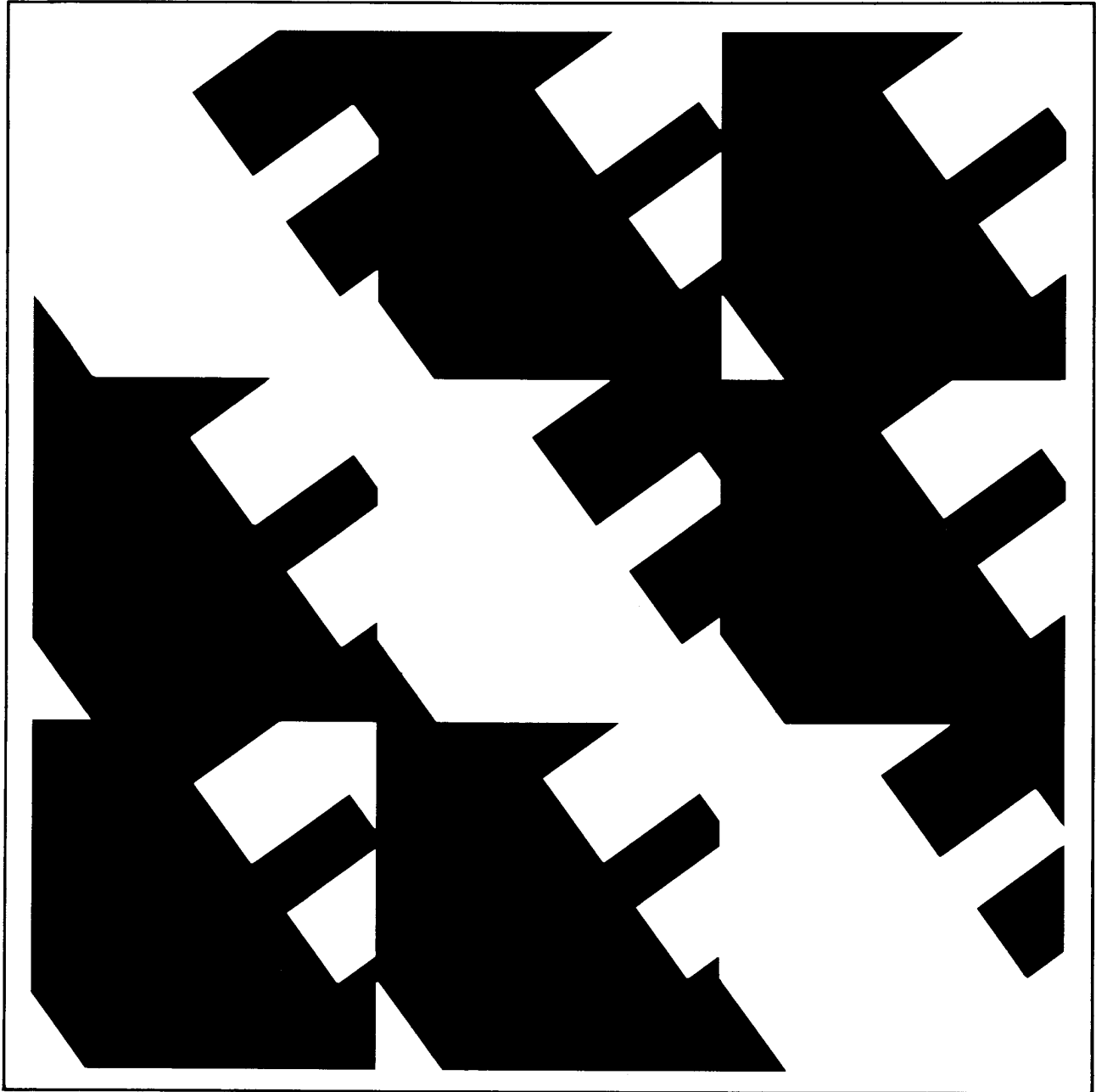


IEEE Standard Test Procedure for Single-Phase Induction Motors

ANSI/IEEE Std 114-1982



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1. Scope

This standard covers instructions for conducting and reporting the more generally applicable and acceptable tests to determine the performance characteristics of single-phase motors, including nonexcited synchronous motors. It is not intended that this standard shall cover all possible tests used in production or tests of a research nature. The standard shall not be interpreted as requiring the making of any or all of the tests described herein in any given transaction.

