

AIEE
No. 806
Jan. 1960

Proposed
Test Procedure for
**AIRCRAFT ALTERNATING-CURRENT
GENERATORS**

(Proposed for trial use)

AIEE No. 806



Published by
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West Thirty-ninth Street, New York 18, N. Y.

CONTENTS

	Page
1.000 Purpose	5
1.100 Scope	5
1.200 Standard Test Conditions	5
1.300 Characteristics of Prime Mover Supply for Testing	5
1.400 Insulation Resistances	5
1.500 Dielectric Tests	6
1.600 Winding-Resistance Measurements	7
1.700 Phase Sequence	8
1.800 Wave Form and Crest Factor	8
1.900 Overspeed Test	9
2.000 Voltage Unbalance	9
2.100 Efficiency and Loss Determination	9
2.200 Temperature Test	11
2.300 Sudden Short-Circuit Tests and Synchronous Machine Quantities	12
2.320 Direct-Axis Synchronous Reactance	13
2.330 Quadrature-Axis Synchronous Reactance	13
2.340 Direct-Axis Transient Reactance	14
2.350 Direct-Axis Subtransient Reactance	15
2.360 Negative-Sequence Reactance	17
2.370 Zero-Sequence Reactance	18
2.380 Potier Reactance	19
2.390 Direct-Axis Transient Open-Circuit Time Constant.....	19
2.400 Direct-Axis Transient Short-Circuit Time Constant.....	21
3.000 Direct-Axis Subtransient Short-Circuit Time Constant	21
3.010 Short-Circuit Time Constant of Armature Winding.....	21
3.020 Synchronizing Coefficient	22
3.030 Pull-Out Torque	22
3.040 Short-Circuit Ratio	23
3.100 Resistances	23

ACKNOWLEDGMENT

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 the AIEE publications are based.

This publication was prepared by the Rotating Machinery Subcommittee of the Air Transportation Committee. The subcommittee personnel was changed during the preparation of this report but the following have been members at some time during that period.

A. J. Wesolowski, *Chairman*
R. R. Miille, *Secretary*

J. W. Allen	A. F. Pelster
R. M. Brown	F. M. Potter
S. S. Burns	J. Salay
J. M. Hibbard	R. R. Smith
V. C. Holloway	H. T. Stowitts
R. D. Jones	W. K. Stubbs
W. R. Krusi	D. S. Toffolo
L. R. Larson	H. R. Tragresser
M. H. Lowe	F. C. Yagerhofer
T. J. Martin	L. A. Zahorsky
R. O. McCants	

Proposed Test Procedure for **AIRCRAFT ALTERNATING-CURRENT GENERATORS**

PURPOSE

- 1.000** It is the purpose of this Procedure to define uniform acceptable test methods for determining the performance and other characteristics of aircraft alternating-current generators.
- 1.001** Rotating electric equipment for aircraft is subjected to requirements and operating conditions not normally encountered by commercial generators. For example, conditions of temperature, altitude, humidity, and vibration vary over much wider ranges. Aircraft requirements dictate minimum weight, and yet utmost reliability is essential. Weight reduction is generally achieved by sacrifice of life expectancy commensurate with aircraft practices. The necessity for accurate design requires that direct measurements to insure reliability and adequate life be an important part of this Test Procedure.
- 1.002** It is recognized that there may be acceptable methods of making tests other than those described. Such other methods may be considered as alternative procedures accepted by agreement between interested parties. The tests outlined herein are not necessarily complete for any specific generator; and likewise the requirements in each case will determine the number of tests to be made.

SCOPE

- 1.100** This Procedure covers aircraft alternating-current generators. (With or without integral rotating exciters.)

STANDARD TEST CONDITIONS

- 1.200** Unless otherwise specified or required by the type of test, all tests in this Procedure should be made under the standard conditions outlined below. For tests made under other conditions, the actual test conditions should be specifically noted and corrections should be made when necessary to reduce the results to equivalent performance under these standard conditions.
- 1.201** Temperature—Room ambient, 20C-40C.
—Blast cooling air (if required),
30C-40C.
Altitude—Sea Level +5000 feet.

