TEST METHOD 31

RATED LOAD CURRENT SATURATION CURVE TEST

31.1 General. The rated load current saturation curve is used by design engineers as an aid in determining the field current requirements of the generator. The family of generator saturation curves can be used to approximate the generator field current for any load condition.

31.2 Apparatus. Instrumentation for measuring load conditions and field voltage and current shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, a separate, variable dc source for generator excitation and a prime mover capable of maintaining the generator speed within ±1 percent of rated speed under all load conditions of this method shall be required. Instruments for measuring the terminal voltage and field current shall have an accuracy of ±0.5 percent of reading or better.

31.3 Procedure.

31.3.1 Preparation for test.

a. Mechanically connect the generator to the prime mover and provide the external excitation supply to the generator.

b. Connect the load and instrumentation to the generator for the voltage connection and frequency specified in the contract.

31.3.2 Test - ac generators.

a. Start the prime mover and operate the generator at rated frequency, approximately 50 percent of rated voltage, rated load current and rated power factor (0.8 lagging if not otherwise specified).

NOTE: The load current of polyphase generators shall be balanced.

b. After the conditions of step a above have been reached, record all instrument readings.

c. Reduce the field current to zero using the adjustment on the dc source.

d. Increase the field current in steps from zero upward while adjusting the load for rated generator output current and rated power factor to vary the terminal voltage to approximately 70, 80, 90, 95, 100, 105, 110, 120, and 130 percent of rated voltage (unless otherwise specified in the contract). All readings must be taken with a rising field current. Should it become necessary to decrease the excitation, the field current must be reduced to zero and then increased to the desired value. Then increase the field current to obtain the desired output voltage. Read and record all instrument readings at

each step. All readings shall be taken without interruption. Take sufficient additional steps to clearly define the curve (figure 31-I).

31.3.3 Test - dc generators.

a. Start the prime mover and operate the generator set at rated speed, approximately 20 percent of rated voltage and rated load current.

b. After the conditions of step a above have been reached, record all instrument readings.

c. Reduce the field current to zero using the rheostat on the separate dc source.

d. Increase the field current in steps to obtain 20, 40, 60, 80, 90, 95, 100, 105, 110, 120, and 130 percent of generator rated voltage (unless otherwise specified in the requirement document) while adjusting the load for rated generator output current. All readings must be taken with a rising field current. Should it become necessary to decrease the excitation, the field current must be reduced to zero and then increased to the desired value. Read and record all instrument readings at each step. All readings shall be taken without interruption.

31.4 Results. Plot a curve of terminal voltage versus generator or exciter field current (figure 31-II) from the data obtained. Compare the results with the requirements of the requirements document.

31.5 Contract requirements. The following items must be specified in the individual contract

a. The voltage connection(s) and frequency(ies) at which this method is to be performed.

b. The maximum allowable generator or exciter field current.

c. The maximum terminal voltage, if other than as specified herein.

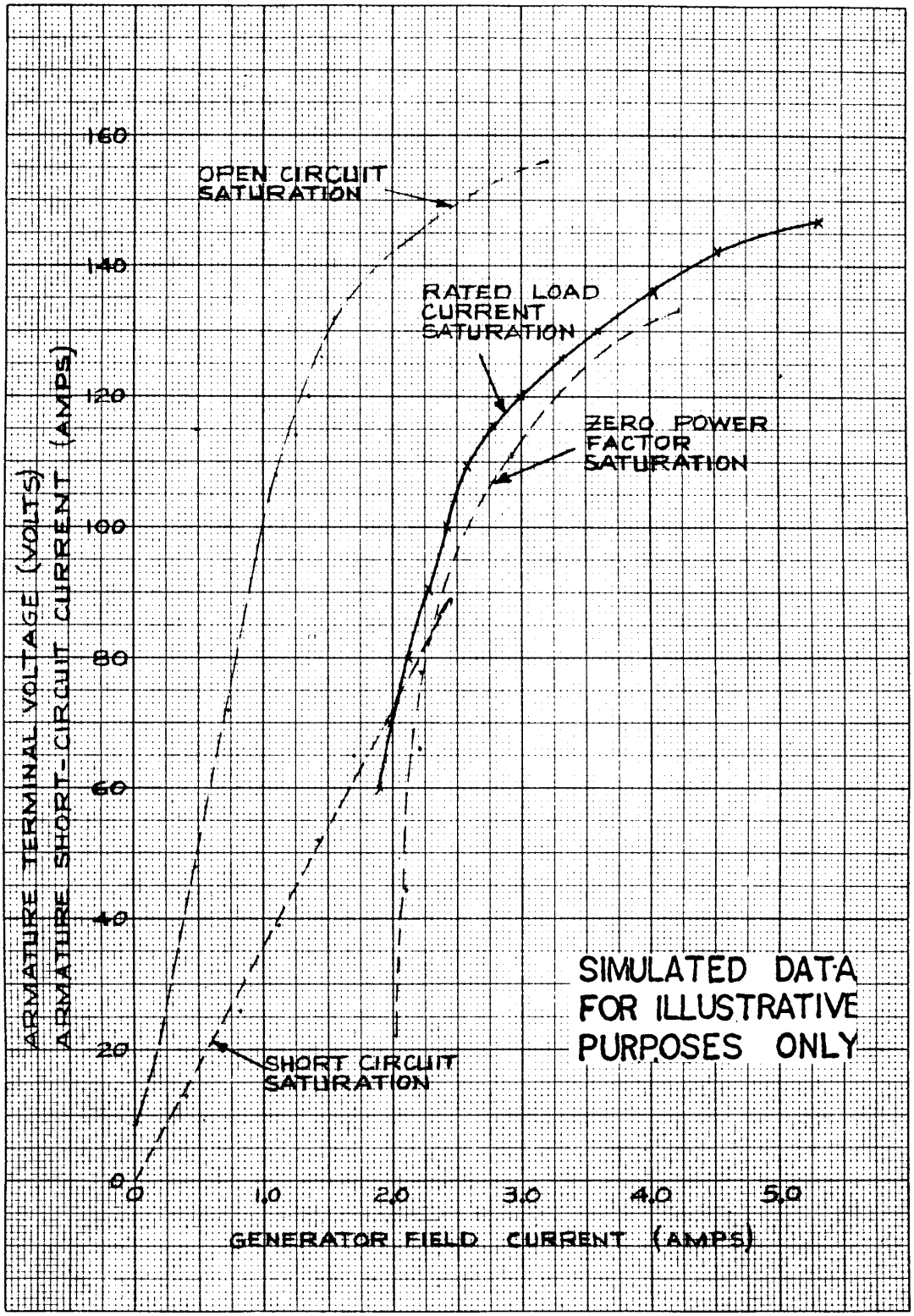

Figure 31-II - Family of saturation curves.

TEST METHOD 32

ROTATING EXCITER SATURATION CURVE TEST (CONSTANT RESISTIVE LOAD)

32.1 General. The saturation curve for a rotating exciter aids the design engineer in determining the suitability of a particular exciter for use with a particular generator.

32.2 Apparatus. Instrumentation for measuring exciter output voltage, exciter field current and exciter speed shall be as described and illustrated in EGSA 107T (unless otherwise specified in the required document). In addition a prime mover capable of driving the exciter at rated speed with a speed regulation not greater than +1 percent of rated speed, a separate variable dc source for excitation and a resistive load equivalent to the generator field resistance at 75 °C shall be required. Instruments for measuring the dc terminal voltage and exciter field current shall have an accuracy of +0.5 percent of reading or better.

32.3 Procedure.

32.3.1 Preparation for test.

a. Connect the instrumentation for the voltage connection and frequency specified in the contract.

b. Connect the resistive load to the output of the exciter. (Slip rings may be necessary if the generator is not so equipped.)

NOTE: In order to obtain zero exciter field current, it may be necessary to open the exciter field circuit. To prevent high voltage hazard to personnel, the exciter field current should be reduced to the minimum possible value before opening the field.

32.3.2 Test.

a. On exciters with brushes, check that the brush settings are positioned in accordance with the manufacturer's recommendation.

b. Start and operate the prime mover such that the exciter is operating at its rated speed. Adjust the exciter field current to obtain nominal exciter voltage. Operate the exciter under these conditions for a 30 minute period. Read and record all instrumentation initially and every 10 minutes thereafter.

c. Reduce the exciter field current to zero. Read and record all instrumentation

d. Increase the exciter current in steps to obtain exciter terminal voltages of approximately 20, 40, 60, 80, 90, 95, 100, 105, 110, 120, and 130 percent of nominal exciter voltage. Read and record all instrumentation at each step. All

readings shall be taken without interruption.

32.4 Results. Plot a curve of exciter terminal voltage versus exciter field current using the data obtained above. This curve shall be known as "the loaded exciter saturation curve". Compare this curve with the requirements of the applicable generator or the contract.

32.5 Contract requirements. The following items must be specified in the individual contract:

a. The nominal exciter voltage.

b. Exciter rated speed.

c. Exciter ceiling voltage, if applicable.

d. Generator field resistance or current value.

TEST METHOD 33

SUMMATION OF LOSSES TEST

33.1 General. The internal generator losses are inversely related to the efficiency. The efficiency of a generator determines the capacity of the prime mover necessary for proper operation. The summation of losses test allows design engineers to investigate the problem of increasing the efficiency of a generator.

33.2 Apparatus. Instrumentation for measuring load conditions, field voltage and current, set temperatures and prime mover output power shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, a prime mover (dynamometer or dc motor) shall be required. If a dc motor is used, a curve of power output (in kW) against input current at a constant input voltage shall be furnished (see figures 33-I and 33-V). If a calibrated dc motor is used as the prime mover, a constant voltage power supply corresponding to the motor calibration curve shall be used. The dc motor, if used, shall have a horsepower rating of not less than 25 percent nor more than 50 percent of the generator kilowatt rating. A separate variable source of dc power for generator excitation shall be provided. A direct reading torque meter (connected between the prime mover and generator) may be utilized for calculating actual generator input power. Electrical instrumentation used for the following tests shall have an accuracy of ±0.5 percent of reading or better.

33.3 Procedure.

33.3.1 Preparation for test.

a. Mechanically connect the generator assembly, including its cooling fan to the prime mover and provide the external excitation supply to the generator.

b. Connect the load and field instrumentation for the voltage connection and frequency specified in the contract.

c. As applicable, connect the instrumentation necessary to measure the output power of the prime mover. The instrumentation requirements of a dynamotor shall be connected in accordance with the manufacturer's instructions; the instrumentation for a calibrated dc motor shall be connected to measure the motor input voltage and current and the field voltage and current.

