To: Current Holders of MG 11-1977
From: NEMA Communications Department
Date: November 30, 2001
Subject: Reaffirmation of MG 11-1977

Setting Standards for Excellence

The NEMA Codes and Standards Committee has reaffirmed MG 11-1977, "Energy Management Guide for Selection and Use of Single-Phase Motors."

The new designator for this standard is: MG 11-1977 (R1997, R2001), "Energy Management Guide for Selection and Use of Single-Phase Motors."

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Energy Management Guide for Selection and Use of Single-Phase Motors

NEMA

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

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NEMA MG 11-1977 (R 1982, 1987)

MG 11

ENERGY MANAGEMENT GUIDE FOR SELECTION AND USE OF SINGLE-PHASE MOTORS

Published by

National Electrical Manufacturers Association
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Foreword

The Motor and Generator Section of NEMA recognized the need for energy management in motor applications and organized the Energy Management Committee in the Spring of 1975. Because motors are part of a system, the Committee concluded that technical information bulletins (or guides) describing motor performance characteristics should be developed to assist users in applying motors. The first edition of MG 11 was subsequently published in 1977 with the statement to periodically review the guide for the purpose of keeping it up to date with advancing technology. This reaffirmation, MG 11-1977 (R 1982, 1987), is the result of this commitment.

The goal of this guide is to assist the reader in the choice of single-phase motors for his application. Polyphase motors are covered separately in the *Energy Management Guide for the Selection and Use of Polyphase Motors*, MG 10-1983.

The practice of periodically reviewing and updating the guide will be continued. Comments on the guide from readers are welcomed and should be addressed to:

Manager, Engineering
National Electrical Manufacturers Association
2101 L Street, N.W.
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Scope

This energy management guide provides practical information concerning the proper selection and application of single-phase induction motors including installation, operation, and maintenance.

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ENERGY MANAGEMENT GUIDE FOR SELECTION AND USE OF SINGLE-PHASE MOTORS

(Approved as Authorized Engineering Information 11-19-1987.)

Section 1

INTRODUCTION

There is an urgent need to conserve energy resources. Therefore, it is important that motor users and specifiers understand the selection, application and maintenance of electric motors in order to improve the management of electrical energy consumption. "Energy Management" as related to single-phase electric motors is a concept in which all factors of the total electric motor drive system are considered in the reduction of energy consumption.

One of the factors to be considered is the motor itself. An electric motor is an energy converter, converting electrical energy to mechanical energy. For this reason, an electric motor should be considered as always being connected to a driven machine or apparatus which has specific operating characteristics such as starting, speed and load. Consequently, the selection of the motor most suitable for any particular application generally involves a host of factors, many of which conflict with one another to some degree. Small (fractional-horsepower) motors in the $^1/_{20}$ through 1 horsepower size are generally connected to single-phase power systems which are found in homes or small businesses and are most frequently used to drive household or commercial appliances.

The system efficiency is the combination of the efficiencies of all of the components in the system. These components include belts, pulleys, fans, pumps, gears and, in the case of refrigeration, such items as the compressor. Other components which are not a part of the system will affect the overall system efficiency; some of these are refrigeration and air conditioning evaporator and condenser coils, plumbing associated with pumps, and ducts and baffles associated with fans and blowers. Selection of a motor to provide for the most efficient system is based on factors such as speed, load versus horsepower, duty cycle, type, and initial motor cost, as well as motor efficiency.

Good energy management is the successful application of the motor and its driven components that results in the least consumption of energy.

Section 2

GENERAL CONCEPTS

The design of an electric motor involves a balance between characteristics such as starting and running, thermal performance and material utilization. Operating efficiency involves a careful consideration of these motor performance characteristics, relating them to the requirements of the specific application and the efficiency of the system of which the motor is a part.

A change in efficiency as a function of load is an inherent characteristic of motors. Operation at less than rated load will result in a substantial reduction in motor efficiency. Oversizing (the use of a motor having an output rating greater than the load) should be avoided.

Motor efficiency can be improved by matching the voltage and frequency of the motor with those of the power supply. The use of motors having a voltage range (i.e. 200-230 volts) or a dual frequency (i.e. 60/50 hz) should be avoided.

In general, for a given type, motors with larger horsepower ratings are more efficient than those with smaller horsepower ratings. In addition, motors with higher synchronous speeds are generally more efficient than those with lower synchronous speeds. This does not imply, however, that all apparatus should be driven by high-speed motors. Where speed-changing mechanisms, such as pulleys or gears, are required to obtain the lower speeds, the additional power losses could reduce the efficiency of the system to a value lower than that provided by a direct-drive lower-speed motor.