2. References

- [1] ANSI/IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing
- [2] ANSI/IEEE Std 43-1974 (R1979), IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery
- [3] ANSI/IEEE Std 100-1977, IEEE Standard Dictionary of Electrical and Electronics Terms
- [4] ANSI/NEMA MG 1-1978, Motors and Generators¹
- [5] IEEE Std 1-1969, IEEE General Principles for Temperature Limits in the Rating of Electric Equipment
- [6] IEEE Std 85-1973 (R1980), IEEE Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery
- [7] IEEE Std 118-1978, IEEE Standard Test Code for Resistance Measurement

¹ ANSI documents are available from the Sales Department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

[8] IEEE Std 119-1974, IEEE Recommended Practice for General Principles of Temperature Measurement as Applied to Electrical Apparatus

[9] IEEE Std 120-1955 (R1972) (ASME PTC 19.6-1955), Master Test Code for Electrical Measurements in Power Circuits

3. Tests

Single-phase induction motors are normally given a routine test but may be given a complete test.

3.1 Routine Test. The routine test includes measurement of power and current input at no-load and at rated voltage, current input with locked rotor at rated voltage, and a high-potential test. A suggested form for reporting such test data is shown in Form 1, on page 22 of this standard.

3.2 Complete Test. The complete test includes all of the data taken during a routine test plus the data necessary for determining efficiency, power factor, starting torque, pull-up torque, breakdown torque, rated-load slip, and rated-load temperature rise. A suggested test form for reporting data is shown in Form 2. Additional tests to determine locked-rotor temperature rise, speed-torque characteristics, shaft current, noise, and vibration may also be conducted.

3.3 Schedule of Tests. Input-output data may be obtained by any of the four following methods:

- Method A — brake
- Method B — dynamometer
- Method C — rope (or cord) and pulley
- Method D — continuous data acquisition (plotter)

Table 1
Tests Applicable to Single-Phase Motors

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
Capacitor (permanent split)	x	x	x			x		x	x	x	x
Capacitor (two-value)	x	x	x	x		x		x	x	x	x
Capacitor-start	x	x	x	x		x		x	x	x	x
Split-phase	x	x	x	x		x		x	x	x	x
Shaded-pole	x	x	x			x		x	x	x	x
Repulsion	x	x						x	x	x	x
Repulsion-induction	x	x	x			x		x	x	x	x
Repulsion-start-induction	x	x	x	x		x		x	x	x	x
Reluctance (synch)	x	x	x		x	x	x	x	x	x	x
Universal*	x	x						x	x	x	x

*The tests listed apply to operation on alternating current only.

The quantities which may be measured are as follows:

- (a) Locked-rotor current
- (b) Locked-rotor torque
- (c) Pull-up torque
- (d) Switching torque
- (e) Pull-in torque
- (f) Breakdown torque
- (g) Pull-out torque
- (h) Speed
- (i) Power factor
- (j) Efficiency
- (k) Temperature rise

NOTE: The definitions for items (a) through (k) can be found in ANSI/IEEE Std 100-1977 [3].²

Items (h) through (k) are usually measured at rated power output. They may, however, be measured at any load required.

Table 1 lists the common types of single-phase motors and the tests that are applicable to each one.

