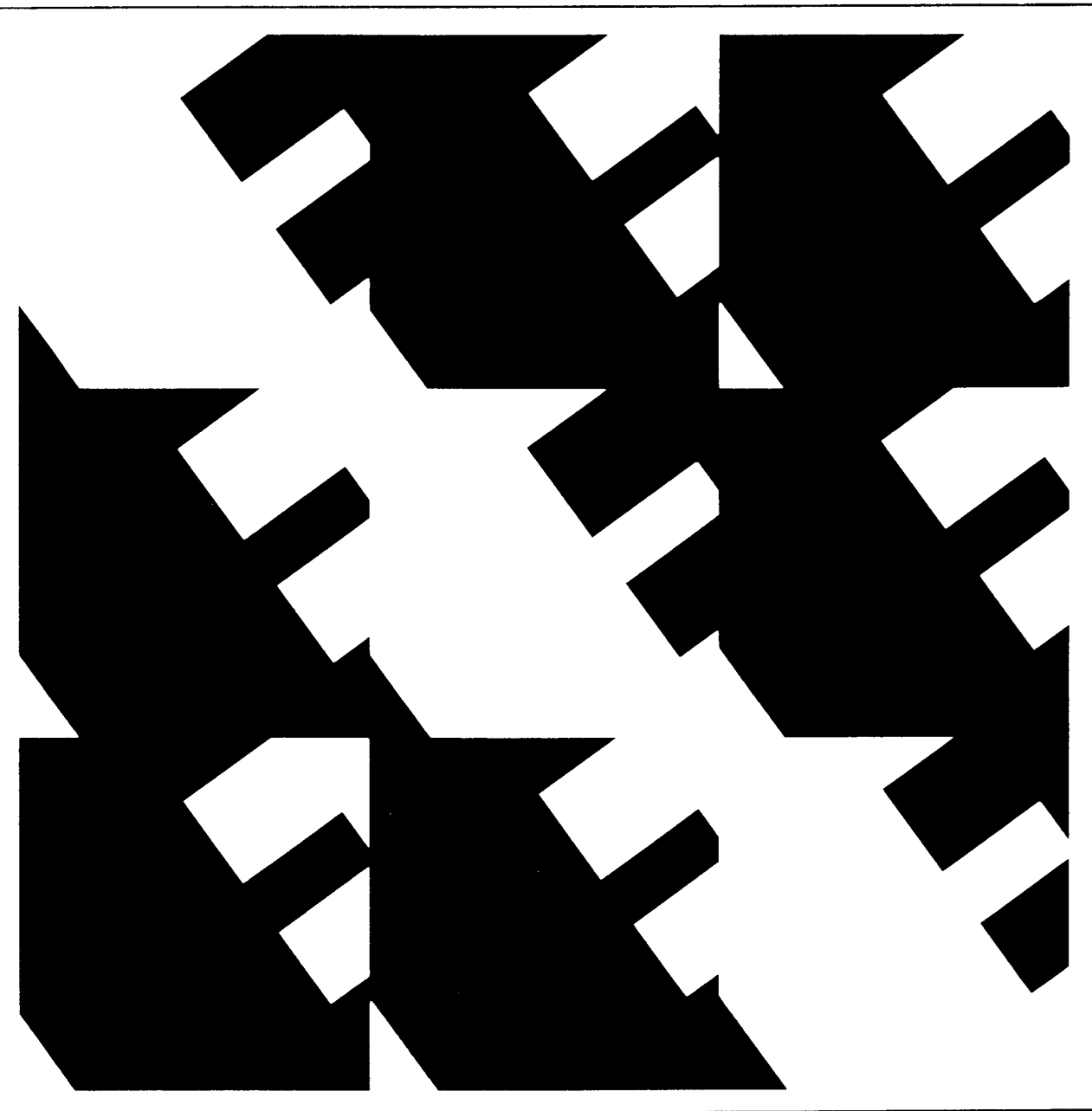


IEEE Standard Test Procedure for Polyphase Induction Motors and Generators

ANSI/IEEE Std 112-1984



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**IEEE Standard Test Procedure for
Polyphase Induction Motors and Generators**

Sponsor
**Rotating Machinery Committee
of the
IEEE Power Engineering Society**

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Foreword

(This Foreword is not a part of IEEE Std 112-1984, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.)