33.3.2 Test.

33.3.2.1 Bearing friction and windage loss.

a. Raise the brushes, if applicable, so that they do not touch the slip rings or the commutator.

b. The friction and windage loss is the power input to the machine being tested, with zero excitation.

c. Start and operate the prime mover at rated generator speed until the bearing(s) reach constant temperature so the bearing friction becomes stable.

d. Record the data necessary to compute the output power of the prime mover (motor input power or dynamometer constant and scale reading).

e. Compute the prime mover output power in kW. This value represents the bearing friction and windage loss of the generator.

33.3.2.2 Brush friction loss.

a. Adjust the brush pressure on all generator brushes to the pressure recommended on the set or in the technical manual.

b. Start and operate the prime mover at rated generator speed until the bearing(s) reach constant temperature so that bearing friction becomes stable.

c. Record the data necessary to compute the output power of the prime mover (motor input power or dynamometer constant and scale reading).

d. Compute the prime mover output power in kW and subtract the prime mover output power found in 33.3.2.1e. This difference represents the brush friction loss.

33.3.2.3 Brush contact loss.

a. Adjust the brush pressure on all generator brushes to the pressure recommended on the set or in the technical manual.

b. Start and operate the prime mover at rated generator speed until the bearing(s) reach constant temperature so that bearing friction becomes stable. For dc generators, apply a short circuit to the output terminals and adjust the excitation to obtain rated load current. For ac generators adjust the field current to its value at rated load.

c. With a low-range voltmeter (range of approximately 3 volts), read and record the voltage between the brush bracket holder and at least four equally spaced points along the commutator brush span (see figure 33-IV).

d. Repeat steps b and c above for all other load conditions specified in the requirement document.

e. For each load condition average the four voltage readings found for that load condition.

f. Compute the brush contact loss by multiplying twice the average voltage found in step e above by the load current under which the average was found.

g. For the summation of losses the brush contact loss shall be taken as the loss found with the generator operating at rated load multiplied by the number of pairs of brushes on the commutator or slip rings.

33.3.2.4 Open-circuit core loss (ac generator only).

a. Start and operate the prime mover at rated generator speed, without generator excitation, until the bearing(s) reach constant temperature and friction becomes stable. (Two-hour operation will be sufficient with no more than a 3 °C change in the average ambient temperature).

b. Using the external excitation supply raise the terminal voltage from zero to give approximately 20, 40, 60, 80, 90, 100, 105, 110, 120, and 130 percent of rated voltage.

c. Simultaneously read and record the generator field current and voltage, the generator terminal voltage and the data necessary to compute the output power of the prime mover for each step, including the zero step. All readings shall be taken with a rising field current. Should it be necessary to reduce the excitation current it must be reduced to zero and then returned to the desired value (see figure 33-VI).

d. From the prime mover output power at each step subtract the bearing friction and windage loss and, if applicable, the brush friction loss to obtain the open circuit core loss for each field current value.

e. Plot a curve of generator open-circuit core loss versus terminal voltage (see figure 33-II). The value of open-circuit core loss at rated voltage shall be used in this summation of losses.

33.3.2.5 Open-circuit core loss (dc generators only).

a. Start and operate the prime mover at rated generator speed, without generator excitation, until the bearing(s) reach constant temperature and friction become stable. (Two-hour operation will be sufficient with not more than a 3 °C change in the average ambient temperature).

b. Using the external excitation supply, raise the terminal voltage from zero to its rated value.

c. Simultaneously read and record the field voltage and current, the generator terminal voltage and the prime mover output power in kW (see figure 33-VII).

d. Calculate the internal generator voltages corresponding to 25, 50, 75, and 100 percent of rated load by adding the armature circuit (armature, brushes, commutating field, and series field) voltage drops due to resistance at each of the above load conditions to the rated terminal voltage.

e. Using the external excitation supply raise the terminal voltage to obtain each of the values calculated in step d above.

f. Simultaneously read and record the generator field voltage and current, the generator terminal voltage and the prime mover output power in kW at each step.

g. From the prime mover output at each step subtract the bearing friction and windage loss and, if applicable, the brush friction loss to obtain the open circuit core loss for each terminal voltage step.

h. Plot a curve of generator open-circuit core loss versus generator terminal voltage (see figure 33-III). The value of open-circuit core loss which corresponds to the calculated internal voltage at rated load shall be used in this summation of losses.

33.3.2.6 Armature I^2R Loss.

a. The armature I^2R loss is defined as the product of the square of the armature current under any specified load and the resistance of the armature winding as measured in accordance with EGSA 107T, Test Method 5, corrected to 25 °C plus the stabilized temperature rise of the armature winding under the same load condition. The following formula for copper windings shall be used to determine the armature resistance:

$$R_c = R_o \frac{(234.5 + T_r)}{234.5 + T_o}$$

Where:

R_c is the corrected resistance.

R_o is the measured resistance.

T_r is the temperature rise in Celsius degrees (➡C).

T_o is the temperature of the winding at the time R_o is measured in degrees Celsius (°C).

b. The armature I^2R loss shall be calculated for rated load current in the armature winding(s) and used in this summation of losses. For a 3-phase machine the loss is the summation of the losses of the individual phase windings.

c. To determine the stabilized armature winding temperature rise perform Test Method 101, Temperature Rise Test (Generator Only).

33.3.2.7 Field I^2R loss.

a. The field I^2R loss is defined as the product of the square of the field current under any specified load condition and the resistance of the field as measured in accordance with EGSA 107T Test Method 5, corrected to 25 °C plus the stabilized temperature rise of the field winding underthe same load condition. Use the formula given in para 33.3.2.6a above to determine the corrected field resistance.

b. The field I^2R loss shall be calculated for rated load field current in the field winding and used in the summation.

c. To determine the stabilized field winding temperature rise perform Test Method 101, Temperature Rise Test (Generator Only).

33.3.2.8 Stray load loss.

a. Short circuit the generator through the load current transformers (or shunt). A wye connected generator shall be shorted line-to-neutral (all phases) while a delta connected generator shall be shorted line-to-line (all phases).

b. Start and operate the prime mover at rated generator speed. Adjust the external excitation supply for approximately 125 percent of rated current (If the phase currents of a multi-phase machine are not approximately balanced, shut down the prime mover and the excitation supply and correct the trouble before proceeding). This test shall be performed with decreasing field current. (During this test, should the field current accidentally be increased, it shall be returned to the value which will cause approximately 125 percent of rated generator current, then reduced to the desired value.)

c. Decrease the excitation to obtain approximately 100, 75, 50, and 25 percent of rated current in the short-circuit ammeters. At each of these steps, including the 125 percent step, read and record the generator output current, the speed of the generator and the prime mover output power in kW (figure 33-VIII).

d. From the recorded values of prime mover output power subtract the bearing friction and windage loss, the brush friction loss, brush contact loss, and the armature I^2R loss

(which must be calculated for each current step-see 33.3.2.6), to obtain the stray load loss.

e. Plot a curve of stray load loss versus armature current (figure 33-IV).

f. The value of stray load loss at the armature current corresponding to rated armature current shall be used in the summation of losses.

33.3.2.9 Exciter loss. Connect a "dummy" load consisting of a resistor equal to the field resistance of the generator as defined in 33.3.2.7.

33.3.2.9.1 Rotating exciter directly coupled to the generator.

a. Start and operate the prime mover at rated generator speed, without generator excitation and with slip ring or commutator brushes raised. Adjust the exciter output voltage and current to the values required to excite the generator at rated load at rated voltage and rated speed.

b. Read and record the prime mover output power in kW, and the output current and voltage of the exciter.

c. From the prime mover output power subtract the field I^2R loss and the bearing friction and windage loss. This value is the exciter loss in kilowatts.

33.3.2.9.2 Rotating exciter separately driven.

a. Mechanically connect the exciter to a calibrated motor dynamotor (prime mover).

b. Start and operate the prime mover at the exciter's rated speed. Adjust the exciter output voltage and current to the values required to excite the generator at rated load at rated voltage and rated speed.

c. Read and record the prime mover output power in kW and the output voltage and current of the exciter.

d. From the prime mover output power subtract the field I^2R loss to obtain the exciter loss in kilowatts.

33.3.2.9.3 Static exciter.

a. Connect the load instrumentation in accordance with the applicable figure of EGSA 107T Test Method 18, for the exciter input power.

b. Using a variable resistor in series with the voltage sensing lines (variable auto transformer for ac generators) adjust the input voltage to vary the excitation voltage and current. Adjust the exciter output voltage and current to the values required to excite the generator at rated load at rated voltage and rated speed.

c. Record all instrument readings.

d. From the kilowatt reading of the input power to the exciter, subtract the field I^2R loss to obtain the exciter loss in kilowatts.

33.4 Results.

a. Total the following power losses:

1. Bearing friction and windage loss at rated speed.
2. Brush friction loss at rated speed, if applicable.
3. Brush contact loss at rated speed, if applicable.
4. Open-circuit core loss at rated voltage.
5. Armature I^2R loss at rated current.
6. Field I^2R loss at rated load.
7. Stray load loss at rated load.
8. Exciter loss at rated load, if applicable.

b. Substitute the above calculated total in the following formula to determine the efficiency of the generator.

$$\text{Generator efficiency (in percent)} = \frac{\text{Rated kW output} \times 100}{\text{Rated kW output} + \text{total losses in kW}}$$

c. Compare the generator efficiency found in step b above with the requirements of the contract.

33.5 Contract requirements. The following items must be specified in the individual contract:

a. The voltage connection and frequency at which this method is to be performed.

b. The minimum allowable generator efficiency.

c. Load conditions at which brush contact loss is to be performed.

