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Proposed
Test Procedure
for
POLYPHASE INDUCTION MOTORS
HAVING LIQUID IN
THE MAGNETIC GAP

(Published for Trial Use)

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FOREWORD

In recent years, induction motors have found increasing usage in applications where the rotor operates in a liquid environment. Frequent applications include driving pumps in primary coolant loops in nuclear reactors, in boiler forced circulating systems, and in deep well pumping. From the viewpoint of testing and test procedures, motors designed for these applications differ from more conventional motors principally in having additional loss due to circulating currents in the metallic barriers in the air gap, in having higher friction loss, and in reduced accessibility to the windings and rotating parts. Because of these differences and the increasing usage of such motors, the Induction Machinery Subcommittee of the Rotating Machinery Committee undertook the preparation of this Test Procedure, which was derived from AIEE No. 500 (now IEEE No. 112) (ASA C50.20-1954), American Standard Test Code for Polyphase Induction Motors and Generators.

ACKNOWLEDGMENT

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**Proposed
Test Procedure
for
POLYPHASE INDUCTION MOTORS
HAVING LIQUID IN THE MAGNETIC GAP**

1. SCOPE

This Test Procedure covers instructions for conducting and reporting the more generally applicable and acceptable tests to determine the performance characteristics of polyphase induction motors having liquid in the magnetic gap. Constants in several equations and forms apply to three-phase motors only and require modification for application to motors having another number of phases. It is not intended that the Procedure cover all possible tests or tests of a research nature. The Procedure shall not be interpreted as requiring the making of any or all of the tests described herein in any given transaction.

2. GENERAL

2.1 Kinds of Tests. These motors are normally given either a routine test or a complete test.

2.1.1 Routine Test. The routine test includes measurement of speed, power and current input at no load, current input with locked rotor, winding resistance, insulation resistance, and dielectric test. Form 1 should be used for reporting such data.

2.1.2 Complete Test. The complete test includes a routine test plus additional tests necessary to determine efficiency, power factor, starting torque, breakdown torque, rated-load slip, and rated-load temperature rise.

Form 2 should be used for reporting such data. Additional tests such as measurement of noise, vibration, and speed-torque characteristics which are described in this Test Procedure, and other tests such as measurement of shaft currents which are not covered in this Test Procedure, may be used.

2.2 Choice of Test. A complete list of tests covered by this Procedure is given in the Contents. Alternate methods are described for making many of the tests. In some cases the preferred method is indicated.

3. ELECTRICAL MEASUREMENTS

3.1 General. Electrical measurements shall be made in accordance with the AIEE Master Test Code for Electrical Measurements in Power Circuits, No. 552 (now IEEE No. 120).

3.2 Power Supply. The supply voltage shall closely approach sine wave form and shall provide balanced phase voltages. The frequency shall be closely regulated and shall be measured within an accuracy of 0.1 percent of rated value.

3.3 Instrument Selection. The instruments used in electrical measurements shall be selected to give indications

well up on the scale, i.e., where a fraction of a division is easily estimated and where such a fraction is a small percentage of the value read.

3.4 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.

3.5 Voltage. The phase voltages shall be read at the motor terminals. The arithmetic average of the root-mean-square phase voltages shall be used in calculating machine characteristics.

3.6 Current. The line current in each phase shall be measured. The arithmetic average of the root-mean-square line currents shall be used in calculating machine characteristics.

3.7 Power. The average power input to a three-phase machine shall be measured by three single-phase wattmeters connected in Y as in the three wattmeter method, or by two single-phase wattmeters connected as in the two wattmeter method, or by a single polyphase wattmeter. Correction shall be made for instrument losses.

4. PERFORMANCE DETERMINATION¹

4.1 Temperature. Precautions shall be taken that the internal coolant approximates the design temperature. All performance determinations shall be corrected to a temperature corresponding to the rated temperature of the supplied coolant.

4.2 Pressure. Some designs may require pressurization of the internal coolant for safe operation. In these cases, safety measures appropriate to the design should be exercised.

4.3 Efficiency. Efficiency is the ratio of output power to input power. Unless otherwise specified, the efficiency shall be determined for rated voltage, frequency, and coolant temperature and flow.

4.3.1 Measurements. Readings of power, current, voltage, frequency, slip, torque, temperature, coolant flow where applicable, and stator coil maximum winding surface temperature or stator winding resistance, shall be obtained for six load points approximately equally spaced from one-quarter to one and one-half times rated load.

