the product of the required phase current (for the level of breakaway torque needed) and the stator phase resistance and the square root of 3 (to convert phase quantity to line-to-line value). A wye connection is assumed. For rated torque at start it will be necessary to adjust the voltage boost to have at least rated current. Since stator and rotor resistances vary with temperature, the actual starting current will be a function of the machine temperature. [MG1-30. 2.2.4.2]

12.3 Efficiency

Motor efficiency will be reduced when it is operated on a control. The harmonics present will increase the electrical losses, which decrease efficiency. This increase in losses will also result in an increase in motor temperature, which further reduces efficiency. [MG1-30. 2.2.5]

12.4 Maximum Safe Operating Speeds

The maximum safe operating speed capability of a typical standard general-purpose Design A or B motor, direct-coupled, at 0–40°C ambient temperature should not exceed the values given in Table 54. For possible operation at speeds greater than those given in the table or conditions other than those stated consult the motor manufacturer. For motors not covered by the table, refer to 9.16 consult the motor manufacturer if required. [MG1-30. 2.2.3]

12.5 Sound

Sound levels should be considered when using induction motors with an adjustable frequency and voltage power supply. Sound levels produced thus will be higher than published values when operated above rated speed.

Experience has shown that typically an increase in the A-weighted noise level by up to 6 dB can occur at rated frequency when motors are used with non-PWM (pulse width modulated) controls, in comparison with operation at sinusoidal supply voltage and frequency. An increase of up to 5 dB to 15 dB can occur at rated frequency in the case when motors are used with pulse-width-modulated PWM controls. For other frequencies the noise levels may be higher. [MG1-30. 2.2.6]

12.6 Resonances, Sound, Vibration

When an induction motor is operated from a control, torque ripple at various frequencies may exist over the operating speed range. Consideration should be given to identifying the frequency and amplitude of these torques and determining the possible effect upon the motor and the driven equipment. It is of particular importance that the equipment not be operated longer than momentarily at a speed where a resonant condition exists between the torsional system and the electrical system (i.e., the motor electrical torque). For example, if the inverter is of the six-step type then a sixth harmonic torque ripple is created

which would vary from 36 to 360 hertz when the motor is operated over the frequency range of 6 to 60 hertz. At low speeds, such torque ripple may be apparent as observable oscillations of the shaft speed or as torque and speed pulsations (usually termed “cogging”). It is also possible that some speeds within the operating range may correspond to the natural mechanical frequencies of the load or support structure and operation other than momentarily could be damaging to the motor and or load and should be avoided at those speeds. [MG1-30. 2.2.7]

12.7 Voltage Stress

When operated under usual service conditions the following voltage limit values at the motor terminals should be observed. [MG1-30. 2.2.8]

$V_{peak} \leq 1kV$

Rise time $\geq 2\mu s$

12.8 Power Factor Correction

The use of power capacitors for power factor correction on the load side of an electronic control connected to an induction motor is not recommended. {MG1-30. 2.2.9]

12.9 Operation in Hazardous (Classified) Locations

WARNING: Motors operated from adjustable frequency or adjustable voltage power supplies or both, should not be used in any Division 1 hazardous (classified) locations unless the motor is identified on the nameplate as acceptable for such operation when used in Division 1 hazardous (classified) locations

For motors to be used in any Division 2 hazardous (classified) locations, the motor manufacturer should be consulted.

Failure to comply with this warning could result in an unsafe installation that could cause damage to property or serious injury or death to personnel, or both. [MG1-30. 2.2.10]

TABLES

Table 1 [MG1-12.0]

Synchronous Speed	Motors, Squirrel-cage, HP
3600	500
1800	500
1200	350
900	250
720	200
600	150
514	125

TABLE 2

ALTERNATING CURRENT MEDIUM MOTOR [MG1 TABLE 1–1]

Synchronous Speed, RPM	Motors HP
1201-3600	500
901-1200	350
721-900	250
601-720	200
515-600	150
451-514	125

TABLE 3

DEGREES OF PROTECTION INDICATED BY THE FIRST AND SECOND CHARACTERISTIC NUMERALS [MG1 TABLE 5-1 & 5-2]

First Characteristic Numeral	Brief Description	Brief Definition	Second Characteristic Numeral	Brief Description	Brief Definition
0	Non-protected motor	No special protection.	0	Non-protected motor	No special protection.
1	Motor protected against solid object greater than 50 mm	Contact with a large surface of the human body	1	Motor protected against dripping water	Vertically falling drops
2	Motor protected against solid objects greater than 12 mm	Contact by fingers or similar objects not exceeding 80 mm in length and 12 mm in diameter	2	Motor protected against dripping water when tilted up to 15 degrees	Machine tilted 15° from normal position
3	Motor protected against solid objects greater than 2.5 mm	Contact with or approach to live or moving parts inside the enclosure by tools or wires exceeding 2.5 mm in diameter. Ingress of solid objects exceeding 2.5 mm in diameter.	3	Motor protected against spraying water	Protected from spray at any angle up to 60° from the vertical
4	Motor protected against solid objects greater than 1 mm	Contact by wires or strips of thickness greater than 1 mm	4	Motor protected against splashing water	Protected from water splashing from any direction
5	Dust-protected machine	Ingress of dust is not totally prevented but does not interfere with operation	5	Motor protected against water jets	Protected from water projected from a nozzle from any direction
6	Dust-tight machine	No ingress of dust	6	Motor protected against heavy seas	Protected from sea water or water from powerful jets

TABLE 3

DEGREES OF PROTECTION INDICATED BY THE FIRST AND SECOND CHARACTERISTIC NUMERALS [MG1 TABLE 5-1 & 5-2]

First Characteristic Numeral	Brief Description	Brief Definition	Second Characteristic Numeral	Brief Description	Brief Definition
—	—	—	7	Motor protected against effects of immersion	Ingress of water is not possible when immersed under stated conditions of pressure and time
—	—	—	8	Motor protected against continuous submersion	Motor is suitable for continuous submersion subject to conditions stated by the manufacturer

TABLE 4

TYPICAL METHODS OF COOLING (IC CODE)

NEMA	IC	Circuit Arrangement	Primary Coolant	Method of Movement	Secondary Coolant	Method of Movement
WP-I	IC	0	A	1		
WP-II	IC	0	A	1		
ODP	IC	0	A	1		
TEFC (guarded)	IC	4	A	1	A	1
TEBC	IC	4	A	1	A	6
TENV	IC	4	A	1	A	0
TEAO	IC	4	A	1	A	7

Complete designation — full description (3 or 5 numerals or letters {numeral letter numeral [letter numeral]}

Simplified designation — 2 or 3 numerals or letters in the final position {numeral numeral numeral or numeral numeral letter}.

Example: The COMPLETE designation of TEFC guarded would be IC4A1A1; the SIMPLIFIED designation would be IC 411.

TABLE 5

UNFILTERED VIBRATION LIMITS [MG1-7.8.2]

Speed, rpm	Rotational Frequency, Hz	Velocity, in/s peak (mm/s)
3600	60	0.15 (3.8)
1800	30	0.15 (3.8)
1200	20	0.15 (3.8)
900	15	0.12 (3.0)
720	12	0.09 (2.3)
600	10	0.08 (2.0)

TABLE 6

HORSEPOWER AND SPEED RATINGS, SMALL INDUCTION MOTORS [MG1 TABLES 10-1 & 10-2]

		All Motors Except Permanent-Split Capacitor	Permanent-Split Capacitor Motors		All Motors Except Permanent-Split Capacitor	Permanent-Split Capacitor Motors
Hp	60-Hz Synchronous Rpm	Approximate Rpm at Rated Load		50-Hz Synchronous Rpm	Approximate Rpm at Rated Load	
1/4 and 1/3	3600	3450	3250	3000	2850	2700
	1800	1725	1625	1500	1425	1350
	1200	1140	1075	1000	950	900
	900	850	825	—	—	—
1/2	3600	3450	3250	3000	2850	2700
	1800	1725	1625	1500	1425	1350
	1200	1140	1075	1000	950	900
3/4	3600	3450	3250	3000	2850	2700
	1800	1725	1625	1550	1425	1350
1	3600	3450	3250	3000	2850	2700

TABLE 7

HORSEPOWER AND SPEED RATINGS, SINGLE-PHASE MEDIUM MOTORS [MG1 TABLE 10-3]

HP	60-Hertz Synchronous Speed				50-Hertz Synchronous Speed			
1/2	—	—	—	900	—	—	1000	750
3/4	—	—	1200	900	—	1500	1000	750
1	—	1800	1200	900	3000	1500	1000	750
1-1/2	3600	1800	1200	900	3000	1500	1000	750
2	3600	1800	1200	900	3000	1500	1000	750
3	3600	1800	1200	900	3000	1500	1000	750
5	3600	1800	1200	900	3000	1500	1000	750
7-1/2	3600	1800	1200	900	3000	1500	1000	750
10	3600	1800	1200	900	3000	1500	1000	750

TABLE 8

HORSEPOWER AND SPEED RATINGS, POLYPHASE MEDIUM INDUCTION MOTORS [MG1 TABLE 10-4]

HP	60-Hertz Synchronous Rpm							50-Hertz Synchronous Rpm			
1/2	—	—	—	900	720	600	514	—	—	—	750
3/4	—	—	1200	900	720	600	514	—	—	1000	750
1	—	1800	1200	900	720	600	514	—	1500	1000	750
1-1/2	3600	1800	1200	900	720	600	514	3000	1500	1000	750
2	3600	1800	1200	900	720	600	514	3000	1500	1000	750
3	3600	1800	1200	900	720	600	514	3000	1500	1000	750
5	3600	1800	1200	900	720	600	514	3000	1500	1000	750
7-1/2	3600	1800	1200	900	720	600	514	3000	1500	1000	750
10	3600	1800	1200	900	720	600	514	3000	1500	1000	750
15	3600	1800	1200	900	720	600	514	3000	1500	1000	750
20	3600	1800	1200	900	720	600	514	3000	1500	1000	750
25	3600	1800	1200	900	720	600	514	3000	1500	1000	750
30	3600	1800	1200	900	720	600	514	3000	1500	1000	750
40	3600	1800	1200	900	720	600	514	3000	1500	1000	750
50	3600	1800	1200	900	720	600	514	3000	1500	1000	750
60	3600	1800	1200	900	720	600	514	3000	1500	1000	750
75	3600	1800	1200	900	720	600	514	3000	1500	1000	750
100	3600	1800	1200	900	720	600	514	3000	1500	1000	750
125	3600	1800	1200	900	720	600	514	3000	1500	1000	750
150	3600	1800	1200	900	720	600	—	3000	1500	1000	750
200	3600	1800	1200	900	720	—	—	3000	1500	1000	750
250	3600	1800	1200	900	—	—	—	3000	1500	1000	750
300	3600	1800	1200	—	—	—	—	3000	1500	1000	—
350	3600	1800	1200	—	—	—	—	3000	1500	1000	—
400	3600	1800	—	—	—	—	—	3000	1500	—	—
450	3600	1800	—	—	—	—	—	3000	1500	—	—
500	3600	1800	—	—	—	—	—	3000	1500	—	—

TABLE 9

BREAKDOWN TORQUE FOR INDUCTION MOTORS, EXCEPT PERMANENT-SPLIT CAPACITOR MOTORS*† [MG1 TABLE 10-5]

60	50	60	50	60	50	60	50		Frequencies, Hz
3600	3000	1800	1500	1200	1000	900	750		Synchronous Speeds, Rpm
3450**	2850**	1725**	1425**	1140**	950**	850**	—	Hp	Small Motors, Nominal Speeds, Rpm
11.5-16.5	13.8-19.8	21.5-31.5	25.8-37.8	31.5-44.0	37.8-53.0	40.5-58.0		1/4	The figures at left are for small motors. Break-down torques in oz-ft
16.5-21.5	19.8-25.8	31.5-40.5	37.8-48.5	44.0-58.0	53.0-69.5	58.0-77.0	—	1/3	
21.5-31.5	25.8-37.8	40.5-58.0	48.5-69.5	58.0-82.5	69.5-99.0	‡	‡	1/2	
31.5-44.0	37.8-53.0	58.0-82.5	69.5-99.0	5.16-6.9	‡	‡	‡	3/4	
44.0-58.0	53.0-69.5	5.16-6.8	6.19-8.2	6.9-9.2	‡	‡	‡	1	
3.6--4.6	4.3-5.5	6.8-10.1	8.2-12.1	9.2-13.8	‡	‡	‡	1-1/2	The figures at left are for medium motors. Break-down torques in lb-ft.
4.6-6.0	5.5-7.2	10.1-13.0	12.1-15.6	13.8-18.0	‡	‡	‡	2	
6.0-8.6	7.2-10.2	13.0-19.0	15.6-22.8	18.0-25.8	‡	‡	‡	3	
8.6-13.5	10.2-16.2	19.0-30.0	22.8-36.0	25.8-40.5	‡	‡	‡	5	
13.5-20.0	16.2-24.0	30.0-45.0	36.0-54.0	40.5-60.0	‡	‡	‡	7-1/2	
20.0-27.0	24.0-32.4	45.0-60.0	54.0-72.0	‡	‡	‡	‡	10	

*The breakdown torque range includes the higher figure down to, but not including, the lower figure.