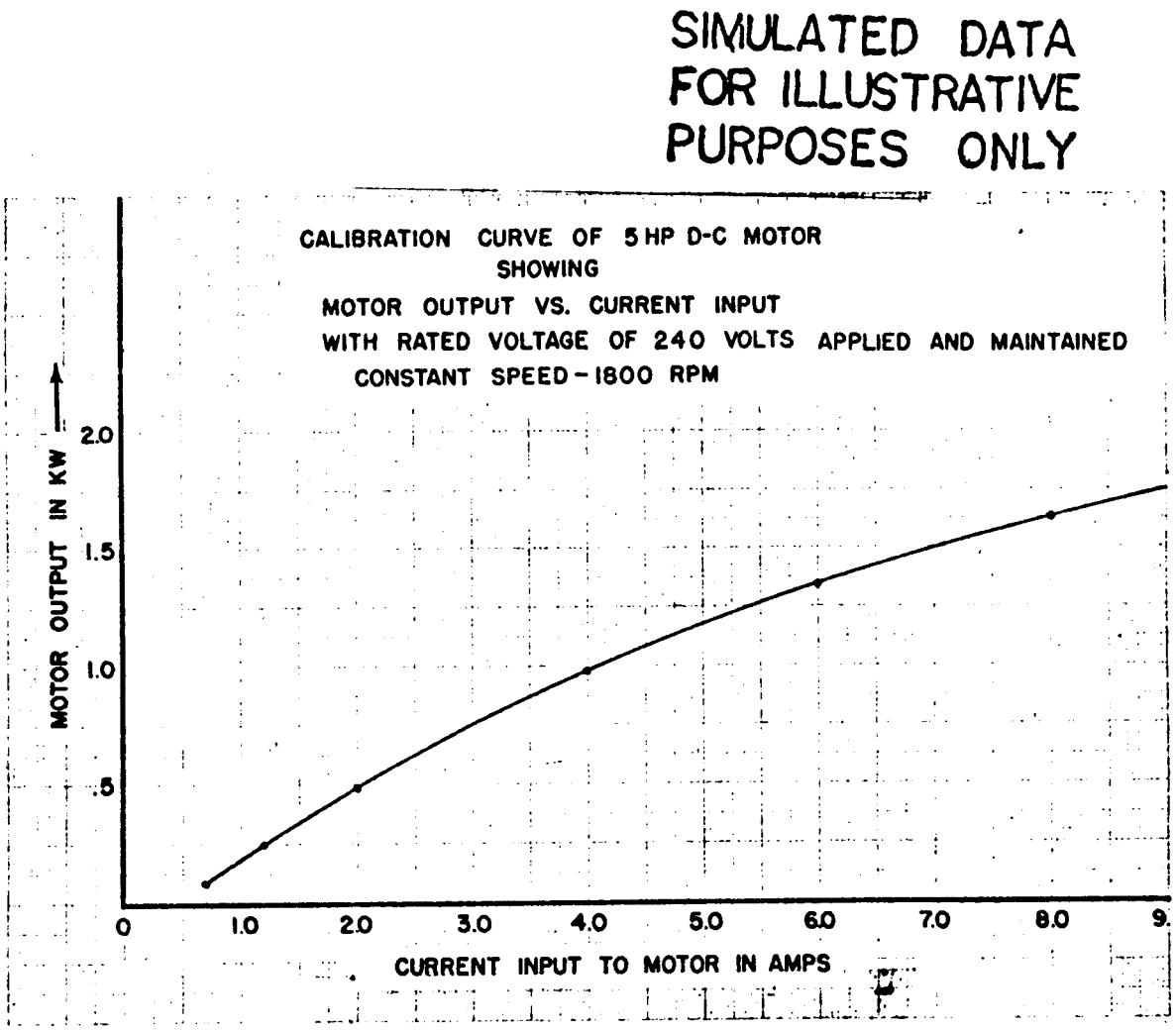

FIGURE 33-I TYPICAL PRIME MOVER CALIBRATION CURVE.