Operation Position—Rotational axis horizontal.

Stabilized Temperature—Substantially stabilized at a temperature corresponding to operation at the specified load within the generator's rating.

Voltage—Rated generator value measured at terminals of the generator.

CHARACTERISTICS OF PRIME MOVER SUPPLY FOR TESTING

- 1.300** It is important to ascertain that the speed of of the prime mover, when checking transient characteristics, does not drop at any instant below the necessary value. This may best be checked by oscillograph record showing variation of generator frequency during the test. No numerical value can be assigned to the relative capacity of the prime mover and that of the generator under test, as this varies over a wide range depending upon the type of machine being tested and the nature of the tests considered necessary to predict satisfactory operation on the systems to which it is to be connected in service.

INSULATION RESISTANCES

- 1.400** Insulation resistance can be a criterion as to whether or not a generator may be safe to operate. This resistance varies greatly with environmental conditions, being affected chiefly by cleanliness, humidity, and temperature.
- 1.401** If the generator needs cleaning, use the proper solvent or cleaner depending on the type of insulation varnish.
- 1.402** A generator exposed to excessive moisture should be dried. A safe criterion is to allow the temperature of the windings to be about 40C above the ambient during the drying procedure, as long as the total temperature of the winding does not exceed the rating of the insulation. During the drying procedure, the insulation resistance will decrease rapidly at first, and then will rise gradually, finally leveling off to its maximum value. It is important to dry a sufficiently long time to reach this constant value.

- 1.403 For all new or reconditioned machines, an insulation resistance of at least one megohm at room ambient is desirable. With old machines in service much lower values may often be obtained.
- 1.404 A practical way of measuring insulation resistance of alternating-current aircraft generators is by using a megohm meter.
- 1.405 The voltmeter method is based on the principle of comparing the current flowing when a fixed direct potential is impressed on a known resistance and when impressed on the same resistance in series with the unknown. In the application of the method, the resistance of the voltmeter is the known resistance. The sensitivity of the instrument will have a direct bearing on the values of insulation resistance which can be measured with reasonable accuracy. For the more generally available commercial voltmeters (100 ohms per volt) the application with a 500 volt direct potential source should be restricted to measurements of one to two megohms maximum. The maximum resistance which can be measured at voltages lower than 500 volts is proportionately less. For instruments of higher sensitivity the maximum value of insulation resistance which can be measured is increased in direct ratio to the sensitivity in ohms per volt. Figure 1 describes the circuit arrangement used for these measurements. A reading is first taken across the circuit and then a second reading with the insulation in series with the voltmeter.

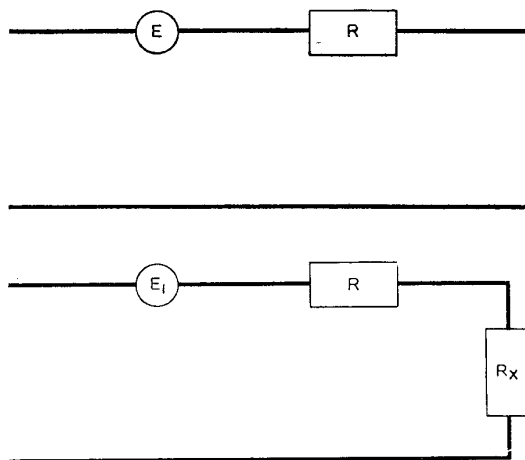


Figure 1

$$\begin{aligned}
 E &= \text{reading of voltmeter across the circuit} \\
 E_i &= \text{reading of voltmeter in series} \\
 &\quad \text{with unknown resistance} \\
 R &= \text{voltmeter resistance} \\
 R_x &= \text{unknown resistance} \\
 R_x &= \frac{R(E - E_i)}{E_i}
 \end{aligned}$$

- 1.406 The following precautions should be observed in performing the above insulation resistance tests:
- All circuits of equal voltage above ground are connected together.
 - The test potential should be applied long enough to obtain a stable reading. Ground terminals after test to discharge capacity effect of winding.
 - Machine is clean and dry.
 - Any capacitors or resistors used in filtering circuits are disconnected.