**These approximate full-load speeds apply only for small motor ratings.

†The horsepower ratings of motors designed to operate on two or more frequencies shall be determined by the torque at the highest rated frequency.

‡These are ratings for which no torque values have been established.

TABLE 10

BREAKDOWN TORQUE FOR PERMANENT-SPLIT CAPACITOR MOTORS FOR FAN AND PUMP APPLICATIONS*† [MG1 TABLE 10-6]

60	50	60	50	60		Frequencies, Hz
1800	1500	1200	1000	900		Synchronous Speeds, Rpm
See *Table 8*.					HP	Approximate Full-Load Speeds, Rpm
16.0-21.0	19.1-25.4	23.6-31.5	28.3-37.6	31.0-41.0	1/4	The figures at left are for break-down torques in oz-ft.
21.0-31.5	25.4-37.7	31.5-47.0	37.6-56.5	41.0-61.0	1/3	
31.5-47.5	37.7-57.3	47.0-70.8	56.5-84.8	3.81-5.81	1/2	
47.5-63.5	57.3-76.5	4.42-5.8	5.30-7.06	5.81-7.62	3/4	The figures at left are break-down torques in lb-ft.
3.97-5.94	4.78-7.06	5.88-8.88	7.06-10.6	7.62-11.6	1	
5.94-7.88	7.06-9.56	8.88-11.8	10.6-14.1	11.6-15.2	1-1/2	

*The breakdown torque range includes the higher figure down to, but not including, the lower figure.

†The horsepower rating of motors designed to operate on two or more frequencies shall be determined by the torque at he highest rated frequency.

TABLE 11

TYPICAL CHARACTERISTICS AND APPLICATIONS OF FIXED FREQUENCY SMALL AND MEDIUM AC SQUIRREL-CAGE INDUCTION MOTORS

Polyphase Characteristics	Locked Rotor Torque (Percent Rated Load Torque	Pull-Up Torque (Percent Rated Load Torque)	Breakdown Torque (Percent Rated Load Torque)	Locked Rotor Current (Percent Rated Load Current)	Slip	Typical Applications	Relative Efficiency
Design A High locked rotor torque and high locked rotor current	70-275*	65-190	175-300*	Not defined	0.5-5%	Fans, blowers, centrifugal pumps and compressors, motor-generator sets, etc., where starting torque requirements are relatively low.	Medium or high
Design B Normal locked rotor torque and normal locked rotor current	70-275*	65-190	175-300*	600-700	0.5-5%	Fans, blowers, centrifugal pumps and compressors, motor-generator sets, etc., where starting torque requirements are relatively low.	Medium or high
Design C High locked rotor torque and normal locked rotor current	200-285*	140-195	190-225*	600-700	1-5%	Conveyors, crushers, stirring motors, agitators, reciprocating pumps and compressors, etc., where starting under load is required	Medium
Design D High locked rotor torque and high slip	275	NA	275	600-700	5-8%	High peak loads with or without flywheels such as punch presses, shears, elevators, extractors, winches, hoists, oil-well pumping and wire-drawing motors	Low
Design N Small motor	—	NA	—	—	NA	Centrifugal loads where starting torque requirements are relatively low.	Low
Design O Small motor	—	NA	—	—	NA		
Design L Medium motor	—	100%	—	—	NA	Fans, blowers, centrifugal pumps and compressors, motor-generator sets, etc., where starting torque requirements are relatively low.	Medium or Low
Design M Medium motor	—	100%	—	—	NA	Fans, blowers, centrifugal pumps and compressors, motor-generator sets, etc., where starting torque requirements are relatively low.	Medium or high

*Higher values are for motors having lower horsepower ratings.

Table 12

Code Letters (for Locked-Rotor kVA)—Nameplate Marking [MG1-10.37.2]

Letter Designation	kVA per Horsepower*	Letter Designation	kVA per Horsepower*
A	0-3.15	K	8.0-9.0
B	3.15-3.55	L	9.0-10.0
C	3.55-4.0	M	10.0-11.2
D	4.0-4.5	N	11.2-12.5
E	4.5-5.0	P	12.5-14.0
F	5.0-5.6	R	14.0-16.0
G	5.6-6.3	S	16.0-18.0
H	6.3-7.1	T	18.0-20.0
J	7.1-8.0	U	20.0-22.4
		V	22.4-and up

*Locked kVA per horsepower range includes the lower figure up to, but not including, the higher figure. For example, 3.14 is designated by letter A and 3.15 by letter B.

TABLE 13

MEDIUM MACHINE FRAME NUMBERING [MG1 TABLE 4-2]

Frame Number Series	Third/Fourth Digit in Frame Number								
	D	1	2	3	4	5	6	7	
		2 F Dimensions							
140	3.50	3.00	3.50	4.00	4.50	5.00	5.50	6.25	
160	4.00	3.50	4.00	4.50	5.00	5.50	6.25	7.00	
180	4.50	4.00	4.50	5.00	5.50	6.25	7.00	8.00	
200	5.00	4.50	5.00	5.50	6.50	7.00	8.00	9.00	
210	5.25	4.50	5.00	5.50	6.25	7.00	8.00	9.00	
220	5.50	5.00	5.50	6.25	6.75	7.50	9.00	10.00	
250	6.25	5.50	6.25	7.00	8.25	9.00	10.00	11.00	
280	7.00	6.25	7.00	8.00	9.50	10.00	11.00	12.50	
320	8.00	7.00	8.00	9.00	10.50	11.00	12.00	14.00	
360	9.00	8.00	9.00	10.00	11.25	12.25	14.00	16.00	
400	10.00	9.00	10.00	11.00	12.25	13.75	16.00	18.00	
440	11.00	10.00	11.00	12.50	14.50	16.50	18.00	20.00	
500	12.50	11.00	12.50	14.00	16.00	18.00	10.00	22.00	
580	14.50	12.50	14.00	16.00	18.00	20.00	22.00	25.00	
680	17.00	16.00	18.00	20.00	22.00	25.00	28.00	32.00	
Frame Number Series		**Third/Fourth Digit in Frame Number**							
	D	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
		2F Dimensions							
140	3.50	7.00	8.00	9.00	10.00	11.00	12.50	14.00	16.00
160	4.00	8.00	9.00	10.00	11.00	12.50	14.00	16.00	18.00
180	4.50	9.00	10.00	11.00	12.50	14.00	16.00	18.00	20.00
200	5.00	10.00	11.00	...	...	...	...	...	...
210	5.25	10.00	11.00	12.50	14.00	16.00	18.00	20.00	22.00
220	5.50	11.00	12.50	...	...	...	...	...	...
250	6.25	12.50	14.00	16.00	18.00	20.00	22.00	25.00	28.00
280	7.00	14.00	16.00	18.00	20.00	22.00	25.00	28.00	32.00
320	8.00	16.00	18.00	20.00	22.00	25.00	28.00	32.00	36.00
360	9.00	18.00	20.00	22.00	25.00	28.00	32.00	36.00	40.00
400	10.00	20.00	22.00	25.00	28.00	32.00	36.00	40.00	45.00
440	11.00	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00
500	12.50	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00
580	14.50	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
680	17.00	36.00	40.00	45.00	50.00	56.00	63.00	71.00	80.00

All dimensions in inches.

TABLE 14

FRAME DESIGNATIONS FOR SINGLE-PHASE, DESIGN L, HORIZONTAL AND VERTICAL MOTORS, 60 HERTZ, CLASS B INSULATION SYSTEM, OPEN TYPE, 1.15 SERVICE FACTOR, 230 VOLTS AND LESS [MG1-13.1]

HP	Speed, Rpm		
	3600	1800	1200
3/4	—	—	145T
1	—	143T	182T
1-1/2	143T	145T	184T
2	145T	182T	—
3	182T	184T	—
5	184T	213T	—
7-1/2	213T	215T	—

TABLE 15

FRAME DESIGNATIONS FOR POLYPHASE, SQUIRREL-CAGE, DESIGNS A AND B HORIZONTAL AND VERTICAL MOTORS, 60 HERTZ, CLASS B INSULATION SYSTEM, OPEN TYPE, 1.15 SERVICE FACTOR, 575 VOLTS AND LESS* [MG1-13.2]

HP	Speed, Rpm			
	3600	1800	1200	900
1/2	—	—	—	143T
3/4	—	—	143T	145T
1	—	143T	145T	182T
1-1/2	143T	145T	182T	184T
2	145T	145T	184T	213T
3	145T	182T	213T	215T
5	182T	184T	215T	254T
7-1/2	184T	213T	254T	256T
10	213T	215T	256T	284TS
15	215T	254T	284TS	286TS
20	254T	256T	286TS	324TS
25	256T	284TS	324TS	326TS
30	284TS	286TS	326TS	364TS
40	286TS	324TS	364TS	365TS
50	324TS	326TS	365TS	404TS
60	326TS	364TS†	404TS	405TS
75	364TS	365TS†	405TS	444TS
100	365TS	404TS†	444TS	445TS
125	404TS	405TS†	445TS	447TS
150	405TS	444TS†	447TS	449TS
200	444TS	445TS†	449TS	—
250	445TS‡	447TS†	—	—
300	447TS‡	449TS‡	—	—
350	449TS‡	—	—	—

*The voltage rating of 115 volts applies only to motors rated 15 horsepower and smaller.

†When motors are to be used with V-belt or chain drives, the correct frame size is the size shown but with the suffix letter S omitted. For the corresponding shaft extension dimensions, Table 20.

‡The 250, 300, and 350 horsepower ratings at the 3600 rpm speed have a 1.0 service factor.

TABLE 16

FRAME DESIGNATIONS FOR POLYPHASE, SQUIRREL-CAGE, DESIGNS A AND B HORIZONTAL AND VERTICAL MOTORS, 60 HERTZ, CLASS B INSULATION SYSTEM, TOTALLY-ENCLOSED FAN-COOLED TYPE, 1.00 SERVICE FACTOR, 575 VOLTS AND LESS* [MG1-13.3]

	Speed, Rpm			
HP	3600	1800	1200	900
1/2	—	—	—	143T
3/4	—	—	143T	145T
1	—	143T	145T	182T
1-1/2	143T	145T	182T	184T
2	145T	145T	184T	213T
3	182T	182T	213T	215T
5	184T	184T	215T	254T
7-1/2	213T	213T	254T	256T
10	215T	215T	256T	284T
15	254T	254T	284T	286T
20	256T	256T	286T	324T
25	284TS	284T	324T	326T
30	286TS	286T	326T	364T
40	324TS	324T	364T	365T
50	326TS	326T	365T	404T
60	364TS†	364TS†	404T	405T
75	365TS†	365TS†	405T	444T
100	405TS†	405TS†	444T	445T
125	444TS†	444TS†	445T	447T
150	445TS†	445TS†	447T	449T
200	447TS	447TS†	449T	—
250	449TS	449TS	—	—

*The voltage rating of 115 volts applies only to motors rated 15 horsepower and smaller.

†When motors are to be used with V-belt or chain drives, the correct frame size is the size shown but with the suffix letter S omitted. For the corresponding shaft extension dimensions, Table 20..

TABLE 17

FRAME DESIGNATIONS FOR POLYPHASE, SQUIRREL-CAGE, DESIGN C, HORIZONTAL AND VERTICAL MOTORS, 60 HERTZ, CLASS B INSULATION SYSTEM, OPEN TYPE, 1.15 SERVICE FACTOR, 575 VOLTS AND LESS* [MG1-13.4]

	Speed, Rpm		
HP	1800	1200	900
1	143T	145T	182T
1-1/2	145T	182T	184T
2	145T	184T	213T
3	182T	213T	215T
5	184T	215T	254T
7-1/2	213T	254T	256T
10	215T	256T	284T
15	254T	284T	286T
20	256T	286T	324T
25	284T	324T	326T
30	286T	326T	364T
40	324T	364T	365T
50	326T	365T	404T
60	364TS†	404T	405T
75	365TS†	405T	444T
100	404TS†	444T	445T
125	405TS†	445T	447T
150	444TS†	447T	449T
200	445TS†	449T	—

*The voltage rating of 115 volts applies only to motors rated 15 horsepower and smaller.

†When motors are to be used with V-belt or chain drives, the correct frame size is the size shown but with the suffix letter S omitted. For the corresponding shaft extension dimensions, see Table 20.

