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IEEE Standard Test Procedure for Polyphase Induction Motors and Generators

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**Electric Machines Committee
of the
IEEE Power Engineering Society**

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Abstract: Instructions are given for conducting and reporting the more generally applicable and acceptable tests to determine the performance characteristics of polyphase induction motors and generators. Electrical measurements, performance testing, temperature tests, and miscellaneous tests are covered.

Keywords: generators, motors, tests

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Introduction

(This introduction is not part of IEEE Std 112-1996, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.)

This standard provides the basic test procedure for evaluating the performance of a polyphase induction motor or generator of any size. The standard has been revised many times due to improvements in instrumentation and increased knowledge of the art of measurement. The emphasis on energy conservation, legislated values for motor efficiency, and the desire for harmonization with Canadian Standard C390 and the requirements for test accuracy under the National Voluntary Laboratory Accreditation Program (NAVLAP®) certification procedure warranted this further review. The accuracy of the test procedure for measuring efficiency has been verified by extensive comparison testing conducted by the National Electrical Manufacturers Association (NEMA) and the Accredited Standards Committee C50. The revision was carefully written so that references in contracts to certain types of tests for machines will apply equally to both this revision and its prior 1991 version.

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IEEE Standard Test Procedure for Polyphase Induction Motors and Generators

1. Overview

1.1 Scope

This standard covers instructions for conducting and reporting the more generally applicable and acceptable tests of polyphase induction motors and generators. Many of the tests described may be applied to both motors and generators, as needed, and no attempt is made to partition the test procedure into clauses applying to motors and subclauses that separately apply to motors or to generators. Whenever the term *motor* is used, it is to be understood that it may be replaced by the term *generator*, if applicable. Since polyphase power systems are almost universally three-phase systems the equations in this standard have been written specifically for three phases. When the test is performed on other than three-phase power, the equations shall be modified appropriately.

1.2 Purpose

Instructions for conducting and reporting the more generally applicable and acceptable tests are covered to determine the performance and characteristics of polyphase induction motors and generators. Additional tests, not specified herein, may be required to satisfy specific research or application needs. These procedures shall not be interpreted as requiring the performing of any specific test in a given transaction.

2. References

This standard shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the latest revision shall apply.

IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing (ANSI).¹

IEEE Std 43-1974 (Reaff 1991), IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery (ANSI).

¹IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

IEEE Std 85-1973 (Reaff 1986), IEEE Standard Test Procedure for Airborne Sound Measurements on Rotating Electrical Machinery (ANSI).²

IEEE Std 118-1978 (Reaff 1992), IEEE Standard Test Code for Resistance Measurements (ANSI).

IEEE Std 119-1974, IEEE Recommended Practice for General Principles of Temperature Measurement as Applied to Electrical Apparatus (ANSI).³

IEEE Std 120-1989, IEEE Master Test Guide for Electrical Measurements in Power Circuits (ANSI).

3. General tests

3.1 Types of tests

Polyphase induction machines are normally given a routine test, but they may also be given additional tests.

For typical routine tests refer to NEMA MG 1-1993 [B3]⁴ parts 12 and 20.

A typical form for reporting routine test data is shown in Annex A. A typical form for reporting additional test data is shown in Annex B.

3.2 Choice of tests

A complete list of tests covered by this standard is given in the table of contents in clauses 6 through 9. Alternate methods are described 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 that 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 test method is chosen, all necessary data may be obtained by following the instructions and precautions given in the subclause describing the test. Many of these subclauses include alternate methods for obtaining the necessary data. Unless otherwise specified, the manufacturer may choose the method best suited to the facilities available. It is anticipated that the development of improved practices and new equipment, such as electronic and automatic devices, will result in new or improved methods of carrying out the intent of these test procedures. New or modified methods may be used as substitutes when their results have been shown to be reliable and consistent with those obtained by the methods given in these test procedures.

3.4 Tests with load

Tests with load are made for the determination of efficiency, power factor, speed, current, and temperature rise. Some of the miscellaneous tests outlined in clause 9 are also made with load. For all tests with load, the machine shall be properly aligned and securely fastened. For readings to be used in performance determina-

²IEEE Std 119-1974 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181.

³IEEE Std 119-1974 has been withdrawn; however, copies can be obtained from Global Engineering.