3.4 General. After the method (A, B, C, or D) of test has been chosen, all necessary data may be obtained by following the instructions and precautions given only in those paragraphs which contain, in their headings, the letter

designating the method chosen. For example, when testing by Method B, reference needs to be made only to the paragraphs opposite the letter *B* or the word *All*, which is employed to designate paragraphs common to all methods. Some of these paragraphs include alternative methods of obtaining the necessary data and the manufacturer may choose the method best suited to the facilities available in such cases, unless otherwise specified.

Inasmuch as the performance of a single-phase motor is dependent not only upon the value of voltage and frequency but also upon the waveshape of the voltage, correct data can be obtained only by careful measurement and the use of a suitable source of power (see 4.1).

4. Electrical Measurements

4.1 (*All*)³ Power Supply

4.1.1 (*All*). The supply voltage shall closely approach sine waveform. The frequency shall be closely regulated. The frequency shall be measured by an accurate frequency meter or by an accurate tachometer driven by a synchronous motor operating on the same power

² The numbers in brackets correspond to the references listed in Section 2 of this standard.

³ Use of the word *all* and the letters *A*, *B*, *C* and *D* in subsection titles is explained in 3.4.

supply. The voltage waveform deviation factor, as defined in ANSI/IEEE Std 100-1977 [3], shall not exceed 10%. The equivalent sine wave referred to is a sine wave having the same frequency and root-mean-square values as the wave being tested.

4.1.2 (All). Rapid changes in frequency cannot be tolerated in input-output tests because such changes in frequency cause changes in speed and the variations are transmitted to the output-measuring device. Any departure from the assumed frequency directly affects the efficiency. The frequency shall be measured (or known to be) within an accuracy of 0.1%.

4.2 (A, B, C) Instrument Selection. The instruments used in electrical measurements shall be selected to give indications well up on the scale; that is, where a fraction of a division is easily estimated and where such a fraction is a small percentage of the value read. Further information regarding the use of instruments can be obtained by referring to IEEE Std 120-1955 [9].

4.3 (D) Transducer Selection. The transducers used in electrical measurements by continuous data acquisition (by plotter) shall be selected to give indications well up on the scale; that is, full scale on the plotter shall correspond as much as possible to full scale for the transducer. The time constant of the transducer selected shall be adequate for the particular output device (plotter). The internal losses of the transducer should be shown to be negligible when compared to the magnitudes being measured.

4.4 (All) Instrument Transformers. When current and potential instrument transformers are used, corrections shall be made for ratio errors in voltage and current measurements and for ratio and phase-angle errors in power measurement. The use of instrument transformers shall be avoided if possible. (See IEEE Std 120-1955 [9].)

4.5 (All) Voltage. The voltage shall be read at the motor terminals. Means should be provided whereby the voltage can be adjusted to the desired value. This control can be effected by the use of a continuously variable transformer or autotransformer, by an induction regulator, or by a controlled motor-generator set.

4.6 (All) Current. The line current of the motor shall be measured by an accurate am-

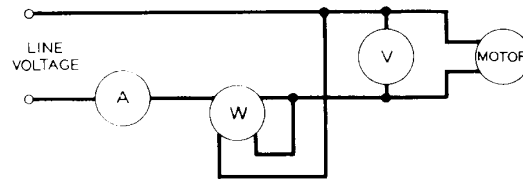


Fig 1
Preferred Meter Arrangement

meter or current transducer. The circuit diagram, Fig 1, shows the preferred arrangement of meters.

The motor current is the line current corrected by subtracting from it the currents taken by the voltmeter and the wattmeter voltage coils and may be computed by using one of the following equations:

$$P = P_W - \frac{E^2}{R_M}$$

$$I = \sqrt{I_A^2 - \frac{2P_W}{R_M} + \left(\frac{E}{R_M}\right)^2}$$

But

$$I_A \geq 7 \frac{E}{R_M}$$

$$I = I_A - \frac{P_W}{I_A R_M}$$

may be used.