TABLE 18

FRAME DESIGNATIONS FOR POLYPHASE, SQUIRREL-CAGE, DESIGN C, HORIZONTAL AND VERTICAL MOTORS, 60 HERTZ, CLASS B INSULATION SYSTEM, TOTALLY ENCLOSED FAN-COOLED TYPE, 1.0 SERVICE FACTOR, 575 VOLTS AND LESS* [MG1-13.5]

	Speed, Rpm		
HP	1800	1200	900
1	143T	145T	182T
1-1/2	145T	182T	184T
2	145T	184T	213T
3	182T	213T	215T
5	184T	215T	254T
7-1/2	213T	254T	256T
10	215T	256T	284T
15	254T	284T	286T
20	256T	286T	324T
25	284T	324T	326T
30	286T	326T	364T
40	324T	364T	365T
50	326T	365T	404T
60	364TS†	404T	405T
75	365TS†	405T	444T
100	405TS†	444T	445T
125	444TS†	445T	447T
150	445TS†	447T	449T
200	447TS†	449T	—

*The voltage rating of 115 volts applies only to motors rated 15 horsepower and smaller.

†When motors are to be used with V-belt or chain drives, the correct frame size is the size shown but with the suffix letter S omitted. For the corresponding shaft extension dimensions, see Table 20..

TABLE 19

LETTERING OF DIMENSION SHEETS [MG1-4.1]

NEMA Letter	IEC Letter	Dimension Indicated
A	AB	Overall dimension across feet of horizontal motor (end view)
B	BB	Overall dimension across feet of horizontal motor (side view)
C	L	Overall length of single shaft extension motor (For overall length of double shaft extension motor, see letter dimension FC.)
D	H	Centerline of shaft to bottom of feet
E	—	Centerline of shaft to centerline of mounting holes in feet (end view)
2E	A	Distance between centerlines of mounting holes in feet or base of motor (end view)
2F	B	Distance between centerlines of mounting holes in feet or base of motor (side view)
G	HA	Thickness of mounting foot at H hole or slot
H	K	Diameter of holes or width of slot in feet of motor
J	AA	Width of mounting foot at mounting surface
K	—	Length of mounting foot at mounting surface
N	—	Length of shaft from end of housing to end of shaft, drive end
O	HC	Top of horizontal motor to bottom of feet
P	AC	Maximum width of motor (end view) including pole belts, fins, etc., but excluding terminal housing, lifting devices, feet, and outside diameter of face or flange
R	G	Bottom of keyseat or flat to opposite side of shaft or bore
S	F	Width of keyseat
T	—	Height of eye bolt above top of motor
U	D	Diameter of shaft extension. (For tapered shaft, this is diameter at a distance V from the threaded portion of the shaft.)
V	—	Length of shaft for coupling, pinion, or pulley hub, drive end. (On a straight shaft extension, this is a

TABLE 19

LETTERING OF DIMENSION SHEETS [MG1-4.1]

NEMA Letter	IEC Letter	Dimension Indicated
		minimum value.)
W	—	For straight and tapered shaft, end of housing to shoulder. (For shaft extensions without shoulders, it is a clearance to allow for all manufacturing variations in parts and assembly.)
AA	—	Threaded or clearance hole for external conduit entrance (expressed in conduit size) to terminal housing
AB	AD	Centerline of shaft to extreme outside part of terminal housing (end view)
AC	—	Centerline of shaft to centerline of hole AA in terminal housing (end view)
AD	—	Centerline of terminal housing mounting to centerline of hole AA (side view)
AE	—	Centerline of terminal housing mounting to bottom of feet (end view)
AF	—	Centerline of terminal housing mounting to hole AA (end view)
AG	LB	Mounting surface of face, flange, or base of motor to opposite end of housing (side view)
AH	—	Mounting surface of face, flange, or base of motor to end of shaft
AJ	M	Diameter of mounting bolt circle in face, flange, or base of motor
AK	N	Diameter of male or female pilot of face, flange, or base of motor
BA	C	Center line of mounting hole in nearest foot to the shoulder on drive end shaft (For motors without a shaft shoulder, it is the centerline of mounting hole in nearest foot to the housing side of N-W dimension.)
BB	T	Depth of male or female pilot of mounting face, flange, or base of motor
BC	R	Distance between mounting surface of face, flange, or base of motor to shoulder on shaft. (For motor without a shaft shoulder, it is the distance between the mounting surface of face, flange, or base of motor to housing side of N-W dimension)
BD	P	Outside diameter of mounting face, flange, or base of motor
BE	LA	Thickness of mounting flange of base of motor
BF	S	Threaded or clearance hole in mounting face, flange, or base of motor
BS	—	Centerline of foot mounting hole, shaft end, to centerline of terminal housing mounting (side view)

TABLE 20

DIMENSIONS FOR ALTERNATING-CURRENT FOOT-MOUNTED MOTORS WITH SINGLE STRAIGHT-SHAFT EXTENSION [1, 2, 3, 4, 5] [MG1-4.4.1]

Frame	A Max	D*	E†	2F†	BA***	H†	U	N-W	V Min	Keyseat R	Keyseat ES Min	Keyseat S	AA Min††
42	—	2.62	1.75	1.69	2.06	0.28 slot	0.3750	1.12	...	0.328	...	flat	...
48	—	3.00	2.12	2.75	2.50	0.34 slot	0.5000	1.50	...	0.453	...	flat	...
48H	—	3.00	2.12	4.75	2.50	0.34 slot	0.5000	1.50	...	0.453	...	flat	...
56	—	3.50	2.44	3.00	2.75	0.34 slot	0.6250	1.88	...	0.517	1.41	0.188	...
56H	—	3.50	2.44	5.00	2.75	0.34 slot	0.6250	1.88	...	0.517	1.41	0.188	...
143T	7.0	3.50	2.75	4.00	2.25	0.34 hole	0.8750	2.25	2.00	0.771	1.41	0.188	3/4
145T	7.0	3.50	2.75	5.00	2.25	0.34 hole	0.8750	2.25	2.00	0.771	1.41	0.188	3/4
182T	9.0	4.50	3.75	4.50	2.75	0.41 hole	1.1250	2.75	2.50	0.986	1.78	0.250	3/4
184T	9.0	4.50	3.75	5.50	2.75	0.41 hole	1.1250	2.75	2.50	0.986	1.78	0.250	3/4
213T	10.5	5.25	4.25	5.50	3.50	0.41 hole	1.3750	3.38	3.12	1.201	2.41	0.312	1
215T	10.5	5.25	4.25	7.00	3.50	0.41 hole	1.3750	3.38	3.12	1.201	2.41	0.312	1
254T	12.5	6.25	5.00	8.25	4.25	0.53 hole	1.625	4.00	3.75	1.416	2.91	0.375	1-1/4
256T	12.5	6.25	5.00	10.00	4.25	0.53 hole	1.625	4.00	3.75	1.416	2.91	0.375	1-1/4
284T	14.0	7.00	5.50	9.50	4.75	0.53 hole	1.875	4.62	4.38	1.591	3.28	0.500	1-1/2
284TS	14.0	7.00	5.50	9.50	4.75	0.53 hole	1.625	3.25	3.00	1.416	1.91	0.375	1-1/2
286T	14.0	7.00	5.50	11.00	4.75	0.53 hole	1.875	4.62	4.38	1.591	3.28	0.500	1-1/2
286TS	14.0	7.00	5.50	11.00	4.75	0.53 hole	1.625	3.25	3.00	1.416	1.91	0.375	1-1/2
324T	16.0	8.00	6.25	10.50	5.25	0.66 hole	2.125	5.25	5.00	1.845	3.91	0.500	2
324TS	16.0	8.00	6.25	10,50	5.25	0.66 hole	1.875	3.75	3.50	1.591	2.03	0.500	2
326T	16.0	8.00	6.25	12.00	5.25	0.66 hole	2.125	5.25	5.00	1.845	3.91	0.500	2
326TS	16.0	8.00	6.25	12.00	5.25	0.66 hole	1.875	3.75	3.50	1.591	2.03	0.500	2
364T	18.0	9.00	7.00	11.25	5.88	0.66 hole	2.375	5.88	5.62	2.021	4.28	0.625	3
364TS	18.0	9.00	7.00	11.25	5.88	0.66 hole	1.875	3.75	3.50	1.591	2.03	0.500	3
365T	18.0	9.00	7.00	12.25	5.88	0.66 hole	2.375	5.88	5.62	2.021	4.28	0.625	3
365TS	18.0	9.00	7.00	12.25	5.88	0.66 hole	1.875	3.75	3.50	1.591	2.03	0.500	3
404T	20.0	10.00	8.00	12.25	6.62	0.81 hole	2.875	7.25	7.00	2.450	5.65	0.750	3
404TS	20.0	10.00	8.00	12.25	6.62	0.81 hole	2.125	4.25	4.00	1.845	2.78	0.500	3
405T	20.0	10.00	8.00	13.75	6.62	0.81 hole	2.875	7.25	7.00	2.450	5.65	0.750	3
405TS	20.0	10.00	8.00	13.75	6.62	0.81 hole	2.125	4.25	4.00	1.845	2.78	0.500	3
444T	22.0	11.00	9.00	14.50	7.50	0.81 hole	3.375	8.50	8.25	2.880	6.91	0.875	3
444TS	22.0	11.00	9.00	14.50	7.50	0.81 hole	2.375	4.75	4.50	2.021	3.03	0.625	3
445T	22.0	11.00	9.00	16.50	7.50	0.81 hole	3.375	8.50	8.25	2.880	6.91	0.875	3
445TS	22.0	11.00	9.00	16.50	7.50	0.81 hole	2.375	4.75	4.50	2.021	3.03	0.625	3
447T	22.0	11.00	9.00	20.00	7.50	0.81 hole	3.375	8.50	8.25	2.880	6.91	0.875	3
447TS	22.0	11.00	9.00	20.00	7.50	0.81 hole	2.375	4.75	4.50	2.021	3.03	0.625	3
449T	22.0	11.00	9.00	25.00	7.50	0.81 hole	3.375	8.50	8.25	2.880	6.91	0.875	3
449TS	22.0	11.00	9.00	25.00	7.50	0.81 hole	2.375	4.75	4.50	2.021	3.03	0.625	3
440	...	11.00	9.00	**	7.50	...	...	...	...	...	...	...	
500	...	12.50	10.00	**	8.50	...	...	...	...	...	...	...	

(Table 20 c0ntinued on following page)

(*Table 20 Continued.)*

All dimensions in inches.
*The tolerances on the D dimension for rigid base motors shall be +0.00 inch, -0.06 inch. No tolerance has been established for the D dimension of resilient mounted motors.
†Frames 42 to 56H, inclusive—The tolerance for the 2F dimension shall be ±0.03 inch and for the H dimension (width of slot) shall be +0.02 inch, -0 inch.
Frames 143T to 500, inclusive—The tolerance for the 2E and 2F dimensions shall be ±0.03 inch and for the H dimension shall be +0.05 inch, -0 inch.
The values of the H dimension represent standard bolt sizes plus dimensional clearances.
H dimension:; Frames 143T to 365T inclusive—The clearance of the std. bolt to hole size is 0.03. The tolerance is +0.05, -0.00 inch. Frames 404T to 449T inclusive—The clearance of std. bolt to hole size is 0.06 inch. The tolerance is =0.020 inch, -0.00 inch.
††For dimensions of clearance holes see MG1 Part 4.
**For the 2F dimension and corresponding third (and when required the fourth) digit in the frame series, see 8.1, and Table 20...
***BA tolerance: ±0.09 inch.
NOTES 1—It is recommended that all motors with keyseats cut in the shaft extension pulley, coupling, pinion, and so forth, be furnished with a key unless otherwise specified by the purchaser.
2—Frames 42 to 56H, inclusive,—If the shaft extension length of the motor is not suitable for the application, it is recommended that deviations from this length be in 0.25-inch increments.
3— For cast-iron products, bottom of feet coplanar: 0.015 inch. (See MG1 Part 4.)
4— For cast-iron products, foot top parallel to foot bottom: 1.5 degree
5— For cast-iron products, shaft parallel to foot plane: 0.015 inch (See MG1 Part 4.)
[1]For the meaning of the letter dimensions, see Table 19 and Figures 3 through 5..
[2]For tolerances on shaft extension diameters and keyseats see MG1 Part 4.