⁴The numbers in brackets correspond to those of the bibliography in Annex C.

tions, the machine temperature rise shall be some value between 50% and 100% of rated temperature rise. The usual procedure is to take readings at higher loads first and then follow with readings at lower loads.

3.5 Tests with rotor locked

It should be recognized that the testing of induction machines under locked-rotor conditions with polyphase power involves high mechanical stresses and high rates of heating. Therefore, it is necessary that

- a) The mechanical means of locking the rotor is of adequate strength to prevent possible injury to personnel or damage to equipment.
- b) The direction of rotation is established prior to the test.
- c) The machine is at approximately ambient temperature before the test is started.

The current and torque readings shall be taken as quickly as possible; and, to obtain representative values, the machine temperature should not exceed rated temperature rise plus 40 °C. The readings for any point shall be taken within 5 s after voltage is applied.

3.6 Precautions

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 4.1.2).

CAUTION

Many of the tests described in these procedures subject the machine to thermal and/or mechanical stresses beyond normal operating limits. To minimize the risk of damage to the machine, it is recommended that all tests be performed either under the manufacturer's supervision or in accordance with the manufacturer's recommendations.

4. Measurements

4.1 Electrical

4.1.1 RMS quantities

All voltage and current measurements are rms values, unless otherwise indicated.

4.1.2 Power supply

The power supply shall provide balanced phase voltages closely approaching a sinusoidal waveform. The voltage waveform deviation factor (see note) shall not exceed 10%. The frequency shall be maintained within $\pm 0.5\%$ of the value required for the test being conducted, unless otherwise specified. Any departure from the assumed frequency directly affects the efficiency obtained with methods A and B. When these methods are used, the average frequency shall be within $\pm 0.10\%$ of the specified test value.

NOTE—The deviation factor of a wave is the ratio of the maximum difference between corresponding ordinates of the wave and of 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 rms value as the wave being tested.

4.1.2.1 Frequency stability

Rapid changes in frequency cannot be tolerated during tests because such variations affect not only the machine being tested, but also the output measuring devices. Variations in frequency during a test shall not exceed 0.33% of the average frequency.

4.1.3 Instrument selection

Calibrated, high-accuracy instrumentation and accessory equipment shall be used. Either analog or digital-type instruments may be used in testing. Factors affecting accuracy, particularly with nonelectronic analog instruments, are

- a) Loading of the signal source
- b) Lead calibration
- c) Range, condition, and calibration of the instrument

Since instrument accuracy is generally expressed as a percentage of full scale, the range of the instrument chosen shall be as low as practical.

The indicating instrument shall bear record of calibration, within 12 months of the test, indicating limits of the error no greater than $\pm 0.5\%$ of full scale for general testing or no greater than $\pm 0.2\%$ of full scale, which is required by Efficiency Test Method B (see 6.4) to maintain accuracy and repeatability of test results. When several instruments are connected in the circuit simultaneously, additional corrections of the instrument indication may be required.

Electronic instruments are generally more versatile and have much higher input impedances than passive (nonelectronic) instruments. Higher input impedance reduces the need to make corrections for the current drawn by the instrument. However, high input impedance instruments are more susceptible to noise.

Common sources of noise are

- a) Inductive or electrostatic coupling of signal leads to power systems
- b) Common impedance coupling or ground loops
- c) Inadequate common mode rejection
- d) Conducted interference from the power line

Good practice requires the use of shielded twisted pairs for signal leads, grounding the shield at only one point, and keeping the signal cables as far away as possible from power cables. All exposed metal parts of these instruments should be grounded for safety.

Instrument calibration requirements are similar to those of nonelectronic instruments. When suitable automatic data acquisition systems or high-speed recorders are available, they may be used. Further information regarding the use of instruments is given in IEEE Std 120-1989.⁵

4.1.4 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.

The errors of the transformers used shall not be greater than 0.5% for general testing or not greater than $\pm 0.3\%$, which is required by Efficiency Test Method B (see 6.4) to maintain accuracy and repeatability of test results. When instrument transformers and instruments for measuring voltage, current, or power are cal-

⁵Information on references can be found in clause 2.

ibrated as a system, the errors of the system shall not be greater than $\pm 0.2\%$ of full scale, which is required by Efficiency Test Method B (see 6.4) to maintain accuracy and repeatability of test results.