This standard is a revision of IEEE Std 112-1978, IEEE Standard for Polyphase Induction Motors and Generators.

The Institute wishes to acknowledge its indebtedness to those who have so freely given of their time and knowledge and have conducted experimental work on which many of its publications are based.

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IEEE Standard Test Procedure for Polyphase Induction Motors and Generators

1. Scope

This standard covers instructions for conducting and reporting the more generally applicable and acceptable tests to determine the performance characteristics of polyphase induction motors and generators. The tests described may be applied to both motors and generators, as needed. Additional tests, not specified herein, may be required to satisfy specific research or application needs. These procedures shall not be interpreted as requiring the making of any specific test in a given transaction.

2. References

- [1] AIEE Committee Report, Stray Load Loss Measurement in Induction Machines. *AIEE Transactions*, vol 78, pt III A, pp 67-71, April, 1959.
- [2] ANSI/IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing.
- [3] ANSI/IEEE Std 43-1974 (R1979), IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.
- [4] ANSI/IEEE Std 100-1977, IEEE Standard Dictionary of Electrical and Electronics Terms.
- [5] ANSI/NEMA MG1-1978,¹ Motors and Generators.
- [6] IEEE Std 1-1969, IEEE General Principles for Temperature Limits in the Rating of Electric Equipment.

¹ ANSI documents are available from the Sales Office, American National Standards Institute, 1430 Broadway, New York, NY, 10018. Copies of this standard are also available from the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037.

[7] IEEE Std 62-1978, IEEE Guide for Field Testing Power Apparatus Insulation.

[8] IEEE Std 85-1973, IEEE Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery.

[9] IEEE Std 118-1978, IEEE Standard Test Code for Resistance Measurement.

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

[11] IEEE Std 120-1955 (R1972), IEEE Master Test Code for Electrical Measurements in Power Circuits.

[12] Morgan, T. H., Brown, W. E., and Schumer, A. J. Reverse-Rotation Test for the Determination of Stray Load Loss in Induction Machines. *Transactions of the American Institute of Electrical Engineers*, vol 58, pp 319-322, July, 1939.

3. Tests — General

3.1 Kinds of Tests. Polyphase induction machines are normally given a routine test, but may be given additional tests.

For typical routine tests refer to ANSI/NEMA MG1-1978 [5],² parts 12 and 20.

A typical form for reporting routine test data is shown in Section 8, Form A-1. A typical form for reporting additional test data is shown in Section 8, Form A-2.

3.2 Choice of Tests. A complete list of the tests covered by this standard is given in the Table of Contents. Alternate methods are described

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

for making many of the tests, suitable for different sizes and types of machines and different conditions. In some cases, the preferred method is indicated.

The schedule of factory and field tests which may be required on new equipment is normally specified by applicable standards or by contract specifications. The manufacturer's choice of method for factory or field tests on new equipment will govern, in lieu of prior agreement or contract specification.

3.3 Use of this Standard. After the method of test is chosen, all necessary data may be obtained by following the instructions and precautions given only in those subsections which contain, in their left-hand margins, the letter designating the method selected. For example: when testing by Method B, reference need be made only to the paragraphs opposite the letter "B" or the word "All," which will be employed to designate subsections common to all methods. Many of these subsections include alternate methods for obtaining the necessary data. Unless otherwise specified, the manufacturer may choose the method best suited to the facilities available in such cases.

3.4 Precautions During Test. Since the performance of an induction machine is dependent not only upon the value of voltage and frequency but also on the wave shape and the balance in magnitude and phase angle of the voltages, correct data can be obtained only by careful measurement and by employing a suitable source of power. (See 4.1.1.)

4. Electrical Measurements

4.1 (All). All quantities are root-mean-square values unless otherwise indicated.

4.1.1 (All) Power Supply. The source of supply shall closely approach sine waveform and shall provide balanced phase voltages. The voltage waveform deviation factor³ shall not exceed 10%. The frequency shall be main-

³ The deviation factor of a wave is the ratio of the maximum difference between corresponding ordinates of the wave and of the equivalent sine wave to the maximum ordinate of the equivalent sine wave when the waves are superposed in such a way as to make this maximum difference as small as possible. The equivalent sine wave is defined as having the same frequency and the same root-mean-square value as the wave being tested.

tained within $\pm 0.5\%$ of the value required for the test being conducted, unless otherwise specified.

