

Test Procedure and Presentation of
**AIRCRAFT GENERATOR AND
REGULATOR CHARACTERISTICS**

(Published for trial use)



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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.

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Test Procedure and Presentation of **AIRCRAFT GENERATOR AND REGULATOR CHARACTERISTICS**

SCOPE

- 1.000 The tests covered herein may be required by the aircraft and/or equipment manufacturers for proper system design. This document is primarily intended for air-blast-cooled machines.

STANDARD TEST CONDITIONS

- 1.100 Unless otherwise specified, the following standard test conditions will prevail.
- 1.101 Drive and Mounting. The generator should be mounted on a suitable drive stand capable of driving the generator at all rated load conditions over the rated speed range. For rating tests, the generator flange should be thermally insulated from the drive stand.
- 1.102 Regulator and Excitation. The generator should be self-excited except where separate excitation is supplied in the service application; in this case, separate excitation may be used to the extent that it is available in the service. The generator should be controlled by a regulator designed for the purpose.
- 1.103 Ambient Temperature. The thermal environment should be in accordance with the applicable specifications and/or drawings.
- 1.104 Altitude. The test should be run at approximately sea level altitude.
- 1.105 Location of Load. The load for the generator should be so located that it will not appreciably affect the ambient or the blast cooling air temperature.
- 1.106 Warm-Up. Prior to the test the generator should be operated at approximately average rated speed delivering full rated load at rated voltage for a sufficient time to reach a substantially constant temperature on both the generator and the regulator.
- 1.107 Speed. For generators with speed ranges of $\pm 10\%$ or less, tests should be conducted at average speed. For wide speed range generators, the speed will be specified on each test.

BRUSH WEAR LIFE SIMULATED ALTITUDE TESTS (DIRECT-CURRENT AND ALTERNATING-CURRENT GENERATORS)

- 1.200 It is the purpose of these tests to determine the performance of the machine under conditions simulating flight in so far as it is possi-

ble. Possible sources of trouble include inadequate cooling, excessive brush and commutator wear.

- 1.201 Some "altitude chambers" cannot reproduce all of the high-altitude conditions that influence brush wear. The contaminants in the cooling air must be maintained at a minimum if reliable results are to be obtained. As a result, check or calibration tests should be taken at regular intervals to be sure that the altitude chamber is functioning properly. The interested parties should be in agreement concerning conditions for the check or calibration test.
- 1.202 These check or calibration tests should be conducted using a machine of known altitude performance under specified conditions. If it is impossible to duplicate the known performance the cause of the lack of correlation must be found and corrected.
- 1.203 The air entering the machine should be at the desired temperature, pressure and dew point. The temperature should be controlled to within $\pm 5^\circ\text{C}$ of the desired value while the altitude is held within ± 1000 feet or 3 percent whichever is the greater. The dew point of the air entering the machine should equal or be lower than the specified value. A dew point measuring device which employs a refrigerated mirrored surface should be used. Care should be taken that no material is used which will absorb moisture.
- 1.204 The ambient air temperature around a blast-cooled machine should be as specified.
- 1.205 For alternating-current generators with speed ranges wider than ± 10 percent, these tests should be conducted at minimum and maximum speeds.

For direct-current generators with speed ranges greater than ± 10 percent these tests should be conducted at the continuous operating speed and the maximum rated speed.

1.210 Preparation of Machine For Test.

In order to obtain repeatable results from chamber tests, it is necessary that the machine be properly prepared for test. The commutator surface should be refinished. After the commutator refinishing and before the start of the altitude tests, the machine should be operated under ground conditions at rated load and rated cooling until a satisfactory brush and commutator condition is produced.

1.211 The following temperature measurement provisions should be made:

(a) Thermocouples should be installed in the brushes as in Section 2.420 of AIEE No. 800, dated January 1953.

(b) In addition means should be provided to measure the temperature of the air entering, the air leaving, the frame, the rotor and the bearings of the machine. The method used in obtaining temperature data should be recorded for comparison purposes.