4.1.5 Voltage

The line voltages shall be measured with the signal leads connected to the machine terminals. If local conditions will not permit such connections, the error introduced shall be evaluated and the readings shall be corrected. Tests may be performed where the voltage unbalance does not exceed 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 V, 215 V, and 210 V, the average voltage is 215 V, the maximum deviation from the average is 5, and the unbalance equals $(100 \times 5)/215 = 2.3\%$.

4.1.6 Current

The line currents to each phase of the motor shall be measured, and the arithmetic average value shall be used in calculating machine performance from the test data.

4.1.7 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 methods. Power readings shall be corrected for meter losses if they are significant.

4.2 Resistance

4.2.1 Reference resistance

To obtain dc resistance measurements of stator (and rotor, in the case of wound-rotor machines), the procedures given in IEEE Std 118-1978 should be used.

4.2.2 Reference ambient

All performance determinations should be corrected to an ambient temperature of 25 °C.

4.2.3 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 equation 1 as follows:

$$R_s = \frac{R_t(t_s + k)}{(t_t + k)} \quad (1)$$

where

R_s	is the winding resistance, corrected to specified temperature, t_s , in Ω
t_s	is the specified temperature for resistance correction, in °C (see 5.1.1)
R_t	the test value of winding resistance, in Ω , at temperature t_t
t_t	the temperature of winding when resistance was measured, in °C
k	is 234.5 for 100% IACS conductivity copper, or 225 for aluminum, based on a volume conductivity of 62%

NOTES

1—For other winding materials, a suitable value of k (inferred temperature for zero resistance) shall be used.

2—The values for t_s and t_t in equation 1 shall be based on the same method of measurement of temperature, 8.3. The value for t_s in 5.1.1 is based on an average winding temperature, 8.3.3, Method C. When t_t is obtained by direct sensing of local temperature, 8.3.4, Method D, the value for t_t in equation 1 must be adjusted to equal the average temperature of the winding. This can be estimated by assuming a linear relationship between the temperature rise obtained by the two methods.

4.3 Mechanical

4.3.1 Power

Mechanical power measurements shall be taken with the greatest care and accuracy. If a mechanical brake is to be used, the tare, if present, shall be carefully determined and compensated for. If dynamometer output measurements are used, coupling and bearing friction losses must be compensated for. Properly sized dynamometers should be used, such that the coupling, friction, and windage losses of the dynamometer (see the note below) measured at rated speed of the machine being tested should not be greater than 15% of the rated output of the machine being tested; and they should be sensitive to a change of torque of 0.25% of the rated torque.

NOTE—A dynamometer is defined as a device for applying torque to the rotating member of the test machine. It is equipped with means for indicating torque and speed, and is not limited to a cradle base construction. An in-line torque transducer may be used to provide a direct measurement of torque at the test machine shaft.

When required by Efficiency Test Method B to maintain accuracy and repeatability of the test results, the errors of the instrumentation used to measure mechanical torque shall not be greater than $\pm 0.2\%$ of full scale.

When using a dynamometer, the dynamometer shaft power, in watts, is obtained from the following equation:

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

where

T	is the torque
n	is the rotational speed, in r/min
k	is 9.549, if T is in $N \cdot m$
k	is 7.043, if T is in $\text{lbf} \cdot \text{ft}$

4.3.1.1 Bearing loss stabilization

Some motors may experience a change in friction loss until the bearings reach a stabilized operating condition. In grease lubricated antifriction bearings, stabilization will not occur until there is no excess grease present in the path of the moving parts. This may require a number of hours of running to completely stabilize the no-load input watts. Stabilization can be considered to have occurred whenever the power input at no-load (or coupled to a deenergized dynamometer) does not vary by more than 3% between two successive readings at the same voltage at half-hour intervals.

4.3.2 Speed and slip

4.3.2.1 Instruments

Analog tachometers or speed counters are not sufficiently accurate for the measurement of slip. Therefore, stroboscopic or digital tachometer methods are recommended. When a stroboscope is used, the power supply for the stroboscope should have the same frequency as the motor power supply.

The instrumentation used to measure speed shall not have an error of greater than ± 1.0 r/min of the reading when required by Efficiency Test Method B to maintain accuracy and repeatability of test results.