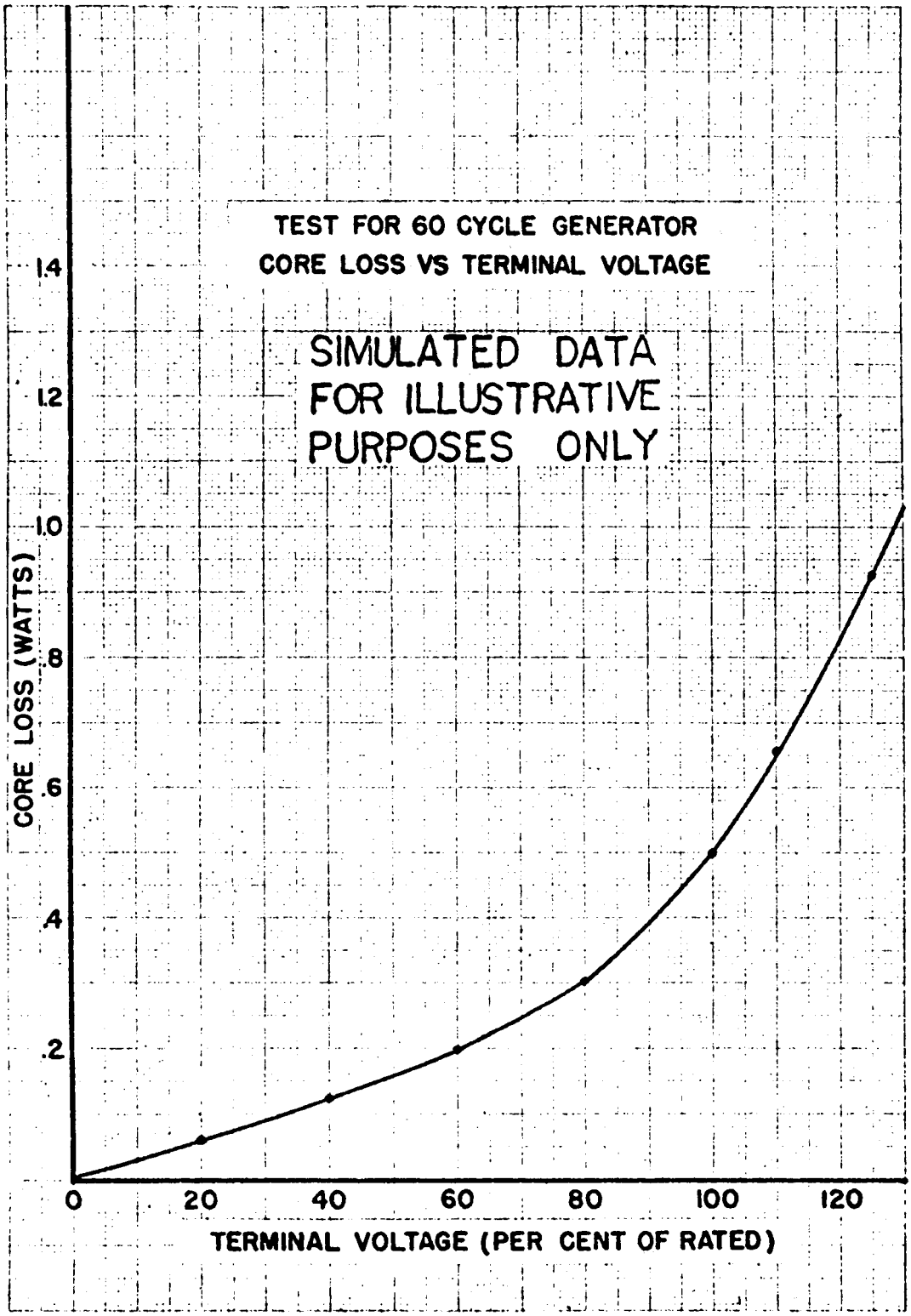

FIGURE 33-II TYPICAL OPEN-CIRCUIT CORE LOSS CURVE FOR A-C GENERATOR

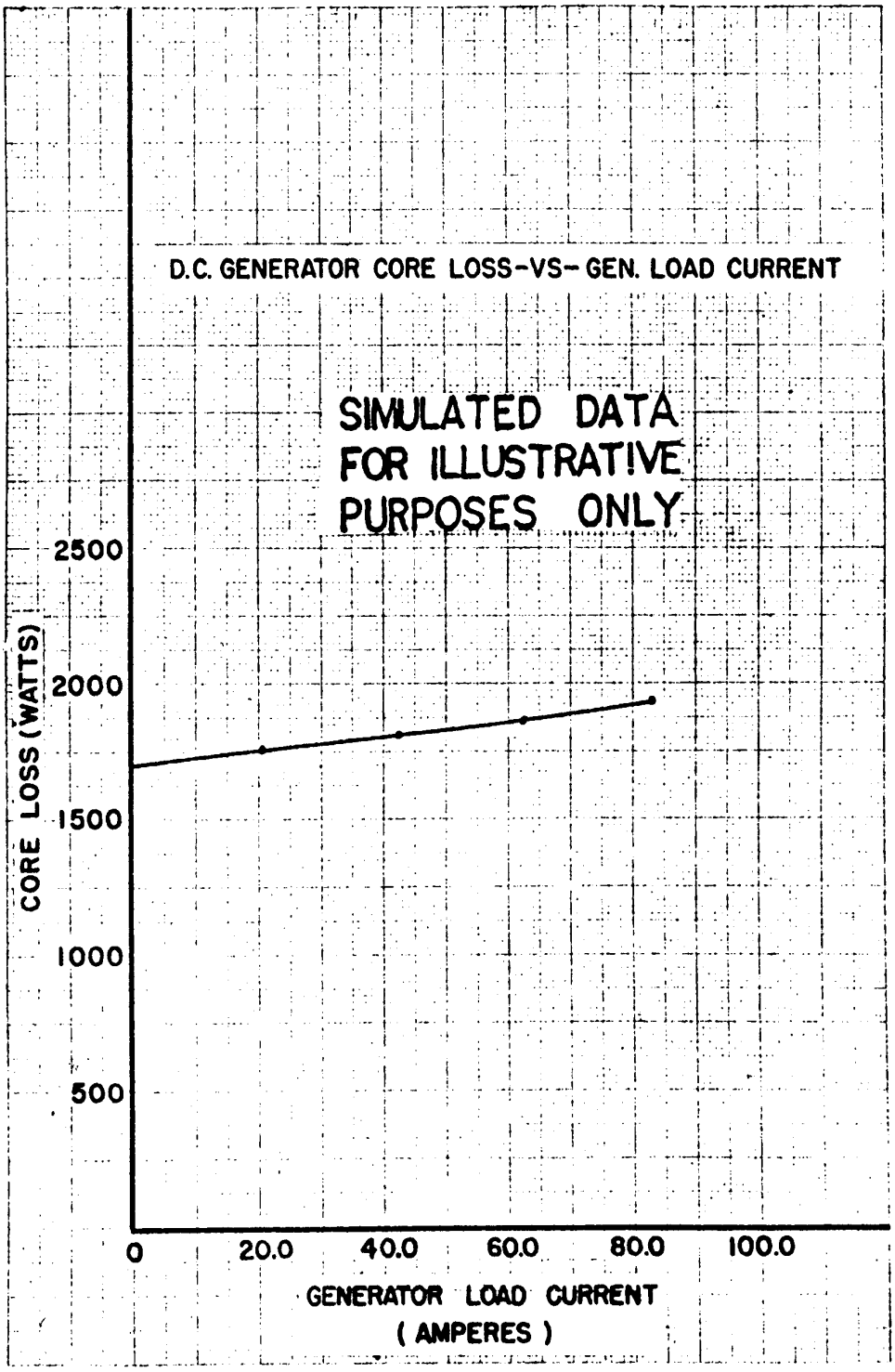

FIGURE 33-III TYPICAL OPEN CIRCUIT CORE LOSS CURVE FOR D-C GENERATOR

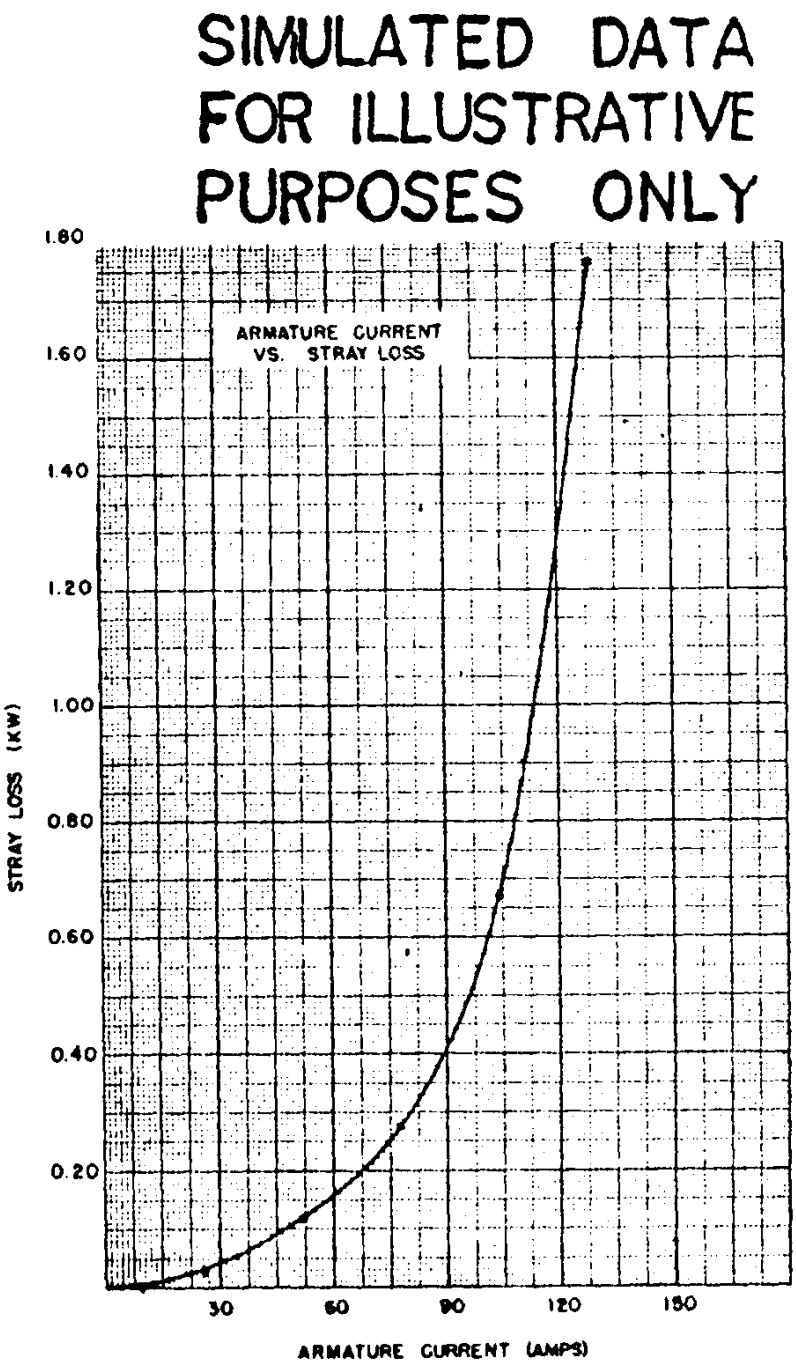

FIGURE 33-IV TYPICAL STRAY LOAD LOSS CURVE.

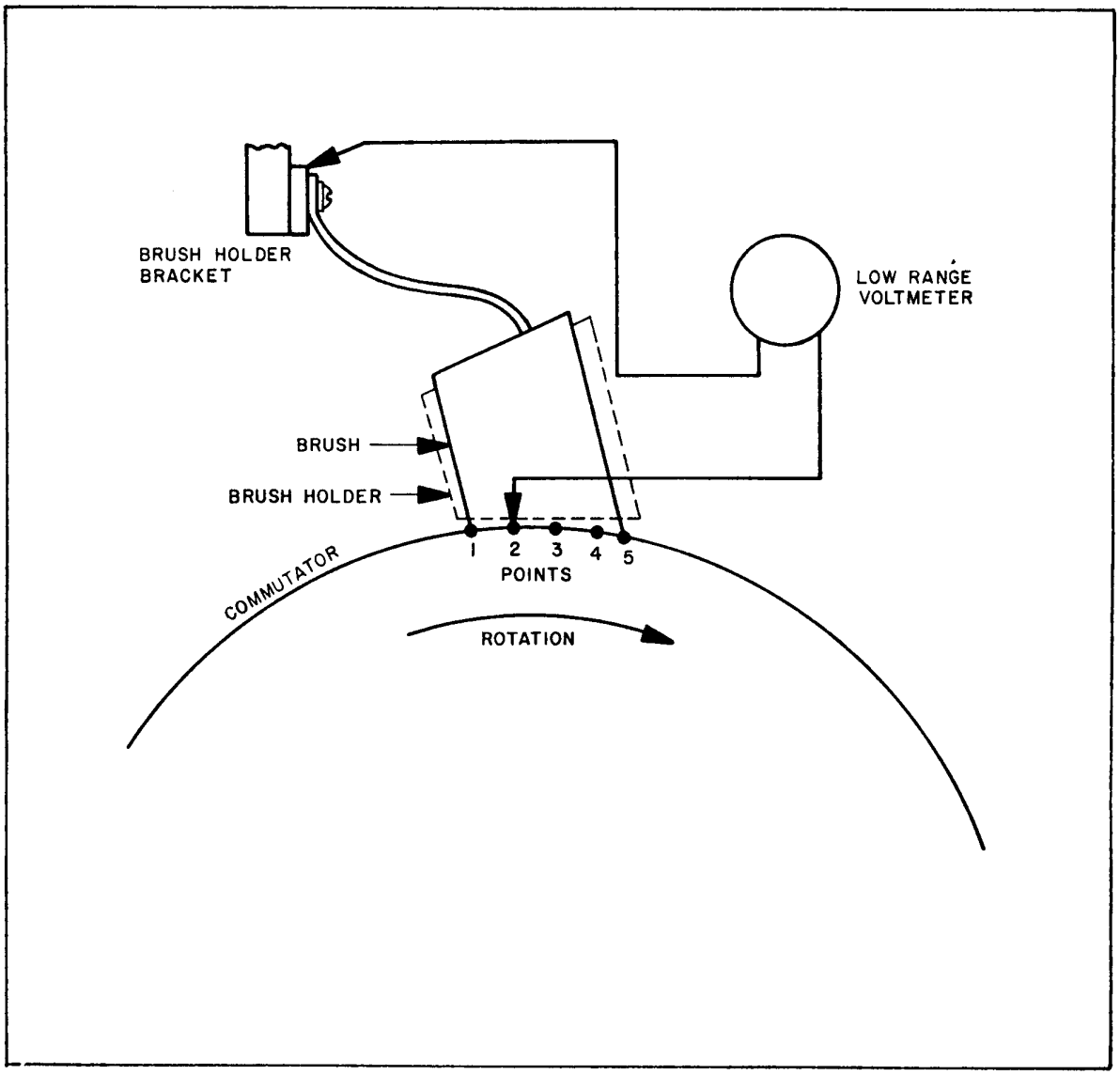

FIGURE 33-V. Method of determining brush contact loss.

TEST METHOD 34

GENERATOR POWER INPUT TEST

34.1 General. The power required to drive the generator at rated load is important in determining the size of the prime mover and expected operating costs.

34.2 Apparatus. Instrumentation for measuring load conditions, field voltage and current, ambient temperature and prime mover output power shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, a dynamometer or calibrated electric motor of sufficient output power to drive the generator under test at rated speed and rated load for extended periods of time shall be required. A direct reading torque meter may be connected between the prime mover and the generator for calculating actual generator power input. Electrical instrumentation used for this test shall have an accuracy of ±0.5 percent of reading or better.

34.3 Procedure.

34.3.1 Preparation for test.

a. Mechanically connect the generator assembly, including its cooling fan, to the prime mover.

b. Connect the load and field instrumentation for the voltage connection and frequency specified in the contract.

34.3.2 Test.

a. Start and operate the prime mover such that the generator is operating at rated speed.

b. With the generator under control of its voltage regulator and exciter, apply rated load. Allow the generator to stabilize at rated load, rated voltage and rated frequency. During this period record all instrument readings including ambient temperature at minimum intervals of 10 minutes. If necessary, adjustments to load, voltage and frequency may be made to maintain rated load at rated voltage and frequency. Adjustments to load, voltage or frequency controls shall be recorded on the data sheet at the time of adjustment. Unless otherwise specified in the contract, stabilization shall be considered to have occurred when four consecutive voltage and frequency recorded readings of the generator line output either remain unchanged or have only minor variations within plus or minus one-half the long-term stability bandwidth with no evident continued increase or decrease in value after the last adjustment of the load, voltage, or frequency has been made.

c. With the generator stabilized at rated conditions, record all instrument readings including the instrumentation necessary to determine the output power of the prime mover (see figure 34-I).

d. Repeat 34.3 for any other load condition, voltage connection, frequency, or power factor specified in the contract.

34.4 Results.

a. Convert the output power of the prime mover to kilowatts. This is the generator power input requirement to produce rated output.

b. Determine the efficiency of the generator by the following formula:

$$\text{Efficiency (in percent)} = \frac{\text{Rated load}}{\text{Input power requirement}} \times 100$$

c. Compare the above results with the requirements of the contract.

34.5 Contract requirements. The following items must be specified in the individual contract:

a. Maximum allowable power input, or minimum allowable efficiency (in percent) with the generator producing rated output power.

b. Voltage connections(s) and frequency(ies) at which this method is to be performed.

c. Power factor(s) at which this method is to be performed, if applicable.

d. Load condition(s) if other than rated load.

METHOD 35

BRUSH POTENTIAL CURVE TEST

35.1 General. The brush potential or contact drop curve is a graphical method for showing the difference in potential between the brush and various points on the commutator surface under and in the vicinity of the brush face. Data for brush potential curves are obtained by reading the voltage between the brush and several points on the commutator surface near and under the brush contact face.

This curve, in conjunction with the recorded armature current, may be used to determine the brush contact loss.

35.2 Apparatus. Instrumentation for measuring load conditions, field voltage and current and ambient temperature shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, a low range dc voltmeter (0-3 volts should be sufficient) having an internal resistance of at least 100 times the brush circuit resistance, and a carbon tipped test probe shall be required.

35.3 Procedure.

35.3.1 Preparation for test.

a. Connect the load and field instrumentation for a voltage connection and speed specified in the contract.

b. Connect the low range dc voltmeter as shown in figure 416.1-I to one of the brush holder brackets.