1.220 **Data To Be Recorded.**

Certain information is necessary to enable analysis of the altitude performance of the equipment.

1.221 Sea level full-load test data should be recorded to show that the machine is in satisfactory operating condition. The appearance of the commutator and brushes, the commutator bar to bar and total run out, the commutator diameter measured at four axial positions, two in the brush track and two outside the brush track, and the length of the brushes should be recorded prior to the start of the altitude test.

1.222 From the time that the altitude test starts the following readings should be taken at intervals of no more than one hour:

(a) Information to permit the calculation of the mass rate of flow of cooling air passing through the machine. Measurement of generator pressure drop.

(b) Altitude and dew point.

(c) Ambient air, entering air, exit air, frame, brush, rotor and bearing temperatures.

(d) Output voltage, output current, power factor, commutation, and main field voltage and current readings.

(e) Machine speed.

1.223 At the completion of the test the same information as called for in paragraph 1.221 should be recorded.

1.230 **Presentation.**

For direct-current generators see Figure 1.

For alternating-current generators see Figure 2.

**ACTUAL AIRFLOW BLAST COOLING
(DIRECT-CURRENT AND ALTERNATING-CURRENT
GENERATORS)**

1.300 The purpose of these tests is to determine the amount of air used in blast-cooling equipment where applicable.

1.301 The method used for measurement of air mass flow should be consistent with the standards of ASME Fluid Meters Handbook, Part I—

Theory and Applications, 1937; or should be of equal accuracy.

1.302 Total head pressure measurements are normally recorded in inches of water. The total head tube should be centered in the blast tube at a point approximately four diameters from the generator inlet and must be facing upstream. The total head tube should not exceed $\frac{1}{4}$ inch OD. The blast tube should have approximately eight diameters straight flow prior to the total head tube if there are no elbows or valves. If elbows and valves are present, refer to paragraph 1.301.

1.310 **Conditions.**

Generators as normally used with or without fan. Variable-speed machines to be tested at standstill, minimum, average and maximum speed, and constant-speed machines at standstill and rated speed. The differential of pressure between the total air inlet and the total air exit should be varied from zero to 40 inches of water at no load. The differential of pressure, at rated load with the machine temperature stabilized for average speed and a six-inch pressure differential, should be varied from zero to 16 inches of water.

1.320 **Presentation.**

Curves of airflow in pounds per minute versus pressure drop in inches of water as abscissa. Air in temperature as specified.

NOTE: Because the shrouding configuration is important in obtaining reverse flow characteristics on generators, it is recommended that these characteristics be obtained by the airframe manufacturer.

NOTE: In order for the generator manufacturer to give a machine rating under reverse and zero airflow conditions, the airframe manufacturer must furnish information concerning temperatures, altitude, air flow, duration of time, and temperature condition of machine prior to specified condition.

**EFFICIENCY
(DIRECT-CURRENT AND ALTERNATING-CURRENT
GENERATORS AND VOLTAGE REGULATORS)**

1.400 Output or input power may be measured directly or determined from measured or calculated losses. These losses normally include field resistors, integral exciters and any other accessory where the losses are controllable by the machine design.

NOTE: For determination of efficiency by separation of losses see AIEE Test Code for Direct-Current Machines, No. 501, AIEE Test Code for Synchronous Machines, No. 503.

1.401 Percent efficiency is given by the following formula:

$$\% \text{ Eff} = 100 \times \frac{\text{output power}}{\text{input power}} = 100 \times \frac{\text{output power}}{\text{output power} + \text{losses}}$$

Input power includes excitation externally supplied as well as mechanical power.

1.410 Torque Measurement.

The most desirable method of measuring torque will be governed by the rating of the machine under test. Three methods in common use are:

- (1) Direct measurement of torque reaction.
- (2) Direct measurement of shaft torque.
- (3) Dynamometer.