In these equations

I_A = current (in amperes) indicated by ammeter A

I = net current, true input to motor

P_W = power (in watts) indicated by wattmeter W

P = net power (in watts) true input to motor

E = voltage (in volts) indicated by voltmeter V

R_M = resistance (in ohms) of the voltmeter and wattmeter voltage coils in parallel

4.7 (All) Power. A single-phase wattmeter or power transducer shall be used. The total watts read on the wattmeter, which shall be connected as shown in 5.5, shall be reduced by the amount of the power lost in the voltage circuit of the instruments unless the wattmeter is of the self-compensating type. Where a

properly selected power transducer is used, the transducer loss shall be shown to be negligible. All instruments must be read as simultaneously as practical.

5. Performance Determination

5.1 (All) Temperature. All performance determinations should be made in an ambient with a temperature as close as possible to 25 °C. The ambient temperature should be between 20 °C and 30 °C, unless otherwise agreed to by the purchaser and manufacturer.

Locked-rotor and breakdown torque tests should be made with the motor temperatures as close to ambient temperature as possible. Other performance data should be obtained with the motor operating as close as possible to its normal operating temperatures, unless otherwise agreed to by the purchaser and manufacturer. (See IEEE Std 119-1974 [8] for temperature corrections.)

5.2 (All) Efficiency. Efficiency is the ratio of output power to input power. The electric power is measured directly. The output power may be measured by Method A, B, C or D. Unless otherwise specified, the efficiency shall be determined at rated voltage, frequency, and temperature rise or actual temperature rise as determined by heat run. If a curve of efficiency versus output power is to be plotted, a minimum of seven points is recommended.

5.2.1 (A, B, C) Direct-Measurement Methods. In all direct-measurement tests the electric and mechanical powers are to be measured directly. The differences between Methods A, B, and C lie in the methods of measuring mechanical power. Readings of power, current, voltage, frequency, slip, torque, ambient temperature, and stator coil end-winding temperature or stator winding resistance shall be obtained for no-load and at least six load points substantially equally spaced from $\frac{1}{4}$ to $1\frac{1}{2}$ times rated load. The motor performance shall be determined as is outlined in Form 3 (see page 24).

5.2.1.1 (A) Method A — Brake. In this method a brake is mounted on the motor shaft and so arranged that a scale will read the retarding force offered by the brake. The torque is computed from the product of the scale reading and the brake arm length. Care shall be exercised in the construction and use of the

brake and the brake pulley. The *tare*, if present, shall be determined and compensated. Performance of a motor shall be calculated as shown on Form 3.

5.2.1.2 (B) Method B — Dynamometer. In this method the motor is connected to a dynamometer usually by means of flexible coupling. The dynamometer is free to rotate and has a torque arm which rests on a scale. The torque output of the motor is a product of the scale reading and the distance from the center of the dynamometer to the point where the torque arm makes contact with the scale. To obtain the mechanical power output of a motor by the dynamometer method the following equation may be used:

$$\text{power (in watts)} = \frac{T \cdot n}{k}$$

in which

$$\begin{aligned} n &= \text{rotational speed in r/min} \\ k &= 7.043 \text{ for } T \text{ in lb}\cdot\text{ft} \\ &= 84.52 \text{ for } T \text{ in lb}\cdot\text{in} \\ &= 112.7 \text{ for } T \text{ in oz}\cdot\text{ft} \\ &= 1352 \text{ for } T \text{ in oz}\cdot\text{in} \\ &= 9.549 \text{ for } T \text{ in N}\cdot\text{m} \end{aligned}$$

5.2.1.3 (C) Method C — Rope and Pulley. In this method a small rope or cord suspended from a spring scale is wrapped around the motor pulley a sufficient number of times so that when the cord is tightened by a small pull on its free end the scale will measure the motor's pull. If the cord is properly adjusted with negligible tension in the free end, the motor will just pull through the minimum torque points and the scale swings will be slow enough so that even the minimum torque in one slow revolution will be obtained. This method may be used to test a motor under load also if the motor power output is not great enough to damage the cord. To obtain accurate results, the following conditions must be fulfilled:

(1) Force may not be exerted on the free end of the cord unless the magnitude of the force is known and a correction for it is made. A distinct curvature in the free end of the cord as it leaves the pulley is the only conclusive evidence that there is no force.