4.3.2 Mechanical-Output Measurement Methods. In all mechanical-output measurement method tests, the electric and mechanical power are measured directly. Per-

¹ See Form 5 for Nomenclature.

formance of a machine should be calculated as shown on Form 3. The output power is calculated as follows:

$$W = 0.142 T N$$

where

W = Output Power, watts

T = Torque, pound-feet

N = Speed, revolutions per minute

Torque corrections appropriate to the equipment used shall be made.

4.3.2.1 Brake. The "tare", if present, shall be determined and compensated.

4.3.2.2 Dynamometer. The dynamometer rating should not exceed three times the machine rating, and it should be sensitive to a torque of 0.25 percent of the rated torque.

4.3.3 Segregated-Loss Methods. The input shall be measured as indicated in Section 4.3.3.1 or calculated as described in Section 4.3.3.2. The output shall be determined by subtracting the losses from the input. An induction machine having liquid in the magnetic gap has, or may have, the following losses:

Loss Designation	Description
(1) Friction and fluid loss	Mechanical loss due to rotation of rotor assembly in its normal environment
(2) Core loss	Loss in iron at no load
(3) Can loss	Loss in cans at no load
(4) Stator I^2R loss	Loss in stator windings
(5) Rotor I^2R loss	Loss in rotor windings
(6) Stray-load loss	Load dependent loss in iron, rotor and stator cans, and eddy current and high-frequency losses in conductors

4.3.3.1 Input Measurements. To obtain the required data, it is necessary to couple, belt, or gear the machine to a variable load.

The required data are:

- (1) Stator resistance
- (2) No-load current and no-load losses
- (3) Rotor slip
- (4) Maximum stator winding surface temperature
- (5) Watts input
- (6) Line current
- (7) Stray-load loss

Data shall be obtained for six load points approximately equally spaced from one-quarter to one and one-half times rated load.

Forms 4 and 6 should be used for calculating and tabulating the performance.

4.3.3.2 Equivalent-Circuit Calculations. When tests under load cannot be made, operating characteristics may be calculated from the equivalent circuit (See Figure 1). Required constants should be calculated from the no-load, impedance, and stray-load loss data using formulas on

Form 5 and should be recorded on Form 6. Form 7 is a work sheet upon which the circuit calculations may be made.

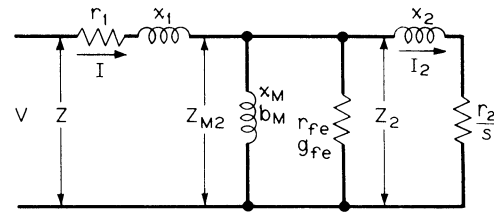


Figure 1
Equivalent Circuit

4.3.3.2.1 The results of the equivalent circuit calculations shall be summarized on Form 6.

4.3.3.2.2 Rotor resistance and reactance may vary considerably with rotor frequency, hence with rotor speed. The values of r_2 and x_2 used in equivalent circuit calculations may be calculated from an impedance test (See Section 4.9.3). An alternate method of obtaining r_2 is described in Section 4.3.3.2.4.

4.3.3.2.3 Form 5 is arranged on the basis of x_1 and x_2 remaining constant throughout the range of operation of the machine. If the impedance curve of current versus volts departs from a straight line in the range of currents under consideration, the values of reactance corresponding to each value of I shall be used in each column of Form 7.

4.3.3.2.4 When a test curve of motor slip versus line current under load is available, r_2 should be determined by the following procedure. Calculate I by solving the equivalent circuit (Form 7) for an assumed value of $\frac{r_2}{s}$. Enter the slip-ampere curve and obtain the value of slip corresponding to the calculated value of I . Obtain r_2 by multiplication of the assumed value of $\frac{r_2}{s}$ by this value of slip.

4.3.3.2.5 Maximum or breakdown torque may be calculated from the equivalent circuit using the value of slip,

$$s = \frac{r_2}{\sqrt{r_1^2 + (x_1 + x_2)^2}}$$

Values of reactance corresponding to the current at the maximum torque point must be used in this calculation.

4.4 Losses

4.4.1 Stator I^2R Loss. The stator I^2R loss is equal to $3 I^2 r_1$

where I is the measured or calculated root-mean-square current per terminal, and r_1 is one-half of the resistance between any two line terminals. The resistance shall be corrected to a temperature equal to the specified external coolant temperature plus the rated-load temperature rise by resistance. When load tests are made, the winding temperature rise shall be determined by resistance measurement for rated load and may be so determined for other loads.