TABLE 21

SHAFT EXTENSIONS AND KEY DIMENSIONS FOR ALTERNATING-CURRENT FOOT-MOUNTED MOTORS WITH SINGLE TAPERED OR DOUBLE STRAIGHT/TAPERED SHAFT EXTENSION[1, 2] [MG1-4.4.2]

Drive End—Tapered Shaft Extension*

Frame Designation	BA	U	N-W	V	X	Y	Z Max	Shaft Threads	Keyseat Width	Keyseat Depth	Key Length**
143TR and 145TR	2.25	0.8750	2.62	1.75	1.88	0.75	1.38	5/8-18	0.188	0.094	1.50
182TR and 184TR	2.75	1.1250	3.38	2.25	2.38	0.88	1.50	3/4-16	0.250	0.125	2.00
213TR and 215TR	3.50	1.3750	4.12	2.62	2.75	1.25	2.00	1-14	0.312	0.156	2.38
254TR and 256TR	4.25	1.625	4.50	2.88	3.00	1.25	2.00	1-14	0.375	0.188	2.62
284TR and 286TR	4.75	1.875	4.75	3.12	3.25	1.25	2.38	1-1/4-12	0.500	0.250	2.88
324TR and 326TR	5.25	2.125	5.25	3.50	3.62	1.38	2.75	1-1/2-8	0.500	0.250	3.25
364TR and 365TR	5.88	2.375	5.75	3.75	3.88	1.50	3.25	1-3/4-8	0.625	0.312	3.50
404TR and 405TR	6.62	2.875	6.62	4.38	4.50	1.75	3.62	2-8	0.750	0.375	4.12
444TR and 445TR	7.50	3.375	7.50	5.00	5.12	2.00	4.12	2-1/4-8	0.875	0.438	4.75

	OPPOSITE DRIVE END—TAPERED SHAFT EXTENSION*†										**OPPOSITE DRIVE END—STRAIGHT SHAFT EXTENSION†**					
								Keyseat						Keyseat		
Frame Number Series	FU	FN-FW	FV	FX	FY	FZ Max	Shaft Threads	Width	Depth	Key Length	FU	FN-FW	FV Min	R	ES Min	S
140	0.6250	2.00	1.38	1.50	0.50	1.12	3/8-24	0.188	0.094	1.12	0.6250	1.62	1.38	0.517	0.91	0.188
180	0.8750	2.62	1.75	1.88	0.75	1.38	5/8-18	0.188	0.094	1.50	0.8750	2.25	2.00	0.771	1.41	0.188
210	1.1250	3.38	2.25	2.38	0.88	1.50	3/4-16	0.250	0.125	2.00	1.1250	2.75	2.50	0.986	1.78	0.250
250	1.3750	4.12	2.62	2.75	1.25	2.00	1-14	0.312	0.156	2.38	1.3750	3.38	3.12	1.201	2.41	0.312
280	1.6250	4.50	2.88	3.00	1.25	2.00	1-14	0.375	0.188	2.62	1.625	4.00	3.75	1.416	2.91	0.375
280 Short Shaft											1.625	3.25	3.00	1.416	1.91	0.375
320	1.8750	4.75	3.12	3.25	1.25	2.38	1-1/4-12	0.500	0.250	2.88	1.875	4.62	4.38	1.591	3.28	0.500
320 Short Shaft											1.875	3.75	3.50	1.591	2.03	0.500
360	1.8750	4.75	3.12	3.25	1.25	2.38	1-1/4-12	0.500	0.250	2.88	1.875	3.75	3.50	1.591	2.03	0.500
360 Short Shaft											1.875	3.75	3.50	1.591	2.03	0.500
400	2.1250	5.25	3.50	3.62	1.38	2.75	1-1/2-8	0.500	0.250	3.25	2.125	5.25	5.00	1.845	3.91	0.500
400 Short Shaft											2.125	4.25	4.00	1.845	2.78	0.500
440	2.3750	5.75	3.75	3.88	1.50	3.25	1-3/4-8	0.625	0.312	3.50	2.375	5.88	5.62	2.021	4.28	0.625
440 Short Shaft											2.375	4.75	4.50	2.021	3.03	0.625

All dimensions in inches.

*The standard taper of shafts shall be at the rate of 1.25 inch in diameter per foot of length. The thread at the end of the tapered shaft shall be provided with a nut and a suitable locking device.

**Tolerance on the length of the key is ±0.03 inch.

†For drive applications other than direct connect, the motor manufacturer should be consulted.

NOTE—It is recommended that all motors with keyseats cut in the shaft extension for pulley, coupling, pinion, etc., be furnished with a key unless otherwise specified by the purchaser.

[1]For the meaning of the letter dimensions, see Table 19 and Figures 3 through 5...

[2]For tolerances on shaft extension diameters and keyseats see MG1 Part 4.

TABLE 22

DIMENSIONS FOR TYPE C FACE-MOUNTING FOOT OR FOOTLESS ALTERNATING-CURRENT MOTORS[1, 2, 3] [MG1-4.4.4]

Frame Designation*							BF Hole					Keyseat		
	AJ**	AK	BA	BB Min	BC	BD Max	Number	Tap Size	Bolt Penetration Allowance	U	AH	R	ES Min	S
42C	3.750	3.000	2.062	0.16†	-0.19	5.00††	4	1/4-20	...	0.3750	1.312	0.328	...	flat
48C	3.750	3.000	2.50	0.16†	-0.19	5.625	4	1/4-20	...	0.500	1.69	0.453	...	flat
56C	5.875	4.500	2.75	0.16†	-0.19	6.50††	4	3/8-16	...	0.6250	2.06	0.517	1.41	0.188
143TC and 145TC	5.875	4.500	2.75	0.16†	+0.12	6.50††	4	3/8-16	0.56	0.8750	2.12	0.771	1.41	0.188
182TC and 184TC	7.250	8.500	3.50	0.25	+0.12	9.00	4	1/2-13	0.75	1.1250	2.62	0.986	1.78	0.250
182TC and 184TCH	5.875	4.500	3.50	0.16†	+0.12	6.50††	4	3/8-16	0.56	1.1250	2.62	0.986	1.78	0.250
213TC and 215TC	7.250	8.500	4.25	0.25	+0.25	9.00	4	1/2-13	0.75	1.3750	3.12	1.201	2.41	0.312
254TC and 256TC	7.250	8.500	4.75	0.25	+0.25	10.00	4	1/2-13	0.75	1.625	3.75	1.416	2.91	0.375
284TC and 286TC	9.000	10.500	4.75	0.25	+0.25	11.25	4	1/2-13	0.75	1.875	4.38	1.591	3.28	0.500
284TSC and 286TSC	9.000	10.500	4.75	0.25	+0.25	11.25	4	1/2-13	0.75	1.625	3.00	1.416	1.91	0.375
324TC and 326TC	11.000	12.500	5.25	0.25	+0.25	14.00	4	5/8-11	0.94	2.125	5.00	1.845	3.91	0.500
324TSC and 326TSC	11.000	12.500	5.25	0.25	+0.25	14.00	4	5/8-11	0.94	1.875	3.50	1.591	2.03	0.500
364TC and 365TC	11.000	12.500	5.88	0.25	+0.25	14.00	4	5/8-11	0.94	2.375	5.62	2.021	4.28	0.625
364TSC and 365TSC	11.000	12.500	5.88	0.25	+0.25	14.00	8	5/8-11	0.94	1.875	3.50	1.591	2.03	0.500
404TC and 405TC	11.000	12.500	6.62	0.25	+0.25	15.50	8	5/8-11	0.94	2.875	7.00	2.450	5.65	0.750
404TSC and 405TSC	11.000	12.500	6.62	0.25	+0.25	15.50	8	5/8-11	0.94	2.125	4.00	1.845	2.78	0.500
444TC and 445TC	14.000	16.000	7.50	0.25	+0.25	18.00	8	5/8-11	0.94	3.375	8.25	2.880	6.91	0.875
444TSC and 445TSC	14.000	16.000	7.50	0.25	+0.25	18.00	8	5/8-11	0.94	2.375	4.50	2.021	3.03	0.625
447TC and 449TC	14.000	16.000	7.50	0.25	+0.25	18.00	8	5/8-11	0.94	3.375	8.25	2.880	6.91	0.875
447TSC and 449TSC	14.000	16.000	7.50	0.25	+0.25	18.00	8	5/8-11	0.94	2.375	4.50	2.021	3.03	0.625
500 frame series	14.500	16.500	...	0.25	+0.25	18.00	4	5/8-11	0.94	...	...	...	...	...

All dimensions in inches.

*For frames 42C to 445TSC, see Table 20.

**For frames 182TC, 184TC, and 213TC through 500TC, the centerline of the bolt holes shall be within 0.025 inch of true location. True location is defined as angular and diametrical location with reference to the centerline of the AK dimension.

†The tolerance on this BB dimension shall be +0.00 inch, -0.06 inch.

††These BD dimensions are nominal dimensions.

NOTES

1—It is recommended that all motors with keyseats cut in the shaft extension for pulley, pinion, etc., be furnished with a key unless otherwise specified by the purchaser.

2—If the shaft extension length of the motor is not suitable for the application, it is recommended that deviations from this length be in 0.25-inch increments.

[1]For the meaning of the letter dimensions see Table 19 and Figure 5.

[2]For tolerances on shaft extension diameters and keyseats see MG1 Part 4.

[3]For tolerances on AK dimensions, face runout, and permissible eccentricity of mounting rabbet, see MG1 Part 4.

TABLE 23

DIMENSIONS FOR TYPE D FLANGE-MOUNTING FOOT OR FOOTLESS ALTERNATING-CURRENT MOTORS[1, 2, 3, 4] [MG1-4.4.6]

								BF Hole					Keyseat		
Frame Designation	AJ	AK	BA	BB*	BC	BD Max	BE Nom	Number	Size	Recom-mended Bolt Length	U	AH	R	ES Min	S
143TD and 145TD	10.00	9.000	2.75	0.25	0.00	11.00	0.50	4	0.53	1.25	0.8750	2.25	0.771	1.41	0.188
182TD and 184TD	10.00	9.000	3.50	0.25	0.00	11.00	0.50	4	0.53	1.25	1.1250	2.75	0.986	1.78	0.250
213TD and 215TD	10.00	9.000	4.25	0.25	0.00	11.00	0.50	4	0.53	1.25	1.3750	3.38	1.201	2.41	0.312
254TD and 256TD	12.50	11.000	4.75	0.25	0.00	14.00	0.75	4	0.81	2.00	1.625	4.00	1.416	2.91	0.375
284TD and 286TD	12.50	11.000	4.75	0.25	0.00	14.00	0.75	4	0.81	2.00	1.875	4.62	1.591	3.28	0.500
284TSD and 286TSD	12.50	11.000	4.75	0.25	0.00	14.00	0.75	4	0.81	2.00	1.625	3.25	1.416	1.91	0.375
324TD and 326TD	16.00	14.000	5.25	0.25	0.00	18.00	0.75	4	0.81	2.00	2.125	5.25	1.845	3.91	0.500
324TSD and 326TSD	16.00	14.000	5.25	0.25	0.00	18.00	0.75	4	0.81	2.00	1.875	3.75	1.591	2.03	0.500
364TD and 365TD	16.00	14.000	5.88	0.25	0.00	18.00	0.75	4	0.81	2.00	2.375	5.88	2.021	4.28	0.625
364TSD and 365TSD	16.00	14.000	5.88	0.25	0.00	18.00	0.75	4	0.81	2.00	1.875	3.75	1.591	2.03	0.500
404TD and 405TD	20.00	18.000	6.62	0.25	0.00	22.00	1.00	8	0.81	2.25	2.875	7.25	2.450	5.65	0.750
404TSD and 405TSD	20.00	18.000	6.62	0.25	0.00	22.00	1.00	8	0.81	2.25	2.125	4.25	1.845	2.78	0.500
444TD and 445TD	20.00	18.000	7.50	0.25	0.00	22.00	1.00	8	0.81	2.25	3.375	8.50	2.880	6.91	0.875
444TSD and 445TSD	20.00	18.000	7.50	0.25	0.00	22.00	1.00	8	0.81	2.25	2.375	4.75	2.021	3.03	0.625
447TD and 449TD	20.00	18.000	7.50	0.25	0.00	22.00	1.00	8	0.81	2.25	3.375	8.50	2.880	6.91	0.875
447TSD and 449TSD	20.000	18.000	7.50	0.25	0.00	22.00	1.00	8	0.81	2.25	2.375	4.75	2.021	3.03	0.625
500 frame series	22.000	18.000	...	0.25	0.00	22.00	1.00	8	0.81	...	...	...	...	...	...

All dimensions in inches.
*Tolerance is +0.00 inch, -0.06 inch.

[1]For the meaning of the letter dimensions see Table 19.
[2]See Table 20 for dimensions A, B, D, E, 2F, and H for frames 143TD-445TSD, and for dimensions D, E, 2F, and BA for the 500 frame series.
[3]For tolerances on shaft extension diameters and keyseats, see MG1 Part 4.
[4]For tolerances on AK dimensions, face runout, and permissible eccentricity of mounting rabbet, see Table 25.

TABLE 24

DIMENSIONS FOR TYPE FC FACE MOUNTING FOR ACCESSORIES ON END OPPOSITE DRIVE OF ALTERNATING-CURRENT MOTORS[1, 2]

[MG1-4.4.5]

Frame Designations	FAJ	FAK	FBB Min	FBD Min	FBF Hole			Hole for Accessory Leads††	
					Number	Tap Size	Bolt Penetration Allowance	DP	Diameter
143TFC and 145TFC	5.875	4.500	0.16*	6.50†	4	3/8-16	0.56	2.81	0.41
182TFC and 184TFC	5.875	4.500	0.16*	6.50†	4	3/8-16	0.56	2.81	0.41
213TFC and 215TFC	7.250	8.500	0.25	9.00	4	1/2-13	0.75	3.81	0.62
254TFC and 256TFC	7.250	8.500	0.25	10.00	4	1/2-13	0.75	3.81	0.62
284TFC and 286TFC	9.000	10.500	0.25	11.25	4	1/2-13	0.75	4.50	0.62
324TFC and 326TFC	11.000	12.500	0.25	14.00	4	5/8-11	0.94	5.25	0.62

*The tolerance on this FBB dimension shall be +0.00, -0.06 inch.