4.1.2 (A-B-C). Rapid changes in frequency cannot be tolerated on input-output tests, as such variations are transmitted to the output-measuring devices. Any departure from assumed frequency directly affects the efficiency obtained by Methods A or B. For these methods, the frequency shall be measured (or known to be) within 0.5% of the specified test value.

4.2 (All) 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.⁴

4.3 (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 measurements.⁴

4.4 (All) Voltage. The phase voltages shall be read at the motor terminals. Tests may be made where the voltage unbalance does not exceed $\pm 0.5\%$. The percent voltage unbalance equals 100 times the maximum voltage deviation from the average voltage divided by the average voltage.

EXAMPLE: With voltages of 220, 215, and 210 the average is 215, the maximum deviation from the average is 5, and the percent unbalance equals $100 \cdot \frac{5}{215} = 2.3\%$.

4.5 (All) Current. The line currents to each phase of the motor shall be measured. If the line currents are unequal, the arithmetic average value shall be used in calculating machine performance from the test data.

4.6 (All) Power. Power input to a three-phase machine may be measured by two single-phase wattmeters connected as in the two-wattmeter method, one polyphase wattmeter, or three single-phase wattmeters. The total power read on a wattmeter shall be reduced by the amount of the I^2R loss in the voltage circuits of the instruments whenever this loss is a measurable portion of the total power read.

⁴ Further information regarding the use of instruments is given in IEEE Std 120-1955 (R1972) [11].

4.7 WARNING (All) Safety. *Because of the dangerous currents, voltages, and forces encountered, safety precautions shall be taken for all tests. No attempt is made here to list or review the manifold general safety precautions which are well established throughout the industry. However, this standard includes special safety precautions applicable to the particular tests described. All tests should be performed by knowledgeable and experienced personnel.*

5. Performance Determination

5.1 (All) Resistance Measurements

5.1.1 Reference Resistance. To obtain direct-current resistance measurements of stator (and rotor in the case of wound-rotor machines), the procedures given in IEEE Std 118-1978 [9] should be used.

5.1.2 Reference Ambient. All performance determination shall be corrected to an ambient temperature of 25 °C.

5.1.3 Correction to a Specified Temperature. When the resistance R_t of a winding has been determined by test at winding temperature t_t , the resistance may be corrected to a specified temperature t_s by Eq 1.

$$R_s = R_t \left(\frac{t_s + k}{t_t + k} \right) \text{ ohms} \quad (\text{Eq 1})$$

where

R_s = winding resistance, corrected to specified temperature t_s , ohms

t_s = specified temperature, degrees Celsius

R_t = test value of winding resistance, ohms

t_t = temperature of winding when resistance was measured, degrees Celsius

k = 234.5 for pure copper

= 225 for aluminum based on a volume conductivity of 62%

NOTE: For other winding materials, a suitable value of k must be used.

5.2 (All) Efficiency. Efficiency is the ratio of output power to input power. The electrical power is measured directly; the mechanical power may be measured directly, or obtained by adding the losses to the electrical power for generator action, or subtracting the losses from the electrical power for motor action. Unless otherwise specified, the efficiency shall be determined for rated voltage and frequency.

5.2.1 (All) Measurement of Input and Out-

put. Direct measurements of input and output are always made on fractional-horsepower machines and generally on small machines, but such measurements become increasingly difficult with the equipment usually available as the size of the machine increases.

5.2.1.1 In general, the brake (Method A) or dynamometer (Method B) method is used on fractional-horsepower machines and the dynamometer method on machines up to about 500 hp at 1800 r/min or equivalent rated torque at other speeds. For larger machines, the pump-back method (Method C) may be used whenever duplicate machines are available. The segregated-loss method (Method E or Method F) is also used for larger machines. In all methods, the precautions listed in 4.1 to 4.6 shall be observed.

5.2.1.2 (A-B) Bearing Loss Stabilization. Some motors may experience a change in efficiency until the bearings reach a stabilized operating condition. Stabilization can be considered to have occurred whenever the power input at no-load (or coupled to a de-energized dynamometer) does not vary by more than 3% under either of the following conditions:

(1) Two successive readings at half-hour intervals

(2) One reading prior to and one reading following the efficiency test

5.2.2 (A-B-C) Direct Measurement Methods. In all direct measurement method tests the electrical and mechanical power are measured directly. The difference between the various methods lies in the manner of measuring mechanical power.