1.411 Direct Measurement of Torque Reaction. In this method the generator to be tested is mounted so that the housing is free to turn about the axis of the driving shaft. A rigid arm is fastened to the housing support; at some definite radius from the driving shaft, the force on the arm required to keep the housing stationary is measured. This force times the radius equals the driving torque.

1.412 A common arrangement for flange mounted generators is shown in Figure 3. Here, the generator is bolted to a flange which is mounted on bearings and is free to turn; the torque arms are also fastened to this flange. The driving shaft must be rigid and must be concentric with the generator mount pilot. The bearings must be chosen and arranged to provide a rigid, firm support for the generator as well as a low value of rotational friction.

1.413 The outboard end of the generator may, if necessary, be supported on ball-bearing rollers.

1.414 Direct Measurement of Shaft Torque. The shaft torque may be directly measured by means of strain gages mounted on the driving shaft with necessary electric connections made through slip rings. Each shaft with its strain gages must be individually calibrated.

1.415 Dynamometer. The dynamometer rating should not be more than three times the machine rating. Frictional errors due to dynamometer trunion bearings or misalignment at the coupling should be kept at a minimum. To nullify the effect of dynamometer bearing friction it is advisable to take two sets of readings with increase in load, and to determine the average value. At each reading care should be exercised to avoid over-running the desired point.

1.416 The windage and friction of the dynamometer may be significant and should be determined. When testing a generator this windage and friction torque will be subtracted from the input to the generator.

1.417 There are various other methods of determining torque input to a generator. Because of the convenience there is frequently a temptation to use a calibrated motor to determine generator input; this may be satisfactory for some purposes

where close accuracy is not essential. This method involves variables not present in the dynamometer, and cannot be recommended in any document which is to promote satisfactory and uniform methods. Other methods of torque measurement will be recognized provided the results have satisfactory accuracy.

1.420 Speed Measurement.

The measurement of speed must be made by methods which will have no appreciable effect on the torque rating. A direct-reading tachometer on the drive shaft is recommended. Where a shaft is not available, a stroboscope or vibrating-reed tachometer may be used.

1.430 Loss Determination and Efficiency.

The losses in the generator may be determined by measuring the total amount of heat rejected by the generator. In testing machines utilizing different types of cooling, this method may be used to some advantage to check values obtained by other methods of testing. Care must be exercised to include all heat rejected by the generator and to exclude all heat coming from external sources. Losses which are chargeable to the generator and which occur in the external circuit (such as field-resistor losses) must be added to the value determined by heat rejection. The details involved in testing of this nature must be tailored to the individual application; no one definite arrangement can be specified herein.

1.431 The measurement of electric input or output in watts for direct-current machines is done by using voltmeters and ammeters of suitable accuracy and range.

1.432 Voltage is generally measured at the machine terminals and the current taken by the voltmeter should be considered if it is significant.

1.433 The feedback or opposition method of determining losses as frequently employed for commercial machines may be applicable for some aircraft equipment, and there is no objection to any valid method providing the procedure is properly carried out. However, there has appeared little, if any, need for this method of testing aircraft motors, generators or electric conversion equipment.

1.434 In determining efficiency, the losses in accessories as stated in the first paragraph of this Section must be included in the measurements. In the case of a generator, the power dissipated in the carbon pile of a carbon-pile regulator is considered generator loss whereas power loss in the potential coil is not. In other words, the generator output current is measured to include the current in the solenoid of the carbon pile, but to exclude the shunt-field current.

1.435 Input and output readings are normally taken under standard test conditions (see AIEE Test Code for Direct-Current Aircraft Rotating Machines, No. 800, January 1953 and AIEE Test Code for Synchronous Machines, No. 503, June 1945). Rated cooling should be supplied to the machine.

1.436 Where possible and not otherwise specified, load readings should be observed at the following loads:

*Double rated load (5 seconds)

** $1\frac{1}{2}$ rated load (5 minutes)

$1\frac{1}{4}$ rated load

Full rated load

$\frac{3}{4}$ rated load

$\frac{1}{2}$ rated load

$\frac{1}{4}$ rated load

1.440 Conditions.

Direct-Current Machines—(With speed range greater than ± 10 percent.) Minimum, continuous operating, and maximum rated speed.