Slip speed is the difference between synchronous speed and measured speed in r/min, but slip is usually expressed in per unit as

$$s = \frac{\text{slip speed (in r/min)}}{\text{synchronous speed (in r/min)}} \quad (3)$$

4.3.2.2 Slip correction for temperature

Slip measurements should be corrected to the specified stator temperature as follows:

$$S_s = \frac{S_t(t_s + k)}{(t_t + k)} \quad (4)$$

where

- s_s is the slip corrected to specified stator temperature, t_s
- s_t is the slip measured at stator winding temperature, t_t
- t_s is the specified temperature for resistance correction, in °C (see 5.1.1)
- t_t is the observed stator winding temperature during load test, in °C
- k is 234.5 for 100% IACS conductivity copper, or 225 for aluminum, based on a volume conductivity of 62% (based on rotor conductor material)

NOTES:

1—For other rotor winding materials, a suitable value of k (inferred temperature for zero resistance) shall be used.

2—The values for t_s and t_t in equation 1 shall be based on the same method of measurement of temperature, 8.3. The value for t_s in 5.1.1 is based on an average winding temperature, 8.3.3, Method C. When t_t is obtained by direct sensing of local temperature, 8.3.4, Method D, the value for t_t in equation 1 must be adjusted to equal the average temperature of the winding. This can be estimated by assuming a linear relationship between the temperature rise obtained by the two methods.

4.4 Procedure

Whenever a series of increasing or decreasing readings of data are made, care should be taken in each case not to overrun the desired setting in order to avoid reversing the direction of the test.

4.5 Safety

CAUTION

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 that are well established throughout 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. Types of losses

5.1 Stator I^2R loss

The stator I^2R loss (in watts) is equal to $1.5 I^2R$ for three-phase machines

where

- I is the measured or calculated rms current per line terminal at the specified load
 R is the dc resistance between any two line terminals corrected to the specified temperature (see 4.2.3)

5.1.1 Specified temperature

The specified temperature used in making resistance corrections should be determined by one of the following, which are listed in order of preference:

- Measured temperature rise by resistance from a rated load temperature test plus 25 °C (see clause 8). Rated load is the rating identified on the nameplate at 1.0 service factor.
- Measured temperature rise on a duplicate machine as outlined in a).

NOTE—A duplicate machine shall be one of the same construction and electrical design.

- When the rated load temperature rise has not been measured, the resistance of the windings should be corrected to the temperature shown in table 1.

Table 1—Specified temperature

Class of insulation system	Temperature in °C
A	75
B	95
F	115
H	130

This reference temperature should be used for determining I^2R losses at all loads. If the rated temperature rise is specified as that of a lower class of insulation system than that used in the construction, the temperature for resistance correction should be that of the lower insulation class.

5.2 Rotor I^2R loss

The rotor I^2R loss, including brush-contact losses for wound-rotor machines, should be determined from the per unit slip, whenever the slip is accurately determinable, using equations 5 and 6 as follows:

$$\text{motor rotor } I^2R \text{ loss} = (\text{measured stator input power} - \text{stator } I^2R \text{ loss} - \text{core loss}) \cdot s \quad (5)$$

$$\text{generator rotor } I^2R = (\text{measured stator output power} + \text{stator } I^2R \text{ loss} + \text{core loss}) \cdot s \quad (6)$$

5.3 Core loss and friction and windage loss (no-load test)

The test is made by running the machine as a motor at rated voltage and frequency without connected load. To ensure that the correct value of friction loss is obtained, the machine should be operated until the input has stabilized (see 4.3.1.1).

5.3.1 No-load current

The current in each line is read. The average of the line currents is the no-load current.

5.3.2 No-load losses

The reading of input power is the total of the losses in the motor at no-load. Subtracting the stator I^2R loss (at the temperature of this test) from the input gives the sum of the friction (including brush-friction loss on wound-rotor motors), windage, and core losses.

5.3.3 Separation of core loss from friction and windage loss

Separation of the core loss from the friction and windage loss may be made by reading voltage, current, and power input at rated frequency and at voltages ranging from 125% of rated voltage down to the point where further voltage reduction increases the current.

5.3.4 Friction and windage

Power input minus the stator I^2R loss is plotted vs. voltage, and the curve so obtained is extended to zero voltage. The intercept with the zero voltage axis is the friction and windage loss. The intercept may be determined more accurately if the input minus stator I^2R loss is plotted against the voltage squared for values in the lower voltage range. An example is the dashed curve shown in figure 1.