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Many motors are used for very short periods of time and for a very low total number of hours per year. Examples of such applications are can openers, food waste disposers, electric lawn mowers, power tools, etc. In these instances, a change in motor efficiency would not substantially change the total energy consumed since very little total energy is involved.

On the other hand, many motors are used for long periods of time and for a high total number of hours per year. Examples of such applications are air moving equipment, circulator pumps, refrigeration compressors, etc. In these instances, an increase in motor efficiency could substantially reduce the total energy consumed.

Section 3
TYPES OF MOTORS

The most commonly used single-phase motors are those of the induction type because of their simplicity, dependability, and relatively constant speed. Induction motors include the following sub-types: shaded-pole, split-phase, capacitor-start, and permanent-split capacitor. Universal motors are also commonly used on single-phase power systems in homes on specific applications. The following is a brief description of each motor type and its primary application:

3.1 SHADED-POLE MOTORS

Shaded-pole motors are used in a wide variety of applications requiring ¼ horsepower or less, and the vast majority of applications require less than $^1/_{10}$ horsepower. They are simple in construction, low in cost, and extremely rugged and reliable because they do not have commutators, starting switches, collector rings, brushes, governors, or contacts of any sort. Their low starting torque and efficiency confines the use of shaded-pole motors to such appliances as rotisseries, fans, humidifiers, slide projectors, and small business machines such as copying machines, vending machines, advertising displays, etc., many of which are intended for intermittent operation. Because of the combination of low horsepower rating and intermittent operation of many of these applications, the total power consumed by shaded-pole motors normally represents only a small portion of the total power consumed by electric motors.

3.2 SPLIT-PHASE MOTORS

Split-phase motors are among the most widely used of all types of single-phase motors in ratings ranging from $^1/_{12}$ to ½ horsepower. They are found in laundry equipment, oil burners, furnace blowers, attic fans, centrifugal pumps, compressors, business machines, buffing machines, grinders, home workshop tools, and a host of other applications. Split-phase motors are characterized by medium starting torque, high starting current, and medium efficiency.

3.3 CAPACITOR-START, INDUCTION-RUN MOTORS

Capacitor-start induction-run motors are most widely used in ratings of $^1/_8$ horsepower and larger for applications where higher starting characteristics are required. They are characterized by high starting torque, low starting current, and medium efficiency.

3.4 CAPACITOR-START CAPACITOR-RUN MOTORS

Capacitor-start capacitor-run motors are most widely used in ratings of ⅓ horsepower and larger for applications where high starting torque, low starting current, low operating current and high efficiency are required.

3.5 PERMANENT-SPLIT CAPACITOR MOTORS

Permanent-split capacitor motors are used in direct-drive applications requiring ratings ranging from $^1/_{20}$ to 1 horsepower, such as fans, business machines and hermetic motor compressors. They are characterized by low starting torque, low starting current and high efficiency.

3.6 UNIVERSAL MOTORS

Universal motors are used in ratings from $^1/_{10}$ to 1 horsepower in applications involving vacuum cleaners, hand-held tools, and appliances which operate intermittently. They are characterized by high starting torque, low starting current, medium to low efficiency, and varying speed.

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Section 4
SELECTION AND APPLICATION

In the selection of single-phase motors for application to the driven equipment, the efficiency of the total electric motor system should always be considered for good energy management. Some of the factors to be evaluated are as follows:

4.1 SHORT OR INTERMITTENT DUTY CYCLE OPERATION

Applications involving can openers, vacuum cleaners, hand-held tools, mixers, blenders, electric knives, etc., fall in this category. Because these appliances operate for short periods of time, even a large increase in the efficiency of the motor or system would have only a negligible effect on total power consumption.

4.2 MOTOR SPEED

Although a 2-pole motor generally has a higher efficiency, the gearing or belting necessary to reduce the speed to that required by the driven equipment may have efficiencies that would reduce the efficiency of the system to a value lower than that which could be obtained with a 4-, 6- or 8-pole motor, the use of which would not require a reduction in speed.

4.3 LOADING

The motor horsepower rating should be so selected that the load imposed on the motor will cause it to operate close to its full-load rating.

4.4 MOTOR TYPE

The most important consideration in selecting a motor of the appropriate type is to obtain a motor that will perform satisfactorily for the application involved. Universal motors are used where high speeds are required, where increasing the speed of induction motors is not feasible, or when varying speeds are desired. Shaded-pole motors are generally used where low starting torque and low efficiency are acceptable because of the intermittent duty of the application. Permanent-split capacitor motors are used where low starting torque is acceptable and a higher efficiency is desired. Split-phase motors are used for general-purpose applications where medium starting torque is required. Capacitor-start motors are generally used where high starting torque is required. Table 1 may be used as a guide for selecting the proper motor for the major applications listed.