5.2.2.1 (A-B) Measurements. Readings of electrical power, current, voltage, frequency, slip, torque, ambient temperature, and stator winding temperature, or stator winding resistance, shall be obtained for six load points substantially equally spaced from one-quarter to one and one-half times rated load.

5.2.2.2 (A-B-C) Determination of Motor Performance. When motor performance is tested using direct measurement methods, it is determined as outlined in Section 8, Form B or Form E, or both. Unless otherwise specified, horizontal, polyphase squirrel-cage motors rated 1 hp to 125 hp shall be tested by dynamometer (Method B). Vertical motors in this horsepower range shall also be tested by Method B if the bearing construction permits. If the bearing construction does not permit

the use of a dynamometer, vertical motors in this horsepower range may be tested by any of the other specified methods. Polyphase motors larger than 125 hp may be tested by dynamometer (Method B), or any of the other specified methods.

5.2.2.3 (A) Method A: Brake. The motor is loaded by means of a mechanical brake which is capable of being adjusted to provide the desired torque loading. Care shall be exercised in the construction and use of the brake and brake pulley. The "tare," if present, shall be carefully determined and compensated for. Performance of a machine shall be calculated as shown in Section 8, Form B.

5.2.2.4 (B) Method B: Dynamometer.⁵ Another method of measuring mechanical power of an induction machine is by loading the machine with a dynamometer. The power in kilowatts is obtained from Eq 2.

$$\text{power in kilowatts} = \frac{T \cdot n}{k} \quad (\text{Eq 2})$$

where

T = torque

n = rotational speed in r/min

k = 9549 if T is in N·m

= 7043 if T is in lb·ft

To obtain accurate results the dynamometer rating shall not exceed three times the machine rating, and it shall be sensitive to a torque of 0.25% of the rated torque. The dynamometer correction shall be made as outlined in Section 8, Form B.

The steps described in items (1)-(4) shall be followed and are a specific means of maximizing the accuracy of the dynamometer test. The method requires that data be taken for at least six approximately equally spaced load points between 25% and 150% of rated load.

All data is taken with the machine operating as a motor or as a generator, depending upon the region of operation for which efficiency data is required. The apparent total loss (input-output) is segregated with stray load loss defined as the apparent total loss minus conventional loss (that is, the sum of stator and rotor I^2R loss, core loss, and friction and windage loss). The value of stray load loss thus determined is plotted versus torque squared, a

⁵ A dynamometer is defined as a load absorber equipped with means for indicating torque and speed and is not limited to a cradle base construction.

linear regression analysis is used to reduce the effect of random error in the test measurements, and the smoothed data is used to calculate the final value of efficiency.

(1) For each load point, measure the input kilowatts and output power, and calculate the apparent total loss by subtracting the measured output from the measured input.

(2) The stray load loss shall be separately calculated for each load point by subtracting from the apparent total loss the stator I^2R loss at the temperature of the test, the core loss, friction and windage loss, and the rotor I^2R loss corresponding to the measured value of slip. The stray load loss shall be calculated for six approximately equally spaced load points between 25% and 150% of rated load.

(3) Smooth the stray load loss data by using a linear regression analysis.

$$W_{LL} = AT^2 + B \quad (\text{Eq 3})$$

where

W_{LL} = stray load loss as plotted versus torque squared

T = torque

A = slope

B = intercept

If the slope is negative or if the correlation factor r is less than 0.9, delete the worst point and recalculate A and B . If this increases r to 0.9 or larger, use the second calculation; if not, the test is unsatisfactory. Errors in the instrumentation or test readings, or both, are indicated. The source of the error should be investigated, corrected, and the test repeated. The smoothed value of stray load loss is:

$$W_{LLc} = AT^2 \quad (\text{Eq 4})$$

(4) Calculate motor efficiency using Section 8, Form E, which includes temperature correction. Use W_{LLc} appropriate to the load point.

Bearing friction or measurement errors, or both, may cause torque readings to differ for the same value of electrical power, depending upon whether the load is increasing or decreasing prior to reading. When a correlation factor r equal to or larger than 0.9 is not obtained after the second calculation, the average of two sets of readings shall be taken. The first set shall be taken while gradually increasing the load; the second set while decreasing the load, care being taken in each case not to overrun the points to be read. Curves of torque versus electrical power shall be plotted for each set