(2) The pulley face should be wide enough to develop the required torque with a single layer of turns of the cord. If a single layer is not practicable, multiple layers may be used but

the first two turns on the scale end of the cord must be single-layer.

(3) The pulley must be in proper alignment with the scale so that there is no scale error caused by a nonrecording component of force in the cord. The alignment must also be such that there is a clearance between the cord and the pulley flange.

5.2.1.3.1 Method C — Correction for Cord Diameter. In calculating the torque, the radius at which the force is applied is to be taken as the pulley radius plus the cord radius. The cord diameter should be measured with the cord under tension. The micrometer anvil and spindle should have flat faces large enough to span at least two strand pitches. Sufficient pressure should be applied to flatten minor irregularities in the cord. Inasmuch as the cord diameter may change because of wear or stretch, the ratio of cord diameter to pulley diameter should be as small as practicable.

5.2.1.3.2 Method C — Correction for Pulley Windage Loss or for Dynamometer Windage Loss. The measured values of torque are to be corrected by adding to them a torque corresponding to the pulley windage or the dynamometer windage loss. The allowance for this loss is made by adding a torque T_W :

$$T_W = \frac{k(P_A - P_B)}{n} - T_D$$

in which

P_A = watts input to the motor driving the pulley or dynamometer

P_B = watts input to the motor without the pulley or dynamometer

n = rotational speed in r/min

k = 7.043 for T in lb·ft

= 84.52 for T in lb·in

= 112.7 for T in oz·ft

= 1352 for T in oz·in

= 9.549 for T in N·m

5.2.1.3.3 Method C — Determination of Friction and Windage Loss. When motors are supplied without bearings by the motor manufacturer it may be desirable to quote the efficiencies on the basis of a specified friction and windage loss and to consider the losses to be charged against the driven device. In such a case it is the usual practice to test the parts in a jig or fixture which does have friction in the bearings. The amount of this friction and windage is then separately determined and added to the motor output. For accurate results, the

friction of this jig or fixture should be low even though a correction is made inasmuch as the jig friction may change while a test is in progress.

5.2.1.3.4 Method C — Dynamometer Method of Measuring Friction and Windage. One method of determining the friction and windage losses is to measure the torque required to drive the parts at normal speed by means of a dynamometer. The friction P_f is then expressed, in watts, as:

$$P_f = \frac{T_f \cdot n}{k}$$

in which

T_f = net friction torque

k = same values as used in 5.2.1.3.2

n = rotational speed in r/min

The dynamometer used for this test should be such that the measured friction torque T_f represents at least 15% of the normal torque capacity of the dynamometer.

5.2.1.3.5 Method C — No-Load Saturation Method of Determining Friction and Windage Loss. The motor is run at no-load at normal frequency and voltage until the power input is constant to assure that the temperature of the oil or grease and the bearing friction have become constant. Readings are taken of volt, ampere, and watt input at rated frequency but with voltages ranging from 125% of rated voltage down to a point where further voltage reduction increases the current. The voltage adjustment is accomplished preferably by a variable-voltage transformer. Immediately following this test and before the temperatures can change sensibly, a reading of input power P_i and input current I_A at 50% or 60% of rated voltage should be taken with the rotor locked and with only the main or running winding excited. This test should be followed immediately by a measurement of the stator resistance R_1 .

If the input current at any voltage is I_s , the total copper loss P_c in the machine at the same voltage is:

$$P_c = \frac{I_s^2}{2} \left(R_1 + \frac{P_f}{I_A^2} \right)$$

The copper loss so calculated should be subtracted from the total input power at the same voltage. The resultant values may then be plotted against applied voltage with an extrap-