†This BD dimension is a nominal dimension.

††When a hole is required in the Type C face for accessory leads, the hole shall be located within the available area defined by a circle located in accordance with the figure and the table.

NOTE—Standards have not been developed for the FU, FAH, FBC, and keys at dimensions.

[1]For the meaning of the letter dimensions, see Table 19.

[2]For tolerances on FAK dimensions, face runout, and permissible eccentricity of mounting rabbets, see Table 25.

TABLE 25

TOLERANCES FOR TYPE C FACE FACE-MOUNTING AND TYPE D FLANGE-MOUNTING MOTORS

MAXIMUM ECCENTRICITY OF MOUNTING RABBET [MG1-4.12]

AK Dimensions, Inches	Tolerances AK on Dimension, Inches		Maximum Face Runout, Inches	Maximum Permissible Eccentricity of Mounting Rabbet , Inches
	Plus	Minus		
<12	0.000	0.003	0.004	0.004
≥12 to 24	0.000	0.005	0.007	0.007
>24 to 40	0.000	0.007	0.009	0.009

TABLE 26

MINIMUM SIZE GROUNDING CONDUCTOR TERMINATION [MG1 TABLE 4-7]

Motor Full-Load Currents	Maximum Size of Grounding Conductor Termination Attachment Means, AWG	Minimum Size of Screw, Stud, or Bolt	
ac		Steel	Bronze
12	14	#6	...
16	12	#8	...
30	10	#10	...
45	8	#12	#10
70	6	5/16”	#12
110	4	5/16”	5/16”
160	3	3/8”	5/16”
250	1	1/2”	3/8”
400	2/0	...	1/2”
600	3/0	...	1/2”

TABLE 27

LOCKED-ROTOR TORQUE OF SINGLE-PHASE SMALL MOTORS [MG1-12.32.2]

MINIMUM LOCKED-ROTOR TORQUE, OUNCE-FEET*						
	60-Hertz Synchronous Speed, RPM			50-Hertz Synchronous Speed, RPM		
HP	3600	1800	1200	3000	1500	1000
1/4	21	46	59	25	55	70
1/3	26	57	73	31	69	88
1/2	37	85	100	44	102	120
3/4	50	119	—	60	143	—
1	61	—	—	73	—	—

*On the high voltage connection of dual voltage motors, minimum locked-rotor torques up to 10% less than these values may be expected.

TABLE 28

LOCKED-ROTOR TORQUE OF SINGLE-PHASE MEDIUM MOTORS [MG1-12.32.3]

MINIMUM LOCKED-ROTOR TORQUE, POUND FEET			
	Synchronous Speed, RPM		
HP	3600	1800	1200
3/4	—	—	8.0
1	—	9.0	9.5
1-1/2	4.5	12.5	13.0
2	5.5	16.0	16.0
3	7.5	22.0	23.0
5	11.0	33.0	—
7-1/2	16.0	45.0	—
10	21.0	52.0	—

TABLE 29

LOCKED-ROTOR CURRENT OF SINGLE-PHASE SMALL MOTORS, DESIGNS N AND O [MG1-12.33.1]

2-, 4-, 6-, AND 8-POLE, 60-HERTZ MOTORS, SINGLE-PHASE				
	Locked-Rotor Current, Amperes			
	115 Volts		230 Volts	
HP	Design O	Design N	Design O	Design N
1/4	50	26	25	15
1/3	50	31	25	18
1/2	50	45	25	25
3/4	—	61	—	35
1	—	80	—	45

Table 30

LOCKED-ROTOR CURRENT OF SINGLE-PHASE MEDIUM MOTORS, DESIGNS L AND M [MG1-12.34]

HP	Locked-Rotor Current, Amperes		
	Design L Motors		Design M Motors
	115 Volts	230 Volts	230 Volts
1/2	45	25	—
3/4	61	35	—
1	80	45	—
1-1/2	—	50	40
2	—	65	50
3	—	90	70
5	—	135	100
7-1/2	--	200	150
10	—	260	200

TABLE 31

LOCKED-ROTOR CURRENT OF 3-PHASE 60-HERTZ SMALL AND MEDIUM SQUIRREL-CAGE INDUCTION MOTORS RATED AT 230 VOLTS [MG1-12.35.1]

HP	LOCKED-ROTOR CURRENT, AMPERES	DESIGN LETTERS	HP	LOCKED-ROTOR CURRENT, AMPERES	DESIGN LETTERS
1/2	20	B, D	60	870	B, C, D
3/4	25	B, D	75	1085	B, C, D
1	30	B, C, D	100	1450	B, C, D
1-1/2	40	B, C, D	125	1815	B, C, D
2	50	B, C, D	150	2170	B, C, D
3	64	B, C, D	200	2900	B, C,
5	92	B, C, D	250	3650	B
7-1/2	127	B, C, D	300	4400	B
10	162	B, C, D	350	5100	B
15	232	B, C, D	400	5800	B
20	290	B, C, D	450	6500	B
25	365	B, C, D	500	7250	B
30	435	B, C, D			
40	580	B, C, D			
50	725	B, C, D			

Note—The locked-rotor current of motors designed for voltages other than 230 volts shall be inversely proportional to the voltages.

TABLE 32

LOCKED-ROTOR TORQUE OF DESIGN A AND B MOTORS [MG1-12.38.1]

	Synchronous Speed, Rpm						
60 Hertz	3600	1800	1200	900	720	600	514
HP **50 Hertz**	**3000**	**1500**	**1000**	**750**	**—**	**—**	**—**
1/2	—	—	—	140	140	115	110
3/4	—	—	175	135	135	115	110
1	—	275	170	135	135	115	110
1-1/2	175	250	165	130	130	115	110
2	170	235	160	130	125	115	110
3	160	215	155	130	125	115	110
5	150	185	150	130	125	115	110
7-1/2	140	175	150	125	120	115	110
10	135	165	150	125	120	115	110
15	130	160	140	125	120	115	110
20	130	150	135	125	120	115	110
25	130	150	135	125	120	115	110
30	130	150	135	125	120	115	110
40	125	140	135	125	120	115	110
50	120	140	135	125	120	115	110
60	120	140	135	125	120	115	110
75	105	140	135	125	120	115	110
100	105	125	125	125	120	115	110
125	100	110	125	120	115	115	110
150	100	110	120	120	115	115	—
200	100	100	120	120	115	—	—
250	70	80	100	100	—	—	—
300	70	80	100	—	—	—	—
350	70	80	100	—	—	—	—
400	70	80	—	—	—	—	—
450	70	80	—	—	—	—	—
500	70	80	—	—	—	—	—

TABLE 33

LOCKED-ROTOR TORQUE OF DESIGN C MOTORS [MG1-12.38.2]

	Synchronous Speed, Rpm		
60 Hertz	1800	1200	900
HP **50 Hertz**	**1500**	**1000**	**750**
1	285	255	225
1-1/2	285	250	225
2	285	250	225
3	270	250	225
5	255	250	225
7-1/2	250	225	200
10	250	225	200
15	225	210	200
20-200, inclusive	200	200	200

TABLE 34

BREAKDOWN TORQUE OF DESIGN A AND B MOTORS [MG1-12.39.1]

	Synchronous Speed, Rpm						
	60 Hertz	3600	1800	1200	900	720	600	514
HP	50 Hertz	3000	1500	1000	750	—	—	—
1/2		—	—	—	225	200	200	200
3/4		—	—	275	220	200	200	200
1		—	300	265	215	200	200	200
1-1/2		250	280	250	210	200	200	200
2		240	270	240	210	200	200	200
3		230	250	230	205	200	200	200
5		215	225	215	205	200	200	200
7-1/2		200	215	205	200	200	200	200
10-125, inclusive		200	200	200	200	200	200	200
150		200	200	200	200	200	200	—
200		200	200	200	200	200	—	—
250		175	175	175	175	—	—	—
300-350		175	175	175	—	—	—	—
400-500, inclusive		175	175	—	—	—	—	—

TABLE 35

BREAKDOWN TORQUE OF DESIGN C MOTORS [MG1-12.39.2]

	Synchronous Speed, Rpm			
	60 Hertz	1800	1200	900
HP	50 Hertz	1500	1000	750
1		200	225	200
1-1/2		200	225	200
2		200	225	200
3		200	225	200
5		200	200	200
7-1/2–20		200	190	190
25–200, incl.		190	190	190`

TABLE 36
PULL-UP TORQUE OF DESIGN A AND B MOTORS [MG1-12.40.1]

	Synchronous Speed, Rpm							
	60 Hertz	**3600**	**1800**	**1200**	**900**	**720**	**600**	**514**
HP	**50 Hertz**	**3000**	**1500**	**1000**	**750**	**—**	**—**	**—**
1/2		—	—	—	100	100	100	100
3/4		—	—	120	100	100	100	100
1		—	190	120	100	100	100	100
1-1/2		120	175	115	100	100	100	100
2		120	165	110	100	100	100	100
3		110	150	110	100	100	100	100
5		105	130	105	100	100	100	100
7-1/2		100	120	105	100	100	100	100
10		100	115	105	100	100	100	100
15		100	110	100	100	100	100	100
20		100	105	100	100	100	100	100
25		100	105	100	100	100	100	100
30		100	105	100	100	100	100	100
40		100	100	100	100	100	100	100
50		100	100	100	100	100	100	100
60		100	100	100	100	100	100	100
75		95	100	100	100	100	100	100
100		95	100	100	100	100	100	100
125		90	100	100	100	100	100	100
150		90	100	100	100	100	100	—
200		90	90	100	100	100	—	—
250		65	75	90	90	—	—	—
300		65	75	90	—	—	—	—
350		65	75	90	—	—	—	—
400		65	75	—	—	—	—	—
450		65	75	—	—	—	—	—
500		65	75	—	—	—	—	—

TABLE 37

PULL-UP TORQUE OF DESIGN C MOTORS [MG1-12.40.2]

	Pull-Up Torque, Percent of Full-Load Torque			
	Synchronous Speed, Rpm			
	60 Hertz	1800	1200	900
HP	50 Hertz	1500	1000	750
1		195	180	165
1-1/2		195	175	160
2		195	175	160
3		180	175	160
5		175	175	160
7-1/2		175	160	140
10		175	160	140
15		160	140	140
20		140	140	140
25		140	140	140
30		140	140	140
40		140	140	140
50		140	140	140
60		140	140	140
75		140	140	140
100		140	140	140
125		140	140	140
150		140	140	140
200		140	140	140

Table 38

Temperature Rise for Small and Medium Single-Phase and Polyphase Induction Motors

Alternating-Current Small Motors—Motor Nameplates Marked with Insulation System Designation and Ambient Temperature [MG1-12.42.1]				
Class of Insulation System (see MG1 Part 1)	A	B	F*	H*
Time Rating (See page 9.)				
Temperature Rise (based on a maximum ambient temperature of 40°C), Degrees C				
a. Windings				
1. Open motors other than those given in items a.2 and a.5—resistance or thermocouple	60	80	105	125
2. Open motors with 1.15 or higher service factor—resistance or thermocouple.....	70	90	115	—
3. Totally-enclosed nonventilated motors, including variations thereof—resistance or thermocouple .	65	85	110	130
4. Totally-enclosed fan-cooled motors, including variation thereof—resistance or thermocouple	65	85	110	135
5. Any motor in a frame smaller than the 42 frame—resistance or thermocouple.	65	85	110	135

Medium Single-Phase and Polyphase Motors [MG1-12.43]				
Class of Insulation System (see MG1 Part 1)	A	B	F	H*†
Time Rating (shall be continuous or any short-time rating given in Time Ratings for Single-Phase and Polyphase Induction Motors)				
Temperature Rise (based on a maximum ambient temperature of 40°C), Degrees C				
a. Windings, by resistance method				
1. Motors with 1.0 service factor other than those given in items a.3 and a.4	60	80	105	125
2. All motors with 1.15 or higher service factor	70	90	115	—
3. Totally-enclosed nonventilated motors with 1.0 service factor	65	85	110	130
4. Motors with encapsulated windings and with service 1.0 factor, all enclosures	65	85	110	—
b. The temperatures attained by cores, squirrel-cage windings, and miscellaneous parts, (such as brushholders, brushes, pole tips, etc.) shall not injure the insulation or the machine in any respect.				

*Where a Class F or H insulation system is used, special consideration should be given to bearing temperatures, lubrication, etc.

†This column applies only to polyphase induction motors.

NOTES

1—Abnormal deterioration of insulation may be expected if the ambient temperature of 40°C is exceeded in regular operation. See Note 3.

2—The foregoing values of temperature rise are based upon operation at altitudes of 3300 feet (1000 meters) or less. For temperature rises for motors intended for operation at altitudes above 3300 feet (1000 meters) see MG1 Part 14.

