TEST METHOD 81

INHERENT VOLTAGE DROOP TEST

81.1 General. The inherent voltage droop of the generator is used by design engineers as an aid in the selection of a suitable voltage regulator and as a check to compare production generators with the preproduction generator.

81.2 Apparatus. Instrumentation for measuring load conditions, field voltage and current, and ambient temperature shall be as described in EGSA 107T . In addition, a variable dc source for external excitation shall be required.

81.3 Procedure.

81.3.1 Preparation for test.

a. Provide the external excitation supply to the generator (disconnect the voltage regulator, if applicable).

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

> **CAUTION**: When operating the generator under manual voltage control, care must be exercised in going from rated load to no load. The terminal voltage may rise to as much as 150 percent of rated terminal voltage and exceed the voltage ratings of test instruments connected in the circuit.

81.3.2 Test.

a. Start and operate the generator set and allow it to stabilize at rated load, rated voltage and rated speed. During this period record all instrument readings at minimum intervals of 10 minutes. If necessary, adjustments to the load, voltage and speed may be made to maintain rated load at rated voltage and speed. Adjustments to the voltage and speed shall be limited to those adjustments available to the operator, specifically adjustments to the voltage or speed adjust devices. On sets utilizing a droop type speed control system as the prime speed control, the speed and droop portions of the control may be adjusted. No other adjustments to the voltage and speed control system shall be made unless permitted by the contract. Adjustments to load, voltage or speed 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 to the load, voltage or frequency has been made.

b. After stabilization has occurred, drop the load to no load and reapply rated load a number of times (three should be sufficient) to assure that the no load and rated load voltage and speed values are repeatable and that the speed regulation is within the limits specified in the requirement document. If any adjustments are necessary step a above must be repeated.

c. Adjust the excitation voltage, if necessary, to obtain the rated terminal voltage at rated load. No further adjustments of the field rheostat shall be made during the test except as permitted under certain conditions of no load, as described in e below.

d. Starting with rated load (or specified overload) operation, reduce the load gradually to no load and record the instrument readings at approximately each 10 percent of rated load value (see figure 81-I).

e. At no load operation, adjust the terminal voltage to its rated value.

e. Gradually increase the load to rated current (or specified overload current) operation and record instrument readings at approximately each 10 percent of rated current value.

81.4 Results.

a. Plot voltage droop curves. The vertical axis shall be "terminal voltage", and the horizontal axis shall be "load current". For each of these curves, the maximum deviation from rated Voltage shall be noted (see figure 81-II).

b. Compare the maximum deviation from rated voltage with the requirements of the requirement document.

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

a. Allowable inherent voltage droop.

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

c. Maximum overload current, if applicable.