35.3.2 Test.

a. Start and operate the generator at rated speed, rated voltage, and rated load.

b. With the low range dc voltmeter, read and record the voltage between the brush bracket holder and at least four equally distanced points along the brush span. (figure 35-I and figure 35-II).

c. Repeat paragraph 35.3 for any other load condition specified in the requirement document.

35.4 Results.

a. Plot a curve of voltage drop across the brush versus distance along the brush span. (figure 35-III).

b. Compute the brush contact loss by multiplying twice the average voltage across the brush by the current through the brush.

c. Compare these results with the requirements of the contract.

35.5 Contract requirements. The following items must be specified in the individual contract:

a. Voltage connection(s) and speed(s) at which this method is to be performed.

b. Load condition(s) at which this method is to be performed if other than as specified herein.

c. Maximum allowable average voltage drop across the brush, if applicable.

d. Maximum allowable brush contact loss, if applicable.

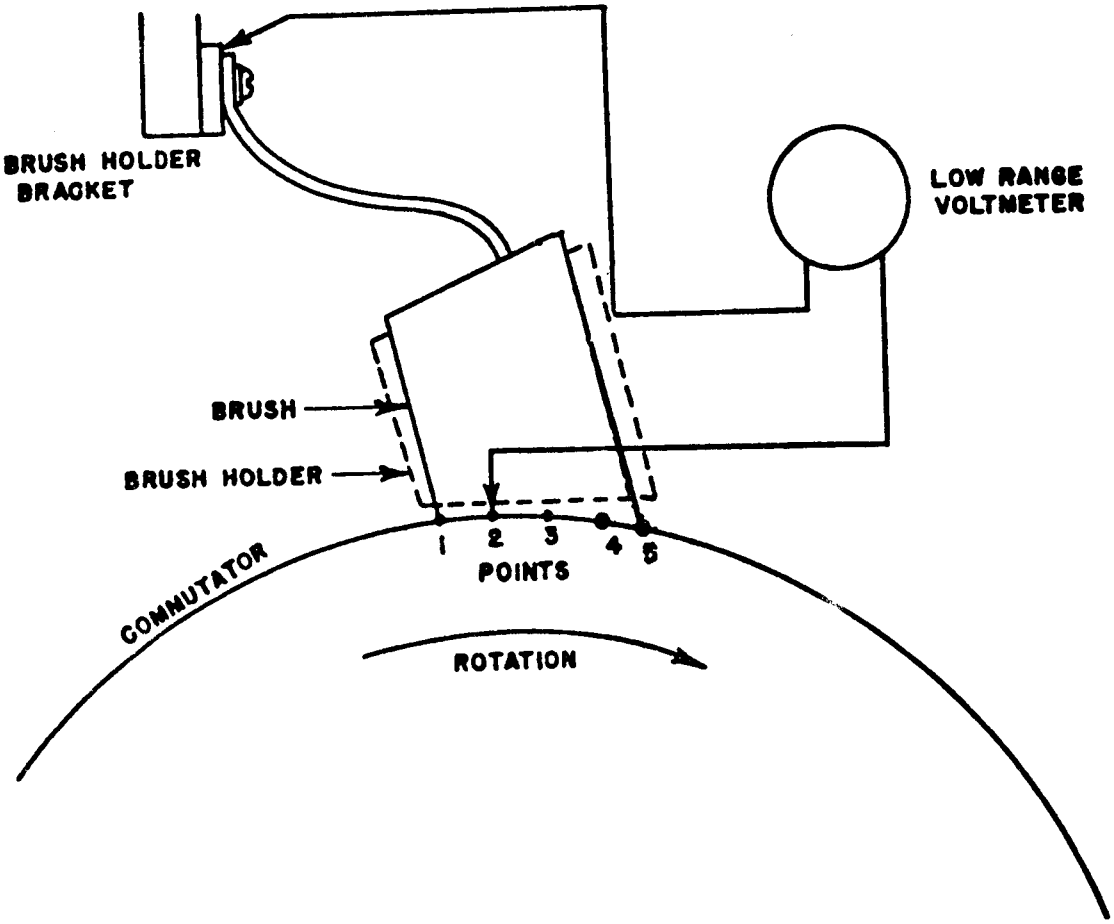

FIGURE 416.1-I METHOD OF DETERMINING BRUSH POTENTIAL CURVE

SIMULATED DATA
FOR ILLUSTRATIVE
PURPOSES ONLY

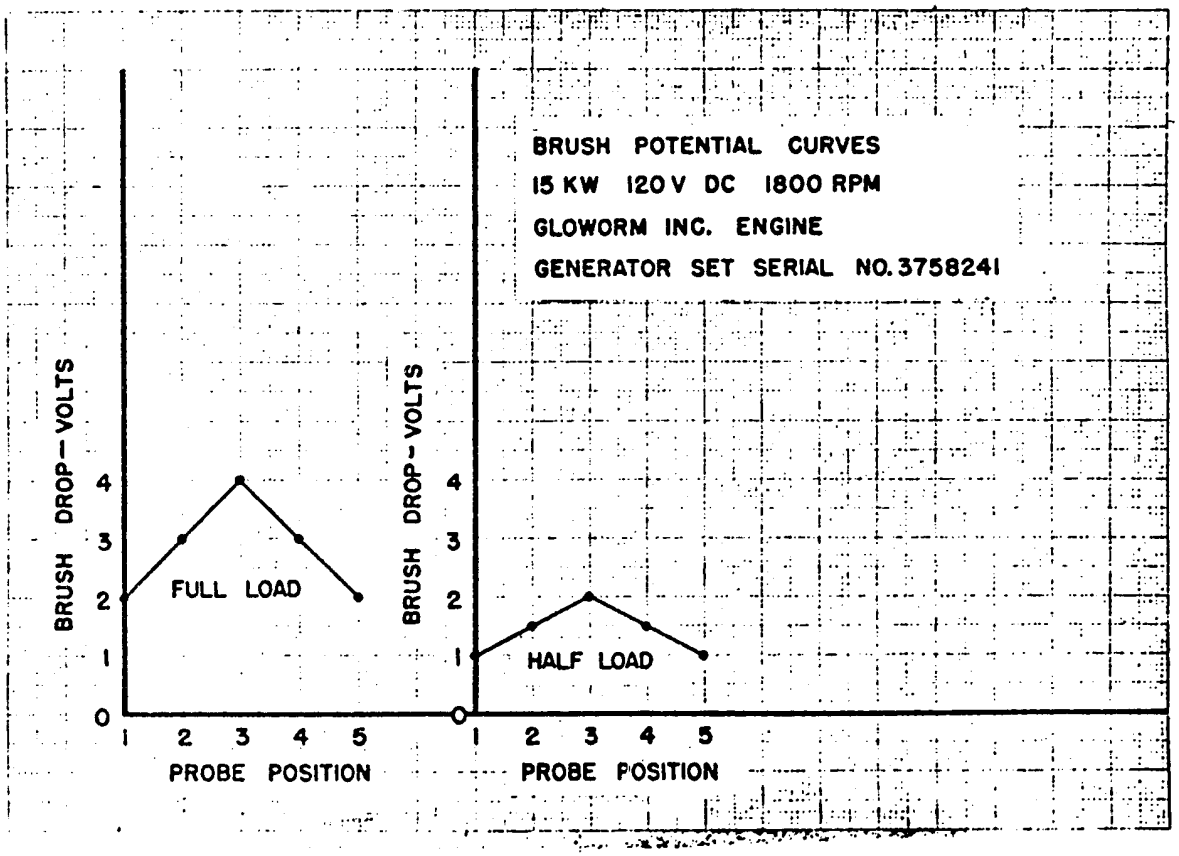

FIGURE 416.1-III SAMPLE BRUSH POTENTIAL CURVE

TEST METHOD 36

SHORT CIRCUIT RATIO TEST

36.1 General. The short circuit ratio is used by design engineers in the evaluation and comparison of the regulation and stability of generators.

36.2 Apparatus. Instrumentation for measuring terminal voltage, generator speed, exciter field voltage and current (generator field voltage and current, if applicable), and line current shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, a prime mover having a steady state speed not greater than ±1 percent of rated speed and a separate, variable dc source for excitation shall be required. Electrical instrumentation for this test shall have an accuracy of ±0.5 percent of reading or better.

36.3 Procedure.

a. Perform Test Method 34, Open Circuit Saturation Curve Test (measure the generator field current.)

b. Perform Test Method 35, Synchronous Impedance Curve Test.

36.4 Results.

a. From the open circuit saturation curve determine the generator field current required to generate rated open circuit armature terminal voltage. In figure 36-I, this value is represented by the distance I_{fgx}.

b. From the synchronous impedance curve (the short circuit saturation curve), determine the generator field current required to produce rated armature short circuit current for a sustained symmetrical short circuit at the generator terminals. In figure 36-I, this value is represented by the distance I_{fsi}.

c. Compute the short circuit ratio by dividing the value obtained in step a above, by the value obtained in step b above. This computation is represented by the following formula:

$$SCR = \frac{I_{fgx}}{I_{fsi}}$$

Where: SCR is the short circuit ratio.

d. Compare the calculated short circuit ratio with the requirements of the requirement document.

36.5 Contract requirements. The following items must be specified in the individual contract:

a. The allowable range of short circuit ratio, if applicable.

b. The voltage connection(s) and frequency(ies) at which this method is to be performed.