3—The temperature rises given above are based upon a reference ambient temperature of 40°C. However, it is recognized that induction motors may be required to operate in an ambient temperature higher than 40°C. For successful operation of induction motors in ambient temperatures higher than 40°C, the temperature rises of the motors given in the forgoing tables shall be reduced by the number of degrees that the ambient temperature exceeds 40°C. When a higher ambient temperature than 40°C is required, preferred values of ambient temperatures are 50°C, 65°C, 90°C, and 115°C.

TABLE 39
SERVICE FACTORS OF GENERAL-PURPOSE ALTERNATING-CURRENT MOTORS OF THE OPEN TYPE [MG1 TABLE 12-4]

HP	Synchronous Speed, Rpm							
	3600	1800	1200	900	720	600	514	
1/4	1.35	1.35	1.35	1.35	—	—	—	Small Motors
1/3	1.35	1.35	1.35	1.35	—	—	—	
1/2	1.25	1.25	1.25	1.15*	—	—	—	
3/4	1.25	1.25	1.15*	1.15*	—	—	—	
1	1.25	1.15*	1.15*	1.15*	—	—	—	
1-1/2-125	1.15*	1.15*	1.15*	1.15*	1.15*	1.15*	1.15*	
150	1.15*	1.15*	1.15*	1.15*	1.15*	1.15*	—	
200	1.15*	1.15*	1.15*	1.15*	1.15*	—	—	Medium Motors
250	1.0	1.15*	1.15*	1.15*	—	—	—	
300	1.0	1.15*	1.15*	—	—	—	—	
350	1.0	1.15*	1.15*	—	—	—	—	
400	1.0	1.15*	—	—	—	—	—	
450	1.0	1.15*	—	—	—	—	—	
500	1.0	1.15*	—	—	—	—	—	

*In the case of polyphase squirrel-cage motors, these service factors apply to Design A, B, and C motors.

TABLE 40
OVERSPEEDS FOR SQUIRREL-CAGE MOTORS [MG1-12.52.1]

HP	Synchronous Speed, Rpm	Overspeed, Percent of Synchronous Speed
200 and smaller	1801 and over	25
	1201 to 1800	25
	1200 and below	50
250-500, inclusive	1801 and over	20
	1800 and below	25

TABLE 41

CONTINUOUS SPEED CAPABILITY FOR GENERAL-PURPOSE SQUIRREL-CAGE INDUCTION MOTORS IN DIRECT COUPLED APPLICATIONS, EXCEPT THOSE MOTORS IN 9.16.2 [MG1 TABLE 12-5]

	Totally Enclosed Fan-Cooled			Open Dripproof		
	Synchronous Speed at 60 Hz			Synchronous Speed at 60 Hz		
	3600	1800	1200	3600	1800	1200
Horsepower	Minimum Design Speed			Minimum Design Speed		
1/4	5200	3600	2400	5200	3600	2400
1/3	5200	3600	2400	5200	3600	2400
1/2	5200	3600	2400	5200	3600	2400
3/4	5200	3600	2400	5200	3600	2400
1	5200	3600	2400	5200	3600	2400
1.5	5200	3600	2400	5200	3600	2400
2	5200	3600	2400	5200	3600	2400
3	5200	3600	2400	5200	3600	2400
5	5200	3600	2400	5200	3600	2400
7.5	4500	2700	2400	5200	2700	2400
10	4500	2700	2400	4500	2700	2400
15	4500	2700	2400	4500	2700	2400
20	4500	2700	2400	4500	2700	2400
25	4500	2700	1800	4500	2700	1800
30	4500	2700	1800	4500	2700	1800
40	3600	2300	1800	4500	2300	1800
50	3600	2300	1800	3600	2300	1800
60	3600	2300	1800	3600	2300	1800
75	3600	2300	1800	3600	2300	1800
100	3600	2300	1800	3600	2300	1800
125	3600	2300	1800	3600	2300	1800
150	3600	2300	1800	3600	2300	1800
200	3600	2300	1800	3600	2300	1800
250	3600	2300	1200	3600	2300	1200
300	3600	1800	1200	3600	2300	1200
350	3600	1800	1200	3600	1800	1200
400	3600	1800	-	3600	1800	-
450	3600	1800	-	3600	1800	-
500	3600	1800	-	3600	1800	-

TABLE 42
CONTINUOUS SPEED CAPABILITY FOR GENERAL-PURPOSE DESIGN A AND B DIRECT COUPLED (TS SHAFT FOR MOTORS ABOVE THE 250 FRAME SIZE) SQUIRREL-CAGE INDUCTION MOTORS [MG1 TABLE 12-6]

	Totally Enclosed Fan-Cooled			Open Dripproof		
	Synchronous Speed at 60 Hz					
	3600	1800	1200	3600	1800	1200
Horsepower	Minimum Design Speed					
1/4	7200	3600	2400	7200	3600	2400
1/3	7200	3600	2400	7200	3600	2400
1/2	7200	3600	2400	7200	3600	2400
3/4	7200	3600	2400	7200	3600	2400
1	7200	3600	2400	7200	3600	2400
1.5	7200	3600	2400	7200	3600	2400
2	7200	3600	2400	7200	3600	2400
3	7200	3600	2400	7200	3600	2400
5	7200	3600	2400	7200	3600	2400
7.5	5400	3600	2400	7200	3600	2400
10	5400	3600	2400	5400	3600	2400
15	5400	3600	2400	5400	3600	2400
20	5400	3600	2400	5400	3600	2400
25	5400	2700	2400	5400	2700	2400
30	5400	2700	2400	5400	2700	2400
40	4500	2700	2400	5400	2700	2400
50	4500	2700	2400	4500	2700	2400
60	3600	2700	2400	4500	2700	2400
75	3600	2700	2400	3600	2700	2400
100	3600	2700	1800	3600	2700	1800
125	3600	2700	1800	3600	2700	1800
150	3600	2700	1800	3600	2700	1800
200	3600	2300	1800	3600	2700	1800
250	3600	2300	1800	3600	2300	1800
300	3600	2300	1800	3600	2300	1800
350	3600	1800	1800	3600	1800	1800
400	3600	1800	-	3600	1800	-
450	3600	1800	-	3600	1800	-
500	3600	1800	-	3600	1800	-

Table 43

Maximum A-Weighted Sound Power Levels, L_{wa} (dB), At No-Load [MG1 Table 9-1]

	Rated Speed											
Rated Power,	1801- 3600 RPM			1201- 1800 RPM			901 - 1200 RPM			900 RPM or less		
Motor HP	ODP	TEFC	WP II	ODP	TEFC	WP II	ODP	TEFC	WP II	ODP	TEFC	WP II
.5										67	67	
.75							65	64		67	67	
1				70	70		65	64		69	69	
1.5	76	85		70	70		67	67		69	69	
2	76	85		70	70		67	67		70	72	
3	76	88		72	74		72	71		70	72	
5	80	88		72	74		72	71		73	76	
7.5	80	91		76	79		76	75		73	76	
10	82	91		76	79		76	75		76	80	
15	82	94		80	84		81	80		76	80	
20	84	94		80	84		81	80		79	83	
25	84	94		80	88		83	83		79	83	
30	86	94		80	88		83	83		81	86	
40	86	100		84	89		86	86		81	86	
50	89	100		84	89		86	86		84	89	
60	89	101		86	95		88	90		84	89	
75	94	101		86	95		88	90		87	93	
100	94	102		89	98		91	94		87	93	
125	98	104		89	100		91	94		93	96	92
150	98	104		93	100		96	98		95	97	92
200	101	107		93	103		99	100	97	95	97	92
250	101	107		103	105	99	99	100	97	95	97	92
300	107	110	102	103	105	99	99	100	97	98	100	96
350	107	110	102	103	105	99	99	100	97	98	100	96
400	107	110	102	103	105	99	102	103	99	98	100	96
450	107	110	102	106	108	102	102	103	99	99	102	98
500	110	113	105	106	108	102	102	103	99	99	102	98

TABLE 44

INCREMENTAL EXPECTED INCREASE OVER NO-LOAD CONDITION, IN A-WEIGHTED SOUND POWER LEVELS ΔL_{WA} (dB), FOR RATED LOAD CONDITION FOR SINGLE-SPEED, THREE-PHASE, SQUIRREL-CAGE, INDUCTION MOTORS [MG1 TABLE 9-3]

Rated Output, P_N HP	2 Pole	4 Pole	6 Pole	8 Pole
$1.0 < P_N \leq 15$	2	5	7	8
$15 < P_N \leq 50$	2	4	6	7
$50 < P_N \leq 150$	2	3	5	6
$150 < P_N \leq 500$	2	3	4	5

TABLE 45

REFERENCE LOAD WK^2 FOR NUMBER OF STARTS OF SQUIRREL-CAGE INDUCTION MOTORS [MG1 TABLE 12-7]

	Synchronous Speed, Rpm						
	3600	1800	1200	900	720	600	514
HP	Load Wk^2 (Exclusive of Motor Wk^2), Lb-Ft^2						
1	—	5.8	15	31	53	82	118
1-1/2	1.8	8.6	23	45	77	120	174
2	2.4	11	30	60	102	158	228
3	3.5	17	44	87	149	231	335
5	5.7	27	71	142	242	375	544
7-1/2	8.3	39	104	208	356	551	798
10	11	51	137	273	467	723	1048
15	16	75	200	400	685	1061	1538
20	21	99	262	525	898	1393	2018
25	26	122	324	647	1108	1719	2491
30	31	144	384	769	1316	2042	2959
40	40	189	503	1007	1725	2677	3881
50	49	232	620	1241	2127	3302	4788
60	58	275	735	1473	2524	3819	5680
75	71	338	904	1814	3111	4831	7010
100	92	441	1181	2372	4070	6320	9180
125	113	542	1452	2919	5010	7790	11310
150	133	640	1719	3456	5940	9230	—
200	172	831	2238	4508	7750	—	—
250	210	1017	2744	5540	—	—	—
300	246	1197	3239	—	—	—	—
350	281	1373	3723	—	—	—	—
400	315	1546	—	—	—	—	—
450	349	1714	—	—	—	—	—
500	381	1880	—	—	—	—	—

TABLE 46

WINDING TEMPERATURES UNDER RUNNING LOAD CONDITIONS [MG1 TABLE 12-8]

Insulation System Class	Maximum Winding Temperature, Degrees C
A	140
B	165
F	190
H	215

TABLE 47

WINDING TEMPERATURE UNDER LOCKED-ROTOR CONDITIONS [MG1 TABLE 12-9]

	Maximum Temperature, Degrees C*				Average Temperature, ** Degrees C*			
	Insulation System Class				Insulation System Class			
Type of Protector	A	B	F	H	A	B	F	H
Automatic reset								
During first hour	200	225	250	275	—	—	—	—
After first hour	175	200	225	250	150	275	200	225
Manual reset								
During first hour	200	225	250	275	—	—	—	—
After first hour	175	200	225	250	—	—	—	—

*Test shall be permitted to be conducted at any ambient temperature within the range of 10°C to 40°C.

**The average temperature is the average of the average peak and average reset winding temperatures. The average temperature shall be within limits during both the second and last hours of the test.

TABLE 48

WINDING TEMPERATURES UNDER RUNNING LOAD CONDITIONS [MG1-12.56.2]

Motor Full-load Amperes	Trip Current as a Percent of Motor Full-load Current
9.0 and less	170
Over 9.0 but not over 20.0	156
Over 20.0	140

Table 49 [MG1-12.58.1]

Class of Insulation System	Temperature, Degrees C
A	75
B	95
F	115
H	130

TABLE 50

EFFICIENCY LEVELS [MG1 TABLE 12-10]

Column A Nominal Efficiency	Column B Minimum Efficiency Based on 20% Loss Difference	Column A Nominal Efficiency	Column B Minimum Efficiency Based on 20% Loss Difference
99.0	98.8	90.2	88.5
98.9	98.7	89.5	87.5
98.8	98.6	88.5	86.5
98.7	98.5	87.5	85.5
98.6	98.4	86.5	84.0
98.5	98.2	85.5	82.5
98.4	98.0	84.0	81.5
98.2	97.8	82.5	80.0
98.0	97.6	81.5	78.5
97.8	97.4	80.0	77.0
97.6	97.1	78.5	75.5
97.4	96.8	77.0	74.0
97.1	96.5	75.5	72.0
96.8	96.2	74.0	70.0
96.5	95.8	72.0	68.0
96.2	95.4	70.0	66.0
95.8	95.0	68.0	64.0
95.4	94.5	66.0	62.0
95.0	94.1	64.0	59.5
94.5	93.6	62.0	57.5
94.1	93.0	59.5	55.0
93.6	92.4	57.5	52.5
93.0	91.7	55.0	50.5
92.4	91.0	52.5	48.0
91.7	90.2	50.5	46.0
91.0	89.5		

TABLE 51

FULL-LOAD EFFICIENCIES OF ENERGY EFFICIENT MOTORS [MG1 TABLE 12-11]