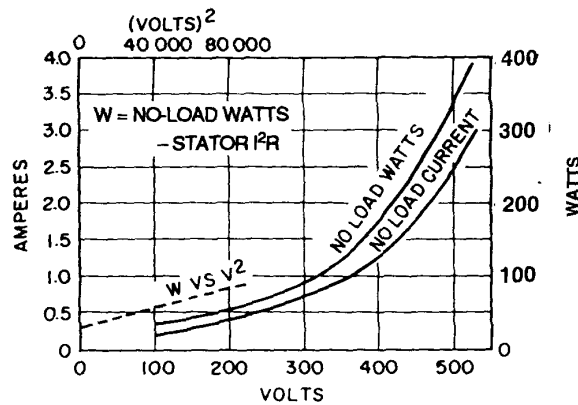


Figure 1—Determination of friction and windage losses

5.3.5 Core loss

The core loss at no load and rated voltage is obtained by subtracting the value of friction and windage loss (obtained from 5.3.4) from the sum of the friction, windage loss, and core loss (obtained from 5.3.2).

5.4 Stray-load loss

The stray-load loss is that portion of the total loss in a machine not accounted for by the sum of friction and windage, stator I^2R loss, rotor I^2R loss, and core loss.

5.4.1 Indirect measurement

The stray-load loss is determined by measuring the total losses, and subtracting from these losses the sum of the friction and windage, core loss, stator I^2R loss, and rotor I^2R loss. Indirect measurement is used in efficiency methods B, C, and C/F (see 6.4, 6.5, and 6.8).

- The procedure for determining the stray-load loss (Method B) is described in 6.4.2.6.
- The procedure for determining the stray-load loss (Method C) is described in 6.5.2.
- The procedure for determining the stray-load loss (Method C/F) is described in 6.8.1.

5.4.2 Direct measurement

Direct measurement is used in efficiency methods E, F, and E/F (see 6.6, 6.7, and 6.8).

5.4.2.1 Stator component in stray-load loss

The stray-load loss occurring at fundamental frequency is determined by applying balanced polyphase voltage to the stator-winding terminals with the rotor removed. The electrical input minus the stator I^2R loss at test temperature is equal to the fundamental frequency stray-load loss. During this test, bearing brackets and other structural parts in which current might be induced shall be in place. The currents used in making this

test and that described in 5.4.2.2 should be identified as I_t and should have values established by equation 7 for magnitudes covering the range of loads from 1/4 to 1-1/2 times rated load, as indicated by the appropriate test procedure.

$$I_t = \sqrt{(I^2 - I_0^2)} \quad (7)$$

where

- I_t is the value of stator winding current during stray-load loss test
- I_0 is the value of no-load current (see 5.3.1)
- I is the operating value of stator line current for which stray-load loss is to be determined

5.4.2.2 Reverse rotation test procedure

The stray-load loss occurring at high frequencies is determined by a reverse rotation test. With the motor completely assembled, balanced polyphase voltage at rated frequency is applied at the stator winding terminals. The rotor is driven by external means at synchronous speed in the direction opposite to the stator field rotation. (The correct speed may be determined easily by stroboscopic methods or by a digital tachometer.) The electrical input to the stator winding is measured.

The mechanical power required to drive the rotor is measured both with and without current in the stator winding. The current magnitude shall be the same values as used in 5.4.2.1. For wound-rotor motors, the rotor terminals shall be short circuited.

5.4.2.3 Stray-load loss calculation for direct method

The stray-load loss, W_{LL} , is calculated as follows:

$$W_{LL} = LL_s + LL_r \quad (8)$$

In equation 8, the values of LL_s and LL_r are calculated for the same values of line currents I_t

where

$$LL_s = W_s - \text{stator winding } I^2 R \text{ loss} = \text{fundamental frequency stray-load loss}$$

The stator winding $I^2 R$ loss shall be the product of the number of phases, $I_t^2 R$ and r_1 , taken at each load point.

$$LL_r = (P_r - P_f) - (W_r - LL_s - \text{stator winding } I^2 R \text{ loss}) = \text{higher frequencies stray-load loss}$$

The stator winding $I^2 R$ loss shall be the product of the number of phases, $I_t^2 R$ and r_1 , taken at each load point.