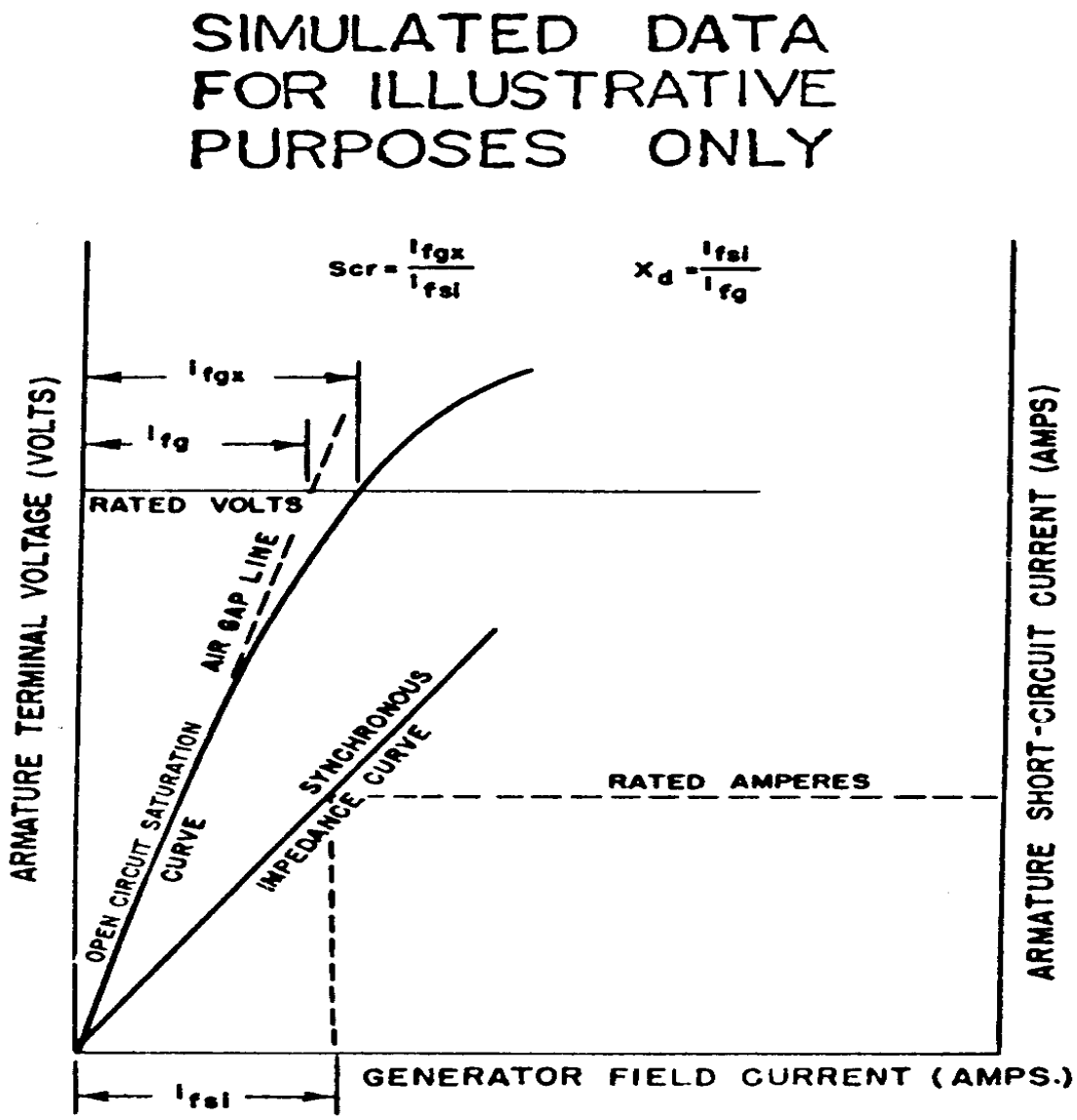

FIGURE 36-I SHORT CIRCUIT RATIO AND DIRECT AXIS SYNCHRONOUS REACTANCE.

TEST METHOD 37

DIRECT-AXIS SYNCHRONOUS REACTANCE TEST

37.1 General. The direct-axis synchronous reactance is the ratio determined by dividing the field current during a sustained symmetrical short circuit, at rated frequency required to produce rated armature current, by the value of the field current at the air-gap line of the open circuit saturation curve, at rated voltage and frequency.

> NOTE: The definition above is actually that of the per unit direct-axis synchronous impedance. However, this definition is used to a great extent in electrical literature and because the resistance of the machine is so small compared to the reactance, the error in using impedance value instead of the reactance value is negligible.

37.2 Apparatus. Instrumentation for measuring terminal voltage, generator speed, exciter field voltage and current (generator field voltage and current, if applicable), and line current shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, a prime mover having a steady state speed not greater than ±1 percent of rated speed and a separate, variable dc source for excitation shall be required. Electrical instrumentation used for this test shall have an accuracy of ±0.5 percent of reading or better.

37.3 Procedure.

a. Perform Test Method 34 (Open Circuit Saturation Curve Test). (Measure the generator field current).

b. Perform Test Method 35 (Synchronous Impedance Curve Test).

37.4 Results.

a. From the synchronous impedance curve (the short circuit saturation curve), determine the field current required to produce rated armature current for a sustained symmetrical short circuit at the generator terminals. In figure 37-I this value is represented by the distance I_{fsi}.

b. From the air-gap line of the open circuit saturation curve (the extended straight line part of the curve, see figure 36-I) determine the field current which corresponds to the rated voltage. In figure 36-I this value is represented by the distance I_{fg}.

c. Compute the direct-axis synchronous reactance by dividing the value obtained in step a above by the value obtained in step b above. This computation is represented by the following formula:

$$X_d = \frac{I_{fsi}}{I_{fg}}$$

Where: Xd is the direct-axis synchronous reactance.

d. Compare the calculated direct-axis synchronous reactance with the requirements of the contract .

37.5 Contract requirements. The following items must be specified in the individual contract:

a. The allowable range of direct-axis synchronous reactance, if applicable.

b. The voltage connection(s) and frequency(ies) at which this method is to be performed.

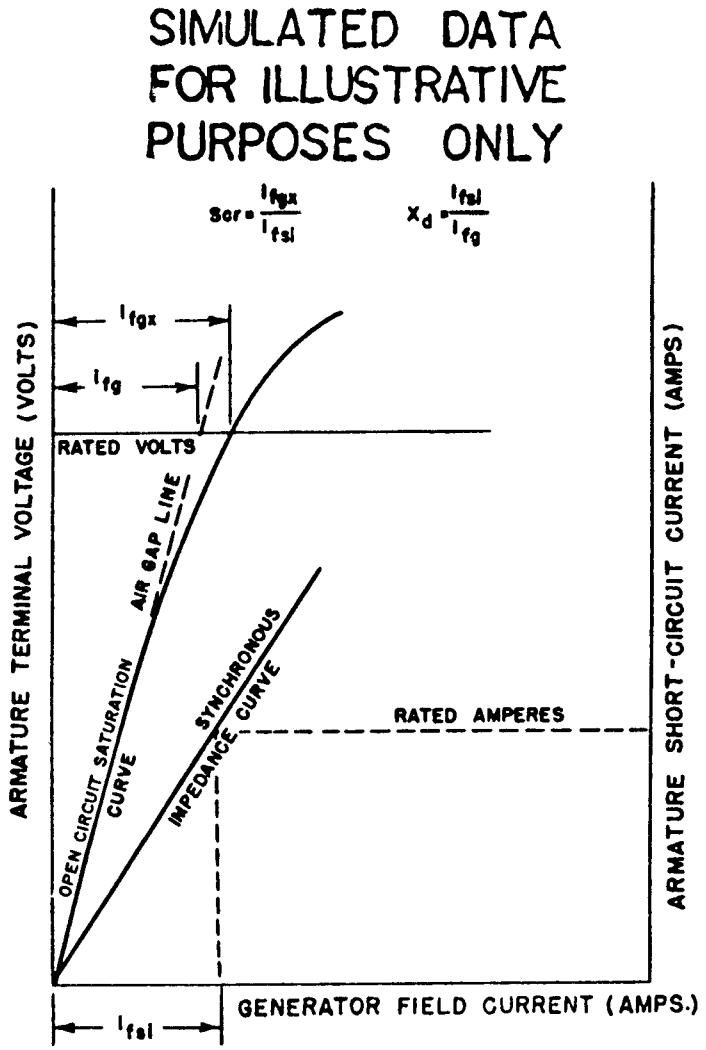

FIGURE 37-I SHORT CIRCUIT RATIO AND DIRECT-AXIS SYNCHRONOUS REACTANCE.

TEST METHOD 38

NEGATIVE-SEQUENCE REACTANCE AND IMPEDANCE TEST

38.1 General. Negative-sequence reactance or impedance is used by design engineers to determine the performance of three-phase wye generators under various load conditions.

38.2 Apparatus. Instrumentation for measuring load conditions, field voltage and current, and ambient temperature shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, a separate, variable source of dc power for generator excitation, a prime mover, and a shorting switch shall be required. Electrical instrumentation for this test shall have an accuracy of ±0.5 percent of reading or better.

38.3 Procedure.

38.3.1 Preparation for test.

a. Mechanically connect the generator to the prime mover and provide the external excitation supply to the generator.

b. Connect the instrumentation and shorting switch in accordance with figure 38-I for the voltage connection specified in the contract.

38.3.2 Test.

a. Start and operate the prime mover such that the generator is at rated speed with no excitation current.

b. Close the shorting switch.

c. Increase the field current until rated current is flowing through the short-circuit.

d. Record all instrument readings (see figure 38-II).

38.4 Results.

38.4.1 Compute the negative-sequence reactance using the following formula:

$$X_2 \text{ (in percent)} = \frac{WI_{RP}}{V_{RP}(1.732)\, I_2} \times 100$$

Where: X_2 = Negative-sequence reactance
W = Power in watts

V_{RP} = Rated line-to neutral (phase) voltage

I_{RP} = Rated phase current
I = ac Current in amperes

38.4.2 Compute the negative-sequence impedance from the data obtained in this method using the following formula:

$$Z_2 \text{ (in percent)} = \frac{E_{IRP}}{1.732 I V_{RP}} \times 100$$

Where: Z_2 = negative-sequence impedance
E = Voltage between the shorted terminals and the third line terminal

V_{RP} = Rated phase voltage

I_{RP} = Rated phase current
I = ac current in amperes

38.4.3 Compare these results with the requirements of the contract.

38.5 Contract requirements. The following items must be specified in the individual contract:

a. The voltage connection (must be three-phase wye) and frequency at which this method is to be performed.

b. The maximum, minimum, or range of allowable negative-sequence reactance, or negative-sequence impedance, if applicable.