	2 POLE		4 POLE		6 POLE		8 POLE	
HP	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency
OPEN MOTORS								
1	—	—	82.5	80.0	80.0	77.0	74.0	70.0
1.5	82.5	80.0	84.0	81.5	84.0	81.5	75.5	72.0
2	84.0	81.5	84.0	81.5	85.5	82.5	85.5	82.5
3	84.0	81.5	86.5	84.0	86.5	84.0	86.5	84.0
5	85.5	82.5	87.5	85.5	87.5	85.5	87.5	85.5
7.5	87.5	85.5	88.5	86.5	88.5	86.5	88.5	86.5
10	88.5	86.5	89.5	87.5	90.2	88.5	89.5	87.5
15	89.5	87.5	91.0	89.5	90.2	88.5	89.5	87.5
20	90.2	88.5	91.0	89.5	91.0	89.5	90.2	88.5
25	91.0	89.5	91.7	90.2	91.7	90.2	90.2	88.5
30	91.0	89.5	92.4	91.0	92.4	91.0	91.0	89.5
40	91.7	90.2	93.0	91.7	93.0	91.7	91.0	89.5
50	92.4	91.0	93.0	91.7	93.0	91.7	91.7	90.2
60	93.0	91.7	93.6	92.4	93.6	92.4	92.4	91.0
75	93.0	91.7	94.1	93.0	93.6	92.4	93.6	92.4
100	93.0	91.7	94.1	93.0	94.1	93.0	93.6	92.4
125	93.6	92.4	94.5	93.6	94.1	93.0	93.6	92.4
150	93.6	92.4	95.0	94.1	94.5	93.6	93.6	92.4
200	94.5	93.6	95.0	94.1	94.5	93.6	93.6	92.4
250	94.5	93.6	95.4	94.3	95.4	94.5	94.5	93.6
300	95.0	94.1	95.4	94.5	95.4	94.5	—	—
350	95.0	94.1	95.4	94.5	95.4	94.5	—	—
400	95.4	94.5	95.4	94.5	—	—	—	—
450	95.8	95.0	95.8	95.0	—	—	—	—
500	95.8	95.0	95.8	95.0	—	—	—	—
Enclosed Motors								
1	75.5	72.0	82.5	80.0	80.0	77.0	74.0	70.0
1.5	82.5	80.0	84.0	81.5	85.5	82.5	77.0	74.0
2	84.0	81.5	84.0	81.5	86.5	84.0	82.5	80.0
3	85.5	82.5	87.5	85.5	87.5	85.5	84.0	81.5
5	87.5	85.5	87.5	85.5	87.5	85.5	85.5	82.5
7.5	88.5	86.5	89.5	87.5	89.5	87.5	85.5	82.5
10	89.5	87.5	89.5	87.5	89.5	87.5	88.5	86.5
15	90.2	88.5	91.0	89.5	90.2	88.5	88.5	86.5
20	90.2	88.5	91.0	89.5	90.2	88.5	89.5	87.5
25	91.0	89.5	92.4	91.0	91.7	90.2	89.5	87.5
30	91.0	89.5	92.4	91.0	91.7	90.2	91.0	89.5
40	91.7	90.2	93.0	91.7	93.0	91.7	91.0	89.5
50	92.4	91.0	93.0	91.7	93.0	91.7	91.7	90.2
60	93.0	91.7	93.6	92.4	93.6	92.4	91.7	90.2
75	93.0	91.7	94.1	93.0	93.6	92.4	93.0	91.7
100	93.6	92.4	94.5	93.6	94.1	93.0	93.0	91.7
125	94.5	93.6	94.5	93.6	94.1	93.0	93.6	92.4
150	94.5	93.6	95.0	94.1	95.0	94.1	93.6	92.4
200	95.0	94.1	95.0	94.1	95.0	94.1	94.1	93.0
250	95.4	94.5	95.0	94.1	95.0	94.1	94.5	93.6
300	95.4	94.5	95.4	94.5	95.0	94.1	—	—
350	95.4	94.5	95.4	94.5	95.0	94.1	—	—
450	95.4	94.5	95.4	94.5	—	—	—	—
500	95.4	94.5	95.8	95.0	—	—	—	—

Table 52

Full-Load Efficiencies For NEMA Premium™ Efficiency Electric Motors Rated 600 Volts Or Less (Random Wound) [MG1 Table 12-12]

	2 POLE		4 POLE		6 POLE	
HP	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency
			OPEN MOTORS			
1	77.0	74.0	85.5	82.5	82.5	80.0
1.5	84.0	81.5	86.5	84.0	86.5	81.5
2	85.5	82.5	86.5	84.0	87.5	81.5
3	85.5	82.5	89.5	84.0	88.5	86.5
5	86.5	84.0	89.5	84.0	89.5	87.5
7.5	88.5	86.5	91.0	89.5	90.2	88.5
10	89.5	87.5	91.7	90.2	91.7	90.2
15	90.2	88.5	93.0	91.7	91.7	90.2
20	91.0	89.5	93.0	91.7	92.4	91.0
25	91.7	90.2	93.6	92.4	93.0	91.7
30	91.7	90.2	94.1	93.0	93.6	92.4
40	92.4	91.0	94.1	93.0	94.1	93.0
50	93.0	91.7	94.5	93.6	94.1	93.0
60	93.6	92.4	95.0	94.1	94.5	93.6
75	93.6	92.4	95.0	94.1	94.5	93.6
100	93.6	92.4	95.4	94.5	95.0	94.1
125	94.1	93.0	95.4	94.5	95.0	94.1
150	94.1	93.0	95.8	95.0	95.4	94.5
200	95.0	94.1	95.8	95.0	95.4	94.5
250	95.0	94.1	95.8	95.0	95.4	94.5
300	95.4	94.5	95.8	95.0	95.4	94.5
350	95.4	94.5	95.8	95.0	95.4	94.5
400	95.8	95.0	95.8	95.0	95.8	95.0
450	95.8	95.0	96.2	95.4	96.2	95.4
500	95.8	95.0	96.2	95.4	96.2	95.4
			Enclosed Motors			
1	77.0	74.0	85.5	82.5	82.5	80.0
1.5	84.0	81.5	86.5	84.0	87.5	85.5
2	85.5	82.5	86.5	84.0	88.5	86.5
3	86.5	84.0	89.5	87.5	89.5	87.5
5	88.5	86.5	89.5	87.5	89.5	87.5
7.5	89.5	87.5	91.7	90.2	91.0	89.5
10	90.2	88.5	91.7	90.2	91.0	89.5
15	91.0	89.5	92.4	91.0	91.7	90.2
20	91.0	89.5	93.0	91.7	91.7	90.2
25	91.7	90.2	93.6	92.4	93.0	91.7
30	91.7	90.2	93.6	92.4	93.0	91.7
40	92.4	91.0	94.1	93.0	94.1	93.0
50	93.0	91.7	94.5	93.6	94.1	93.0
60	93.6	92.4	95.0	94.1	94.5	93.6
75	93.6	92.4	95.4	94.5	94.5	93.6
100	94.1	93.0	95.4	94.5	95.0	94.1
125	95.0	94.1	95.4	94.5	95.0	94.1
150	95.0	94.1	95.8	95.0	95.8	95.0
200	95.4	94.5	96.2	95.4	95.8	95.0
250	95.8	95.0	96.2	95.4	95.8	95.0
300	95.8	95.0	96.2	95.4	95.8	95.0
350	95.8	95.0	96.2	95.4	95.8	95.0
400	95.8	95.0	96.2	95.4	95.8	95.0
450	95.8	95.0	96.2	95.4	95.8	95.0
500	95.8	95.0	96.2	95.4	95.8	95.0

Table 53

Full-Load Efficiencies For Nema Premium™ Efficiency Electric Motors Rated 5000 Volts Or Less (Form Wound) [MG1 Table 12-13]

	2 POLE		4 POLE		6 POLE	
HP	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency
			OPEN MOTORS			
250	94.5	93.6	95.0	94.1	95.0	94.1
300	94.5	93.6	95.0	94.1	95.0	94.1
350	94.5	93.6	95.0	94.1	95.0	94.1
400	94.5	93.6	95.0	94.1	95.0	94.1
450	94.5	93.6	95.0	94.1	95.0	94.1
500	94.5	93.6	95.0	94.1	95.0	94.1
			ENCLOSED MOTORS			
250	95.0	94.1	95.0	94.1	95.0	94.1
300	95.0	94.1	95.0	94.1	95.0	94.1
350	95.0	94.1	95.0	94.1	95.0	94.1
400	95.0	94.1	95.0	94.1	95.0	94.1
450	95.0	94.1	95.0	94.1	95.0	94.1
500	95.0	94.1	95.0	94.1	95.0	94.1

TABLE 54

MAXIMUM SAFE OPERATING SPEED FOR STANDARD DESIGN A AND B DIRECT DRIVE (TS SHAFT FOR FRAMES OVER 250) SQUIRREL-CAGE INDUCTION MOTORS [MG1 TABLE 30-1]

	Totally Enclosed Fan-Cooled			Open Dripproof		
	Synchronous Speed at 60 Hz			Synchronous Speed at 60 Hz		
	3600	1800	1200	3600	1800	1200
Horsepower	Maximum Operating Speed			Maximum Operating Speed		
1/4	7200	3600	2400	7200	3600	2400
1/3	7200	3600	2400	7200	3600	2400
1/2	7200	3600	2400	7200	3600	2400
3/4	7200	7600	2400	7200	3600	2400
1	7200	3600	2400	7200	3600	2400
1.5	7200	3600	2400	7200	3600	2400
2	7200	3600	2400	7200	3600	2400
3	7200	3600	2400	7200	3600	2400
5	7200	3600	2400	7200	3600	2400
7.5	5400	3600	2400	7200	3600	2400
10	5400	3600	2400	5400	3600	2400
15	5400	3600	2400	5400	3600	2400
20	5400	3600	2400	5400	3600	2400
25	5400	2700	2400	5400	2700	2400
30	5400	2700	2400	5400	2700	2400
40	4500	2700	2400	5400	2700	2400
50	4500	2700	2400	4500	2700	2400
60	3600	2700	2400	4500	2700	2400
75	3600	2700	2400	3600	2700	2400
100	3600	2700	1800	3600	2700	1800
125	3600	2700	1800	3600	2700	1800
150	3600	2700	1800	3600	2700	1800
200	3600	2300	1800	3600	2700	1800
250	3600	2300	1800	3600	2300	1800
300	3600	2300	1800	3600	2300	1800
350	3600	1800	1800	3600	1800	1800
400	3600	1800	-	3600	1800	-
450	3600	1800	-	3600	1800	-
500	3600	1800	-	3600	1800	-

FIGURES

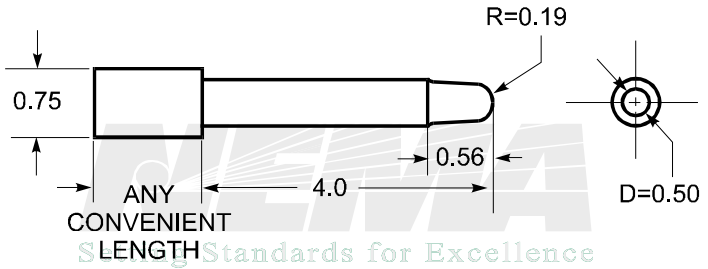


FIGURE 1 [MG1 FIGURE 1-1]

PROBE

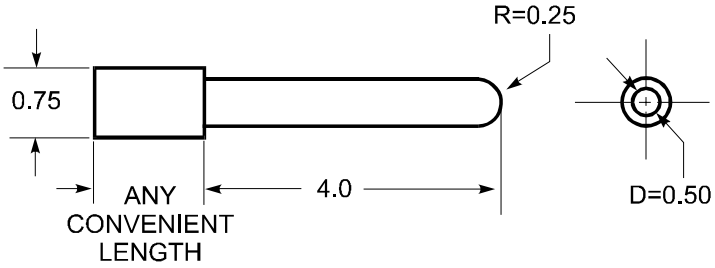


FIGURE 2 [MG1 FIGURE 1-2]