Alternating-Current Machines—(With speed range greater than ± 10 percent.) Power Factor—rated (lagging) and unity.

Speeds—Minimum, average, maximum rated.

1.450 Presentation.

Tabulation or curves.

UNDERSPEED CHARACTERISTICS (DIRECT-CURRENT AND ALTERNATING-CURRENT GENERATORS)

1.500 The purpose of this test is to determine generator output at reduced speeds with a specified external resistance in the shunt-field circuit when operating at a temperature corresponding to full load at normal sea level conditions. This test is normally performed under standard sea level conditions.

1.501 The test procedure is as follows: Set the field rheostat to the desired value. If the generator requires forced cooling, furnish rated cooling air and operate at full load, adjusting speed to give full voltage, until temperatures have stabilized. Then take the following test as quickly as possible to minimize changes in temperatures. Hold load current constant and adjust speed to give voltages from rated to 70 percent

* For efficiency data at double rated load the machine should be stabilized at full load and specified cooling conditions. Double rated load should be applied for not more than five seconds. During the five seconds, readings for efficiency data should be taken. If it is not feasible to obtain all the necessary readings in five seconds with the equipment available, the double rated load efficiency can be obtained by calculation extrapolation of efficiency test data at smaller loads.

** For efficiency data at $1\frac{1}{2}$ rated load the machine should be stabilized at full load and specified cooling conditions. $1\frac{1}{2}$ rated load should be applied for not more than five minutes. During the last half minute of the five-minute run, reading for efficiency data should be taken.

of rated in 10 percent steps. Record line voltage, speed and shunt-field temperature for each voltage point.

1.502 Repeat the procedure above for load currents of $1\frac{1}{4}$, $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{4}$ and 0. Stabilize the shunt-field temperature for each value of load current for rated voltage and cooling air.

1.503 For generators not forced cooled, stabilize temperatures for each load current at rated voltage and record the shunt-field temperature at each test point.

1.510 Conditions.

Direct-Current Generators—One inch water pressure drop and applicable specification conditions.

Alternating-Current Generators—Unity and rated (lagging) power factor. One inch water pressure drop and applicable specification conditions.

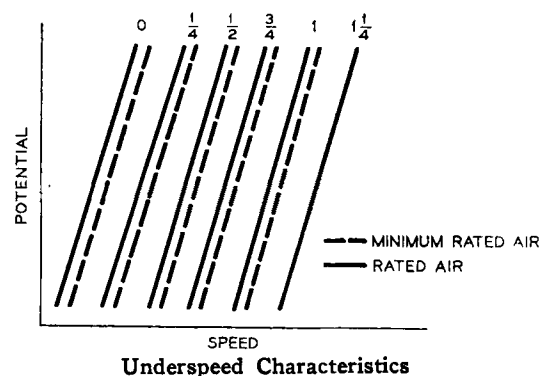
Voltages L/N 120, 100 and 80. (120/208 volt generator).

Care should be exercised in observing generator heating during the low-speed runs to be certain that overheating of none of the parts occurs. Data taken for continuous and short time (10 seconds) conditions.

1.520 Presentation.

Direct-Current Generators—Curve of voltage versus speed for various loads and air.

Alternating-Current Generators—Curve of voltage versus speed for various loads, air and power factor.



INTERIM METHOD OF PRESENTING BLAST-COOLED GENERATOR RATING DATA (DIRECT-CURRENT AND ALTERNATING-CURRENT GENERATORS)

(Proposed by AIEE Subcommittee on Rating of Airborne Electric Apparatus—July, 1954)

1.600 Introduction.

The process of rating blast-cooled generators falls naturally into three phases; namely, aero-

dynamic, thermodynamic, and electric output characteristics.¹ The application of these generators requires knowledge of the electric output characteristics over a broad range of environmental and operating conditions. In some applications, it is necessary to know the generator losses and required air-weight flow for this same range of conditions.