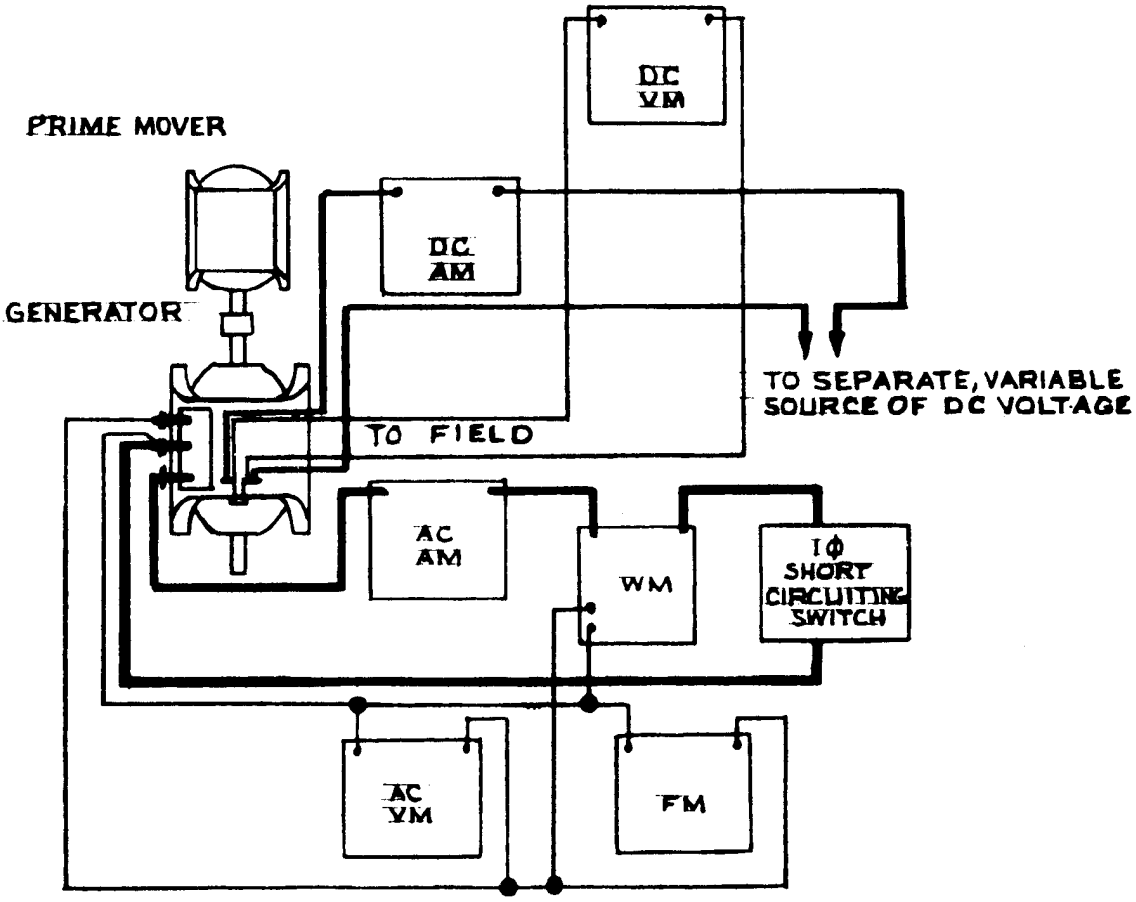

FIGURE 38-I APPARATUS HOOK-UP FOR NEGATIVE SEQUENCE REACTANCE AND IMPEDANCE TEST

TEST METHOD 39

ZERO-SEQUENCE REACTANCE TEST

39.1 General. Zero-sequence reactance is used by design engineers to determine the performance of three-phase wye connected generators under various load conditions.

39.2 Apparatus. Instrumentation for measuring line-to-line voltage, line current, generator speed and field current shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition a separate, variable source of dc power for generator excitation and a prime mover shall be required. Electrical instrumentation for this test shall have an accuracy of ±0.5 percent of reading or better.

39.3 Procedure.

39.3.1 Preparation for test.

a. Mechanically connect the generator to the prime mover and provide the external excitation supply to the generator.

b. Connect the instrumentation in accordance with figure 39-I for one "wye" voltage connection and frequency specified in the contract.

39.3.2 Test.

a. Start and operate the prime mover such that the generator is at rated speed and with zero field current.

b. Adjust the field current such that the ammeter, which short-circuits two generator phases to neutral, indicates a reading equal to three times the rated phase current.

c. Record all instrument readings.

CAUTION: To prevent serious overheating of the generator, the field current shall be reduced to zero and the generator shut down immediately following the reading of the instruments.

39.4 Results.

39.4.1 Compute the zero-sequence reactance using the following formula:

$$X_O \text{ (in percent)} = \frac{E_a I_{RP}}{I_n V_{RP}} \times 100$$

Where: X_O is the zero-sequence reactance

E_a is the armature voltage between the open phase and the short circuit.

I_{RP} is the rated phase current

V_{RP} is the rated phase voltage

I_n is the current flowing between the short-circuited phase terminals through the ammeter short-circuiting these terminals to the neutral.

39.4.2 Compare the zero-sequence reactance with the requirements of the contract.

39.5 Contract requirements. The following items must be specified in the individual contract:

a. The voltage connection (must be three-phase wye) and frequency at which this method is to be performed.

b. The maximum, minimum or range of allowable zero-sequence reactance, if applicable.

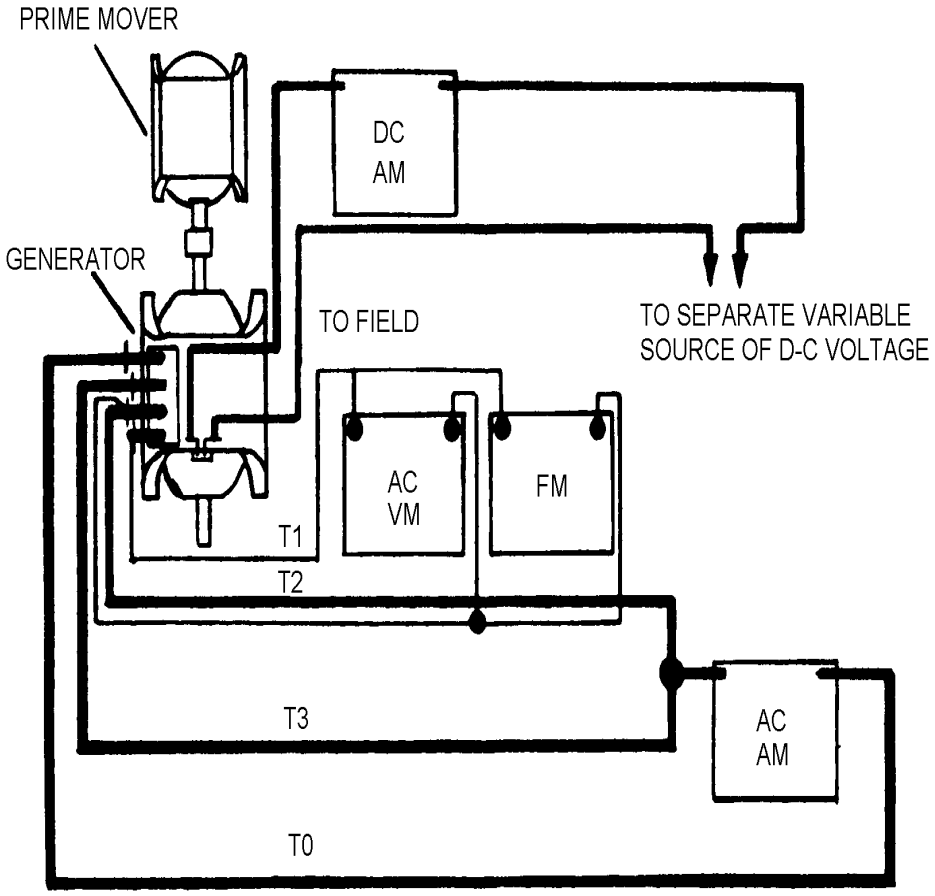

FIGURE 39-I APPARATUS HOOK-UP FOR ZERO-SEQUENCE REACTANCE TEST

TEST METHOD 40

QUADRATURE-AXIS SYNCHRONOUS REACTANCE TEST

40.1 General. Quadrature-axis synchronous reactance is used by design engineers to determine the performance of generators under various load conditions.

40.2 Apparatus. Instrumentation for measuring generator terminal voltage, line current and field voltage shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, the test recording equipment shall be as described in EGSA 107T, Test Methods 1, 4, and 6, a non-inductive shunt, a variable voltage ac power supply with sufficient power to deliver rated current to the generator at generator rated frequency, a variable speed prime mover and instrumentation for measuring generator speed shall be required. Electrical instrumentation for this test shall have an accuracy of ±0.5 percent of reading or better.

40.3 Procedure.

424.1.3.1 Preparation for test.

a. Mechanically connect the generator to the prime mover.

b. Connect the apparatus in accordance with figure 40-I or 40-II whichever is applicable.

c. Open circuit the generator field by disconnecting the exciter leads to the field (for brushless machines this method will require lifting slip rings and pilot brushes).

40.3.2 Test.

a. Start the prime mover and operate the generator in its normal rotation at rated speed.

b. Apply the variable voltage, ac power supply to the generator load terminals at a voltage value well below rated (zero voltage if possible). Slowly increase the applied voltage to the value required to circulate rated current through the generator windings.

c. Record all instrument readings.

d. Adjust the test recording equipment to record the generator phase voltage trace, the voltage across the open field trace, and the armature current trace to 2-inch amplitudes. Then record this information for calibration purposes.

e. Gradually reduce the generator speed approximately 5 %, but not more than 5 %.

f. Record the traces at not less than 5 seconds on the test recording equipment. Inspect traces of the recorded information to ensure that the individual peaks of the voltage and current waves can be identified.

g. Gradually increase the generator speed to rated.

h. Record all instrument readings. Then record the generator phase voltage, the voltage across the open field, and the armature current traces for calibration purposes.

CAUTION: Gradually reduce the stator current to zero before the prime mover is brought to rest.

40.3.3 Computations. The determination of the quadrature-axis synchronous reactance is made from an interpretation of the traces obtained in para 40.3.2, step f, above when the generator was being driven at a reduced speed. Under these conditions, the quadrature-axis synchronous reactance is in effect when the impedance is at a minimum (i.e., when the ratio of rms armature voltage to rms armature current is at a minimum). The direct-axis synchronous reactance is in effect when the ratio of rms armature voltage to rms armature current is at a maximum.

a. From the charts or stored waveforms taken in para 40.3.2, step f, determine the rms values of line-to-line voltage and the rms values of line current at each peak. Tabulate these values against time in cycles, as shown in the sample tabulation (figure 40-V). Each value of line-to-line voltage shall be expressed as a decimal fraction of rated line-to-line voltage. Each value of line current also shall be expressed as a decimal fraction of rated line current (see procedure 4, figure 40-III).

b. Divide each value of rms voltage (expressed as a decimal), by the corresponding rms current (expressed as a decimal). These values shall be tabulated and used as a basis for plotting a curve (figures 40-V and 40-VI).

c. These ratios shall be plotted versus time in cycles (figure 40-VI).

d. The approximate per unit direct-axis synchronous reactance is the maximum value of the ratio obtained in step b above.

e. The approximate per unit quadrature-axis synchronous reactance is the minimum value of the ratio obtained in step b above.

f. The ohmic values of direct-axis and quadrature-axis synchronous reactance are the unit values obtained in steps d and e above, multiplied by base ohms. The base ohms are determined by dividing rated phase voltage by rated phase current.

40.4 Results. Compare the value of quadrature-axis synchronous reactance obtained in para 40.3 with the requirements of the contract.

40.5 Contract requirements. The following items must be specified in the individual contract:

a. The voltage connection(s) and frequency(ies) at which this method shall be performed.

b. The maximum, minimum or range of allowable quadrature-axis synchronous reactance, if applicable.