PROBE

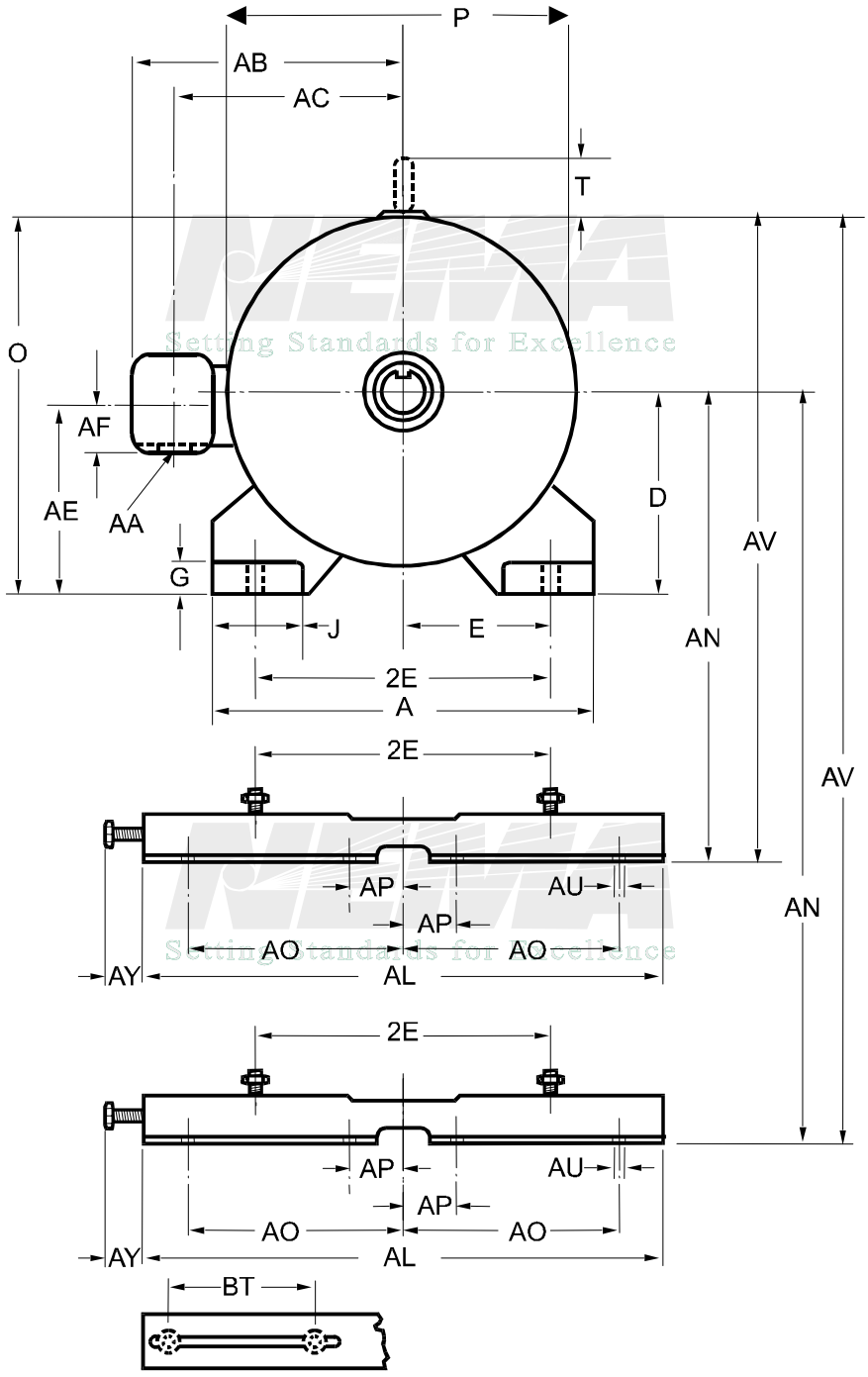
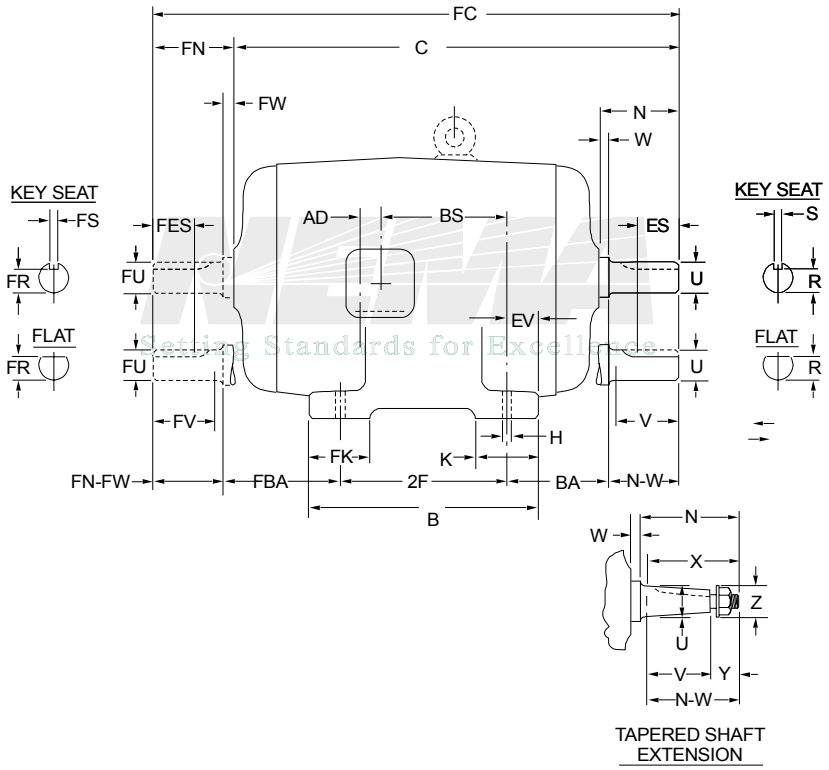
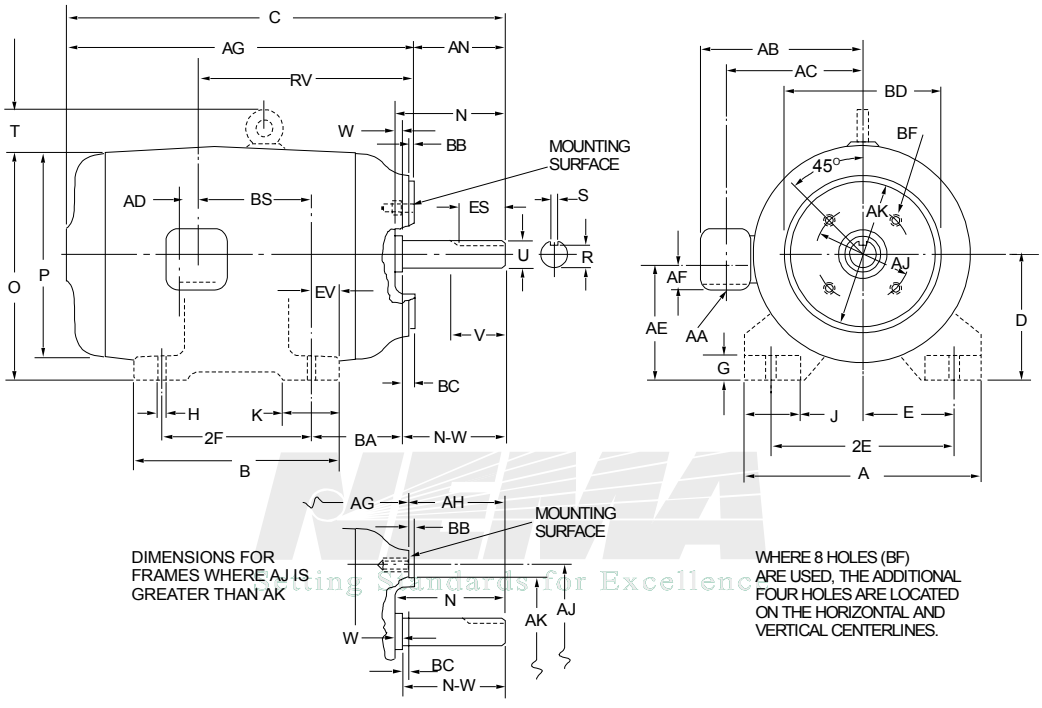


FIGURE 3 [MG1 FIGURE 4-2]



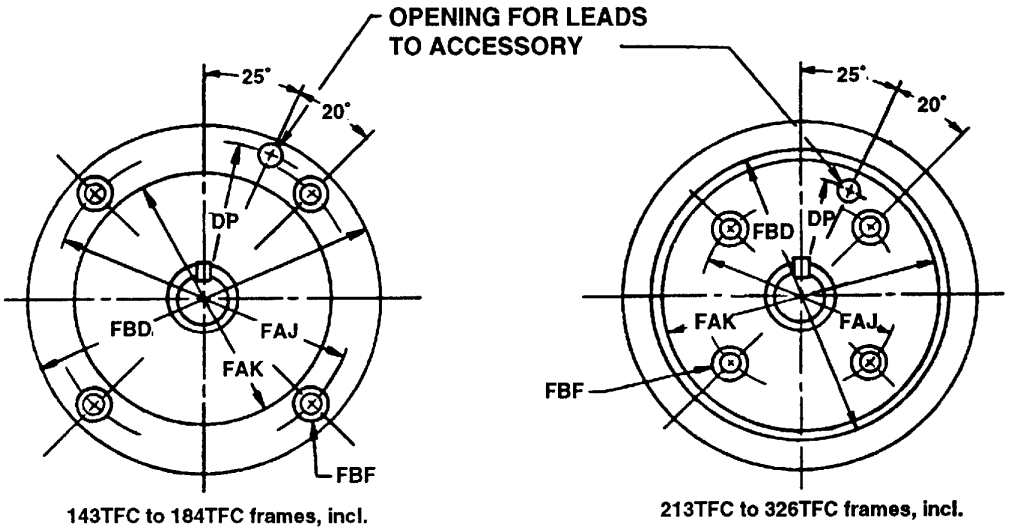
LETTERING OF DIMENSION SHEETS FOR FOOT-MOUNTED MACHINES - SIDE VIEW

FIGURE 4 [MG1 FIGURE 4-1]



LETTERING OF DIMENSION SHEETS FOR TYPE C FACE-MOUNTING FOOT OR FOOTLESS MACHINES

FIGURE 5 [MG1 FIGURE 4-3]



All dimensions in inches.

FIGURE 6 [MG1-4.4.5]

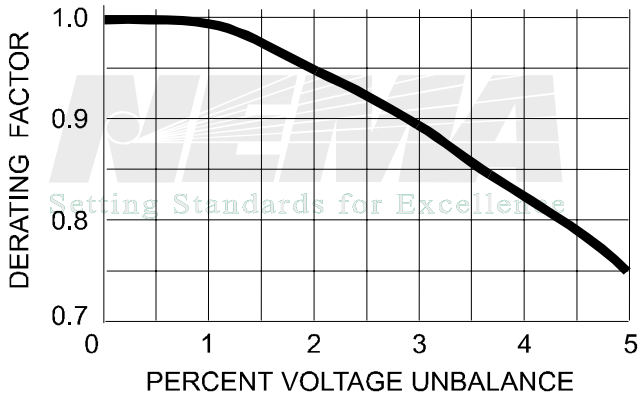


FIGURE 7 [MG1 FIGURE 14-1]

MEDIUM MOTOR DERATING FACTOR DUE TO UNBALANCED VOLTAGE

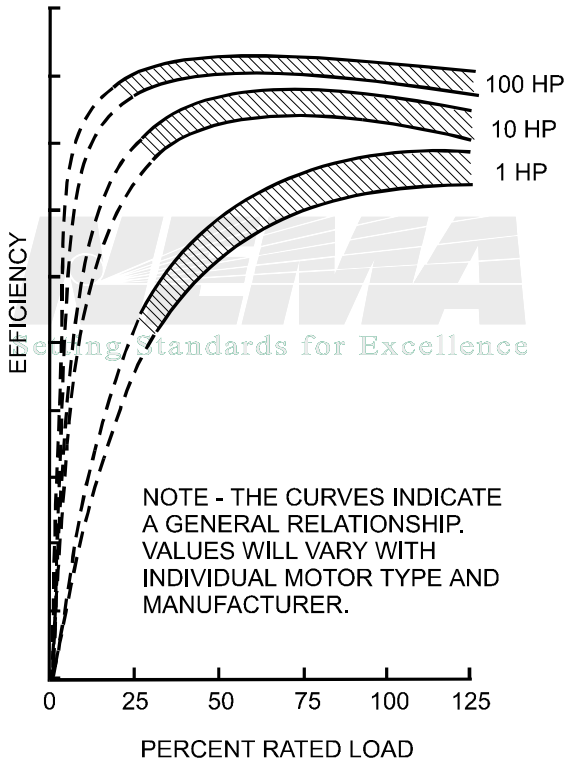
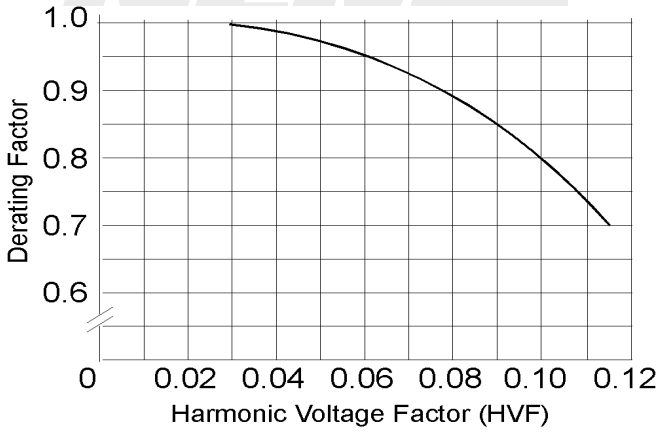


FIGURE 8 [MG1 FIGURE 14-2]



DERATING CURVE FOR HARMONIC VOLTAGES
FIGURE 9 [MG1 FIGURE 30-1]