DIELECTRIC TESTS*

- 1.500 The purpose of these tests is to determine the adequacy of insulating materials, leakage, and clearance distances in a new generator.
- 1.501 The standard test voltage should be an alternating voltage whose root-mean-square value is 1000 volts plus twice the rated voltage of the machine except for windings rated 50 volts or lower. In the latter case, the test voltage should have a root-mean-square value of 500 volts.
- 1.502 When the windings are completely assembled at the plant of the manufacturer, and unless otherwise agreed upon, dielectric tests shall be made at the plant of the manufacturer immediately after the completion of other shop tests. In the case of generators designed to have windings interconnected or connected to an internal ground point, the dielectric tests on these windings may be made prior to final assembly and test while the winding terminal is unconnected or ungrounded.

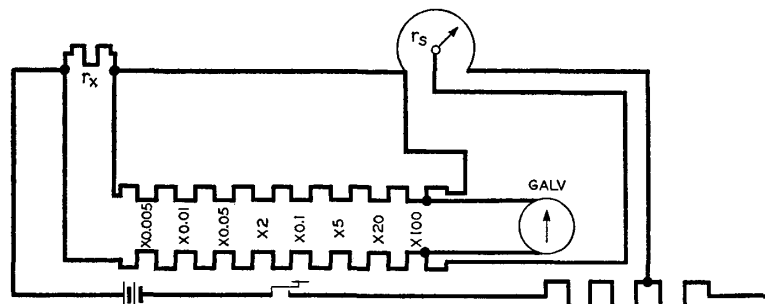
*Note: When desirable, other tests may be used for determining the condition of insulation in windings. Among these tests are the following:

- High-Frequency Test—In the high-frequency test the internal insulation of the winding is tested by applying or inducing a high-frequency voltage of substantially sinusoidal waveshape. The voltage to ground should not exceed the high-potential test voltage.
- Repetitive Surge Test—In the repetitive surge test, a surge voltage is alternately applied to the winding being tested and one known or presumed to be good. The various faults in the insulation of either winding are indicated by characteristic distortions of an image on an oscilloscope. A test voltage, 75 percent to 90 percent of that which produces fault indications in a satisfactory winding, is normally used.

- 1.503 When the windings are completely or partly assembled at the destination, the tests should be made at the destination, as soon as possible after completing the assembly of the winding.
- 1.504 When a test is made on a new generator which has previously passed its dielectric test at the factory, and whose windings have not since been disturbed, the test voltage, unless otherwise agreed upon, should be 75 percent of the value specified above for any particular case.
- 1.505 The test voltage should be applied continuously for a period of one minute except that, when agreed upon, an alternative production test may be made using a voltage 20 percent higher than the one-minute test voltage for a period of one second.
- 1.506 The waveshape of the test voltage should be of acceptable commercial standards. Unless otherwise specified, the test voltage should have a frequency of 60 cycles per second.
- 1.507 The test voltage should be applied between each electric circuit and the frame, with the circuits not under test and the core and other metal parts connected to the frame.
- 1.508 Any capacitors or resistors used in filtering circuits should be disconnected during these tests.

WINDING-RESISTANCE MEASUREMENTS

- 1.600 Direct-current resistance measurements are used for several purposes in alternating-current generators—chiefly:
- To calculate a portion of the I^2R loss.
 - To determine the average temperature of the windings.
 - To determine the resistance component of the internal voltage drop.
 - To check manufacturing defects such as poor joints, or unbalanced windings.
- 1.601 It is important to obtain the true temperature of the windings when measuring cold resistance. The temperature of the ambient air is not to be considered the winding temperature unless the generator has been shut down for at least eight hours in a stable ambient.
- 1.602 To calculate the temperature of a winding use the following:
- $$R_1 = \left(\frac{K + t_1}{K + t_2} \right) R_2$$
- where
- R_1 = resistance at temperature t_1
 R_2 = resistance at temperature t_2
 $K = 234.5$ for t in Centigrade for copper.
 $K = 228$ for t in Centigrade for aluminum.
- 1.610 **Volt-Ampere Method:**
 This method will give the direct-current resistance of a winding merely by application of Ohm's law—where $R = E/I$.
 Care should be taken to—
- Impress a direct potential across winding to be measured so that only a fraction of the rated current flows—say not above 15 percent.
 - Test should be conducted rapidly to prevent heating.
 - Make sure to avoid contact and lead resistance by using proper ammeter leads and separate voltmeter leads.
- 1.611 **Bridge Method:**
 A Kelvin double bridge should be used in measuring resistance of alternating-current aircraft generators since resistances encountered are usually less than five ohms. There are several advantages of using this type of bridge.
- A high degree of accuracy is obtained — especially for low values of resistance.
 - Lead and connection resistance effects are eliminated.
 - Instrument requires but little maintenance.
- The bridge circuit is as follows:



If a Wheatstone bridge is used, certain precautions as outlined in paragraph 1.152-1.153 of AIEEE 503, Test Code for Synchronous Machines, should be followed.

1.612 Resistances of Rotating Elements:

While the generator is in operation under load it is possible to measure, quite accurately, the resistance of alternating-current generator fields through slip rings by use of auxiliary brushes and volt-ampere method.

This is simply done by placing auxiliary brushes insulated from the main brushes between the slip rings and measuring the voltage with a voltmeter, then the proper winding resistance is equal to the voltage measured on the auxiliary brushes divided by the field current. A comparison with the cold resistance will then give the temperature rise.

PHASE SEQUENCE

1.700 Phase-sequence tests are made to determine if the alternating-current output terminal markings agree with specifications. It is determined by using a phase-sequence meter or an induction motor.

1.701 One type of phase-sequence meter used has no moving parts and is available to check three-phase generators. This indicator, Figure 2, makes use of a small capacitor and two neon lamps connected in wye across the three phases of the generator to be tested. For a phase sequence of 1, 2, 3, the L_2 lamp will glow brightly and for a sequence of 3, 2, 1, the L_1 lamp will glow brightly.

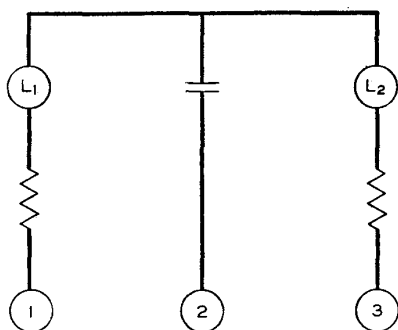


Figure 2

1.702 Two other practical ways of determining phase sequence are:

- Use of an induction motor of known phase sequence. In this case the generator to be checked is then driven and its output terminals connected to the motor, phase A to phase A of motor, etc. The direction of rotation of the motor then determines the phase sequence of the generator.
- Use of an alternating-current generator of known phase sequence. In this case connect the generator to be tested the same as the induction motor in part (a). The generator under test then runs as an induction motor and its phase sequence is then determined.*

In both the above cases, the connections may be made at standstill, then the driven generator brought up to speed unexcited. The excitation may then be applied and removed quickly. The direction of rotation of the motor in case (a), and the generator in case (b) determines the phase sequence of the generator.

WAVE FORM AND CREST FACTOR

1.800 Wave form means the shape of the voltage output wave. Two methods of demonstrating the wave shape are practical.

- Use of an oscillograph will show the actual shape of wave. This is not a practical method of separating out the harmonic components.
- Use of a harmonic analyzer such as the General Radio Wave Analyzer Type 736A, will measure the amplitude of any harmonic relative to the fundamental. This information is useful in that the proper filter circuits can be used to eliminate objectionable harmonics.

1.801 Crest factor shows the magnitude of the peak of the voltage wave relative to the root-mean-square value of the wave. This test is conducted by using a carefully calibrated peak-to-peak voltmeter and a root-mean-square voltmeter—thus the crest factor is:

$$\text{C.F.} = \frac{\text{peak-to-peak voltage}}{2 (\text{rms voltage})}$$

For a pure sine wave this factor is 1.414. In conducting the above tests it is extremely important to use unsaturated reactors for the reactive loads to eliminate wave distortion by external factors.

*CAUTION: Short circuit generator field during this test to prevent high induced secondary voltage.