4.5 EVALUATION OF INCREASED EFFICIENCY

For two similar motors operating at the same specified load, but having different efficiencies, the following equation can be used to calculate the savings in operating costs when using motor A rather than motor B:

$$S = 0.746 \times HP \times C \times N \left(\frac{100}{E_B} - \frac{100}{E_A} \right)$$

Where —

S = Savings in dollars per year
HP = Horsepower rating of the specified load
C = Energy cost, dollars per kilowatt hour
N = Running time, hours per year
E_A = Efficiency (in percent) of motor A at the specified load
E_B = Efficiency (in percent) of motor B at the specified load

The equation applies to motors operating at a specified constant load. For varying loads, the equation can be applied to each portion of the cycle where the load is relatively constant for an appreciable period of time. The total savings is the sum of the savings for each load-time period.

The equation is not applicable to motors operating on pulsating loads or on loads which cycle at rapidly repeating intervals.

Section 5
CONCLUSION

Proper selection, application and maintenance of electric motors is essential to an effective energy management program. With today's increasing costs of energy, and potential shortages in the future, energy management is important. It is crucial to the country from the standpoint of conservation of natural resources, energy independence and energy availability. As part of a system, electric motors play a significant role in determining the total energy consumption; however, they cannot be considered alone and are only one factor in any analysis of an entire system.

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Table MG 11-1
ALTERNATING-CURRENT SINGLE-PHASE SMALL (FRACTIONAL-HORSEPOWER) MOTORS RATED 1/20 TO 1 HORSEPOWER, 250 VOLTS OR LESS

Application	Motor Type	Horsepower	Speed, RPM	Starting Torque	Efficiency
Fans					
Direct Drive	Permanent Split Capacitor	1/20–1	1625, 1075, 825	Low	High
	Shaded Pole	1/20–1/4	1550, 1050, 800	Low	Low
	Split Phase	1/20–1/2	1725, 1140, 850	Low	Medium
Belted	Split Phase	1/20–1/2	1725, 1140, 850	Medium	Medium
	Capacitor Start – Induction Run	1/8–3/4	1725, 1140, 850	Medium	Medium
	Capacitor Start – Capacitor Run	1/8–3/4	1725, 1140, 850	Medium	High
Pumps					
Centrifugal	Split Phase	1/8–1/2	3450	Low	Medium
	Capacitor Start – Induction Run	1/8–1	3450	Medium	Medium
	Capacitor Start – Capacitor Run	1/8–1	3450	Medium	High
Positive Displacement	Capacitor Start – Induction Run	1/8–1	3450, 1725	High	Medium
	Capacitor Start – Capacitor Run	1/8–1	3450, 1725	High	High
Compressors					
Air	Split Phase	1/8–1/2	3450, 1725	Low or Medium	Medium
	Capacitor Start – Induction Run	1/8–1	3450, 1725	High	Medium
	Capacitor Start – Capacitor Run	1/8–1	3450, 1725	High	High
Refrigeration	Split Phase	1/8–1/2	3450, 1725	Low or Medium	Medium
	Permanent Split Capacitor	1/8–1	3250, 1625	Low	High
	Capacitor Start – Induction Run	1/8–1	3450, 1725	High	Medium
	Capacitor Start – Capacitor Run	1/8–1	3450, 1725	High	High
Industrial	Capacitor Start – Induction Run	1/8–1	3450, 1725, 1140, 850	High	Medium
	Capacitor Start – Capacitor Run	1/8–1	3450, 1725, 1140, 850	High	High
Farm	Capacitor Start – Induction Run	1/8–3/4	1725	High	Medium
	Capacitor Start – Capacitor Run	1/8–3/4	1725	High	High
Major Appliances	Split Phase	1/6–1/2	1725, 1140	Medium	Medium
	Capacitor Start – Induction Run	1/6–3/4	1725, 1140	High	Medium
	Capacitor Start – Capacitor Run	1/6–3/4	1725, 1140	High	High
Commercial Appliances	Capacitor Start – Induction Run	1/3–3/4	1725	High	Medium
	Capacitor Start – Capacitor Run	1/3–3/4	1725	High	High
Business Equipment	Permanent Split Capacitor	1/20–1/4	3450, 1725	Low	High
	Capacitor Start – Induction Run	1/8–1	3450, 1725	High	Medium
	Capacitor Start – Capacitor Run	1/8–1	3450, 1725	High	High

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Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard. *(Standardization Policies and Procedures, p. 1)*

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

(Standardization Policies and Procedures, p. 2)

Dimensions

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

(Standardization Policies and Procedures, p. 9)

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National Electrical Manufacturers Association Standards are of two classes:

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2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 8 & 17)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.

(Standardization Policies and Procedures, pp. 8 & 17)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment, and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 8 & 17)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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