- r_1 is the stator phase resistance (for a three-phase machine, this is taken as one-half of the resistance between terminals)
- P_r is the mechanical power required to drive rotor with voltage applied at stator winding terminals
- P_f is the mechanical power required to drive rotor without voltage being applied at stator winding terminals

- W_s is the electrical input to stator winding with rotor removed
 W_r is the electrical input to stator winding during reverse-rotation test

5.4.2.4 Smoothing of test data

Smooth the test values of $(P_r - P_f)$, W_s , and W_r by using a regression analysis of the log of the power vs. the log of the current. Then,

$$(P_r - P_f) = A_1(I_t)^{N1} \quad (9)$$

$$W_s = A_2(I_t)^{N2} \quad (10)$$

$$W_r = A_3(I_t)^{N3} \quad (11)$$

where

- A is the y intercept on a log-log plot (a constant)
 N is the slope on a log-log plot (approximately 2)
 I is the observed line current during the stray-load loss test

If the data are accurate, each curve will conform to a square-law relationship between power and current. Thus, the correlation factor from the regression and exponent for each curve both serve as indicators of data accuracy.

NOTE—The low power factors encountered during the tests specified in 5.4.2.1 and 5.4.2.2 make it imperative that phase-error corrections be applied to all wattmeter readings. Refer to IEEE Std 120-1989.

5.4.2.5 Calculating stray-load loss at a specified point

(1) Determine an approximate value of rotor current I_2' corresponding to the rated value of stator line current, I , as

$$I_2' = (I^2 - I_o^2)^{1/2} \quad (12)$$

where

- I is the rated value of stator line current
 I_o is the value of no-load stator current

(2) For the value of rotor current I_2' , calculate a value of stray-load loss W'_{LL} for three-phase machines as follows:

$$W'_{LL} = A_1 \times (I_2')^{N1} + 2A_2 \times (I_2')^{N2} - A_3 \times (I_2')^{N3} - 3 \times (I_2')^2 \times (2 \times r_{1s} - r_{1r}) \quad (13)$$

where

- W'_{LL} is the value of stray-load loss for approximate value of rotor current corresponding to rated load
 I_2' is the approximate value of rotor current corresponding to rated load from equation 12

- r_{1s} is the stator resistance per phase during rotor removed test at test temperature (see 5.4.2.1)
 r_{1r} is the stator resistance per phase during reverse rotation test at test temperature (see 5.4.2.2)

The value of stray-load loss, W_{LL} , reported in 10.4 or 10.6, corresponds to a value of I_2' as calculated using equation 12.

(3) The value of stray-load loss, W_{LL} , for any load point, is then calculated as

$$W_{LL} = W'_{LL} \cdot \left(\frac{I_2}{I_2'} \right)^2 \quad (14)$$

where

- I_2 is the value of rotor current appropriate to the load point for which stray-load loss is to be determined

(4) The value of rotor current is calculated as

$$I_2 = \sqrt{(I^2 - I_0^2)} \text{ or } (I^2 - I_0^2)^{\frac{1}{2}} \quad (15)$$

where

- I is the operating value of stator line current for which stray-load loss is to be determined
 I_0 is the value of no-load current

5.4.3 Alternate direct method for wound-rotor motors

This method is used with efficiency methods E, F, and E/F (see 6.6, 6.7, and 6.8). In this method, the rotor is excited with direct current, and the stator winding terminals are short-circuited with ammeters included to read the stator current. The rotor is driven by external means at synchronous speed. The rotor excitation is adjusted until the current circulating in the stator winding has the value for which a stray-load loss determination is desired. The mechanical power required to drive the rotor, with excitation, (P_r), and without excitation, (P_f), is measured.

$$W_{LL} = P_r - P_f - \text{stator winding } I^2R \text{ loss at temperature during test} \quad (16)$$

If six load points are used, the accuracy can be improved by plotting stray-load loss vs. stator winding current squared and by following a smoothing procedure similar to 5.4.2.4.

5.4.4 Assumed stray-load loss

This measurement is used with efficiency methods E1, F1, and E1/F1 (see 6.6, 6.7, and 6.8). If the stray-load loss is not measured, and it is acceptable by applicable standards or by contract specifications, the value of stray-load loss at rated load may be assumed to be the value shown in Table 2.