1.601 Rating charts are a convenient means of presenting generator rating characteristics for a variety of environmental and operating conditions. An improved three-chart method has been prepared which presents the three phases of rating separately, and at the same time properly relates these phases.² This presentation method is illustrated by Figures 4 and 5.

1.602 Figure 4 is a blank chart to be completed from either experimental or specification data. The form and range of data will depend on the generator design and the anticipated application. The example rating chart of Figure 5 represents test data recently reported on a direct-current generator.³

1.610 Explanation of Charts.

1.611 Data. Information is required to identify the generator, establish reference values (provide numeric values for 100 percent), and describe the air-inlet and outlet configuration. Recommended data lists are included in the lower left-hand corner of Figures 4 and 5. Additional data may prove useful as experience dictates.

1.612 Air Weight Flow. The air weight flow as a function of static outlet pressure is shown on the upper left-hand chart. Pressure drop (total inlet minus static outlet) appears as a parameter. Figure 5 illustrates a possible method of including speed effects.

1.613 Heat Transfer. The heat-rejection rate (generator losses) as a function of air weight flow with inlet air temperature as a parameter is shown in the upper right-hand chart. To relate the two upper charts, the air-weight-flow scales are identical. As indicated in Figure 5, component A limited the losses (and the output) to the left of the dotted line, while to the right of this transition line component B was limiting.

1.614 Output Characteristics. The allowable output versus losses is shown in the lower right-hand chart. Rotor speed and power factor (when applicable) are the recommended parameters. The heat rejection scales are identical to relate the two right-hand charts.

1.615 Example Use of Chart.

Known Conditions:

Static outlet pressure—1.7 psi or 50,000 ft.

Pressure drop (total inlet-static outlet)—
6 inches of water

Inlet air temperature—0 C

Rotor speed—8000 rpm

Desire to Know:

Air weight flow

Heat rejection

Allowable output

Directions—Refer to Figure 5.

Enter the upper left-hand chart at 1.7 psi or 50,000 feet, proceed vertically to 6-inch line, then horizontally to weight flow scale and read answer of 35 percent. Enter upper right-hand chart at 35 percent weight flow, proceed horizontally to 0 C inlet air temperature line, then vertically to heat rejection scale and read 75 percent. Enter lower right-hand chart at 75 percent heat rejection, proceed vertically to 8000 rpm line, then horizontally to output scale and read 80 percent.

1.620 References.

1. Ten Years of Progress in Predicting the Aerodynamic, Thermodynamic, and Output Characteristics of Blast-Cooled Aircraft Generators, Dale H. Scott. Submitted to AIEE Headquarters for publication in AIEE Transactions and for presentation at the AIEE Fall General Meeting in Chicago, Illinois in October, 1954.
2. Rating Tests of a 40 KVA Alternator, E. O. A. Naumann. Wright Air Development Center, Wright-Patterson AFB, Ohio, WADC Technical Memorandum Report WCLE 53-338, December 1953, 27 pages.
3. Correlation of Rating Data for Rotating Electrical Machinery, Erwin O. A. Naumann. Submitted to AIEE Headquarters for publication in AIEE Transactions and for presentation at the AIEE Fall General Meeting in Chicago, Illinois, October, 1954.

SHORT-TIME OVERLOAD TEMPERATURE RISE VERSUS LOAD MAXIMUM CRITICAL TEMPERATURE LIMITS (DIRECT-CURRENT AND ALTERNATING-CURRENT GENERATORS)

- 1.700** High current, short time overload ratings under different specific conditions of generator speeds, air inlet temperature and pressure could be established with sufficient testing. The test procedure would consist of instrumenting the generator sufficiently to obtain all temperature data which may be critical, establishing temperature limits and determining from test the time required to reach a critical tem-

NOTE: This interim method of presenting rating data is an improvement over earlier methods. It does not, however, apply rigorously to all machines and, therefore, should be used with caution in interpreting performance at points other than actual test points.