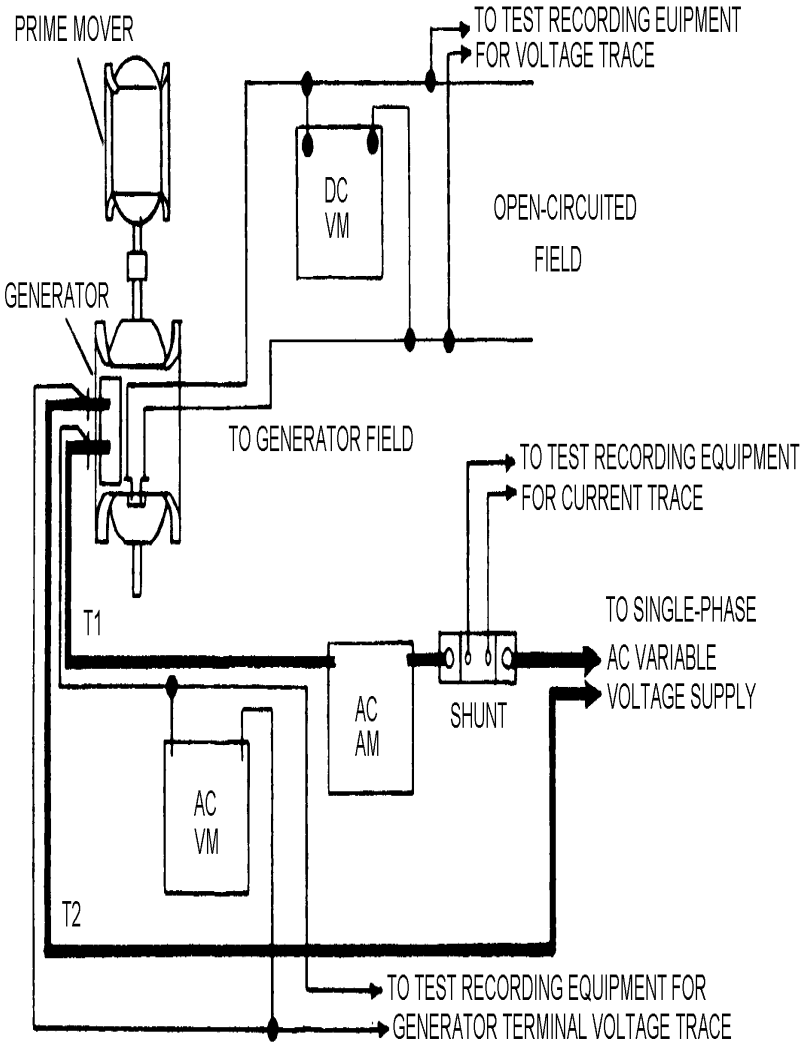

FIGURE 40-I APPARATUS HOOKUP FOR DETERMINATION OF QUADRATURE-AXIS SYNCHRONOUS REACTANCE OF SINGLE-PHASE GENERATORS.

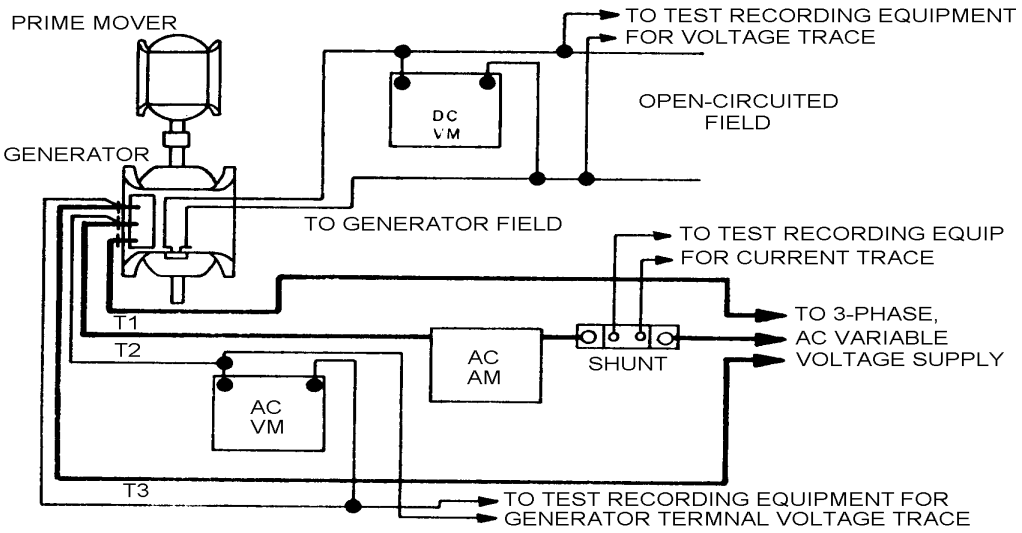

FIGURE 40-II APPARATUS HOOKUP FOR DETERMINATION OF QUADRATURE-AXIS SYNCHRONOUS REACTANCE OF THREE-PHASE GENERATORS.

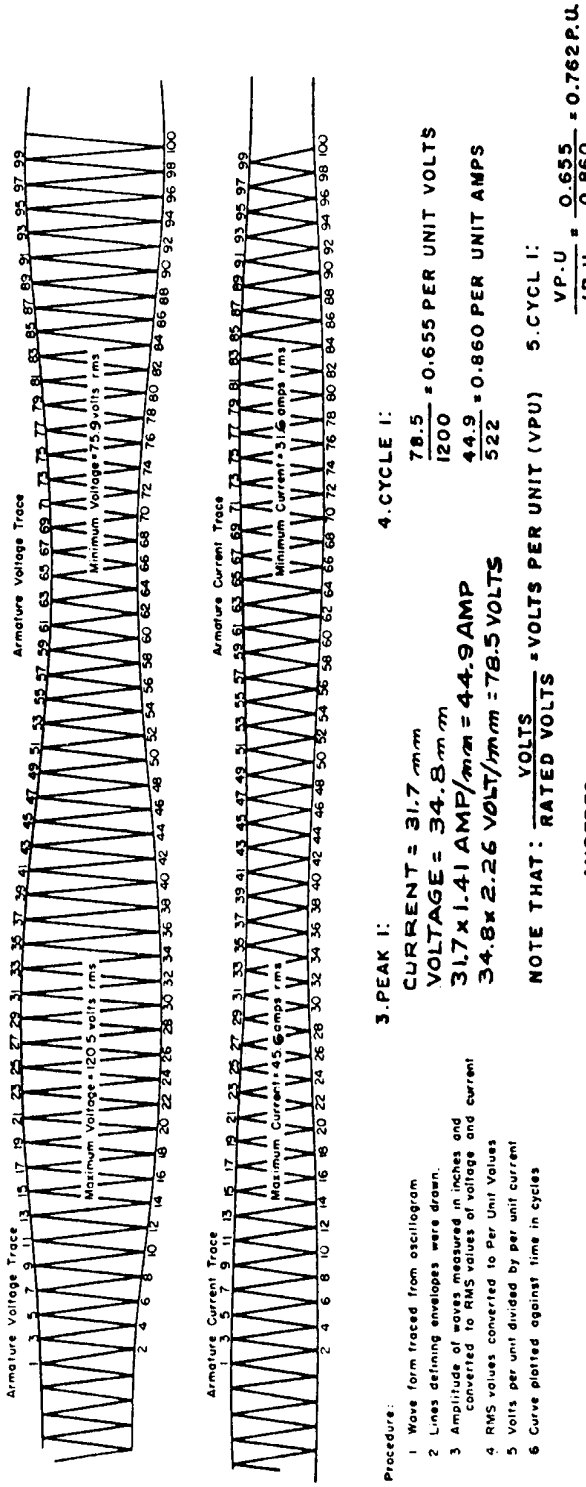

FIGURE 40-III TYPICAL TRACE OBTAINED DURING QUADRATURE-AXIS SYNCHRONOUS REACTANCE TEST.

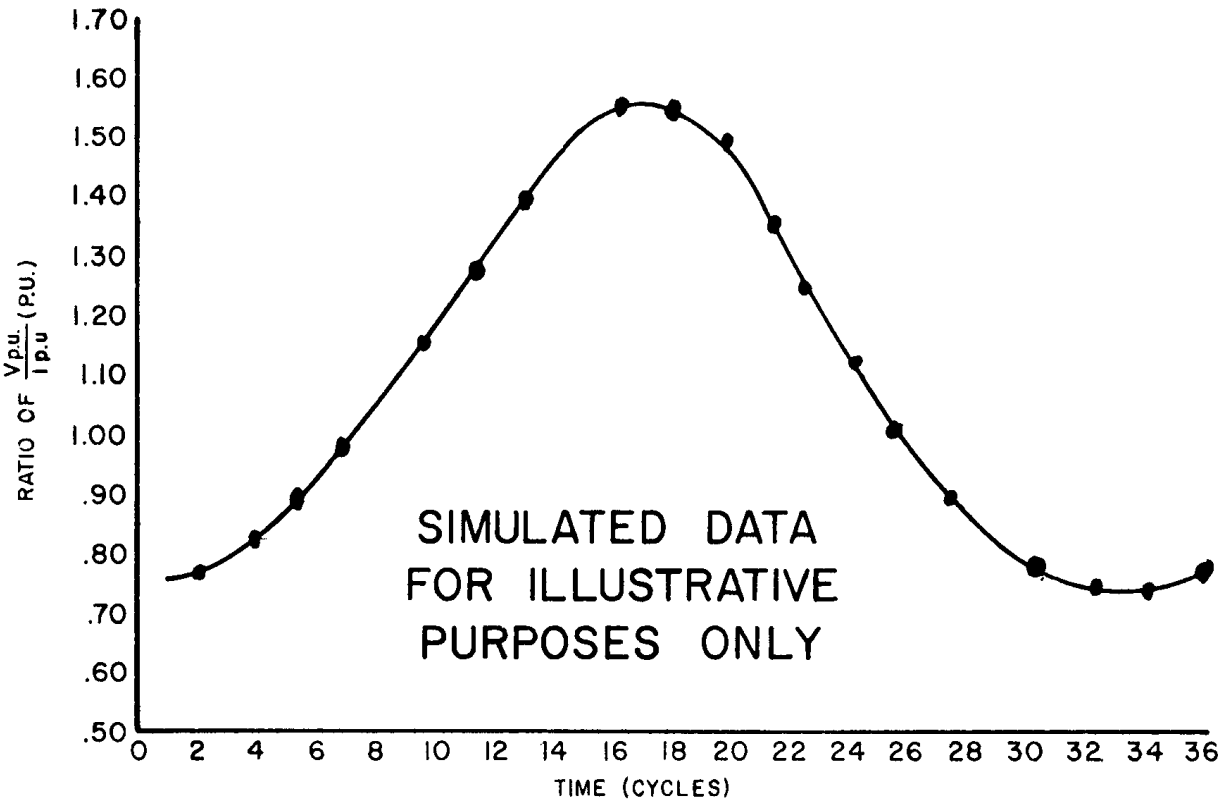

FIGURE 40-IV REACTANCE VERUS TIME CURVE