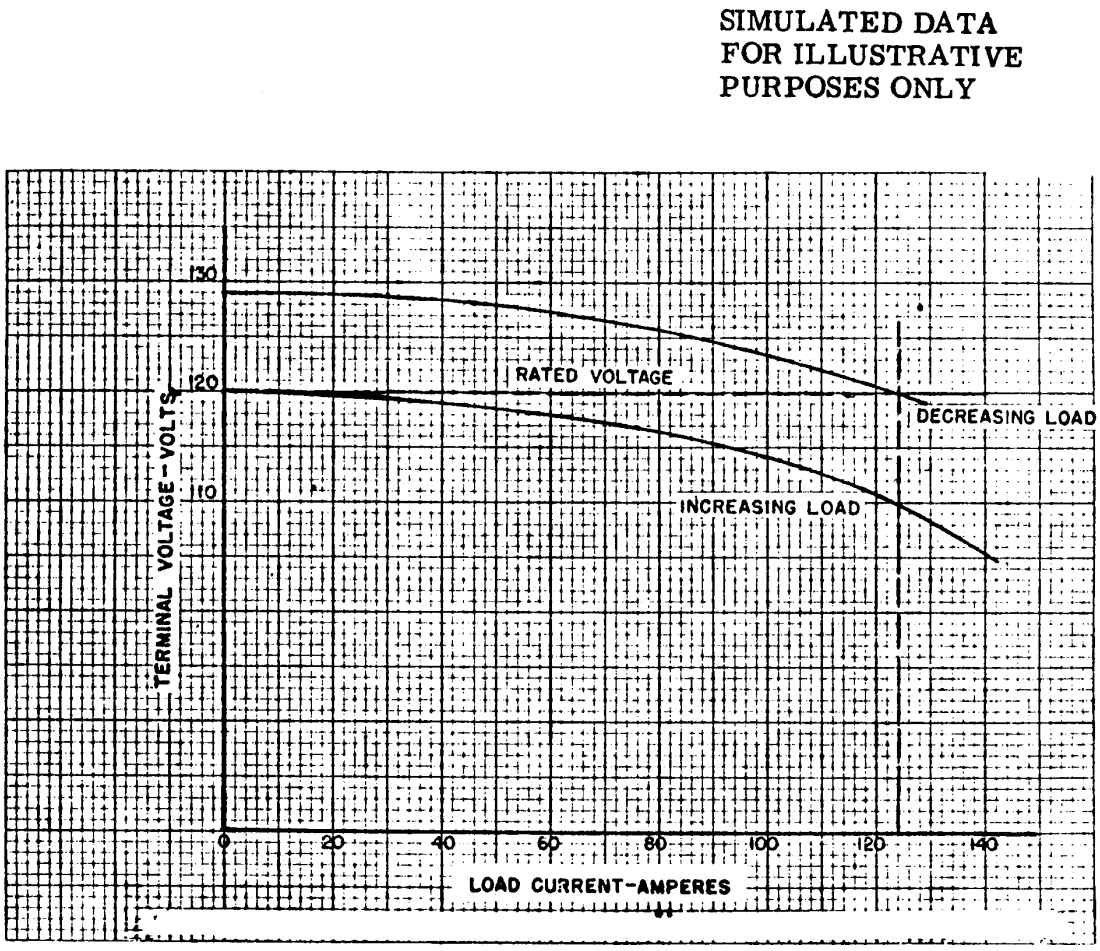


FIGURE 81-I TYPICAL CURVE FOR INHERENT VOLTAGE DROOP TEST

TEST METHOD 82

VOLTAGE AND FREQUENCY REGULATION TEST

(FOR GENERATOR SETS)

82.1 General. The frequency regulation (sometimes referred to as droop) of a generator set is the maximum difference between the no load value of frequency and the value at any load up to and including rated load. This difference is expressed as a percentage of the rated load frequency of the generator set. The voltage regulation is expressed similarly except that the rms value of voltage is used. Frequency stability describes the tendency of the frequency to remain at a constant value at a constant load. Generally, the instantaneous value of frequency is not constant but varies randomly above and below a mean value. Stability may be described as either short-term or long-term depending upon the length of time that the frequency is observed. Another term, bandwidth, describes the limits of these variations. Bandwidth is expressed as a percentage of the rated frequency of the generator set. Voltage stability is described similarly.

82.2 Apparatus. Instrumentation for measuring load conditions, and ambient temperature shall be as described in EGSA 107T .

82.3 Procedure.

82.3.1 Preparation for test.

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

b. Disconnect or otherwise render inoperative the cross current compensation circuits, if provided.

82.3.2 Test.

a. Start and operate the generator set at rated voltage. Adjust the engine governor so that the.frequency regulation is within the specified limits.

b. Operate the generator set and allow the set to stabilize at rated load, voltage and frequency. During this period record all instrument readings including ambient temperature at minimum intervals of 10 minutes. If necessary, adjustments to the load, voltage and frequency may be made to maintain rated load at rated voltage and frequency. Adjustments to the voltage and frequency shall be limited to those adjustments available to the operator, specifically adjustments to the voltage and frequency adjust devices. On sets utilizing a droop-type frequency control system as the prime speed control, the frequency and droop portions of the control may be adjusted.

No other adjustments to the voltage and frequency control systems shall be made unless permitted by the contract.

Adjustments to the load, voltage or frequency controls shall be recorded on the data sheet at the time of adjustment. Unless otherwise specified in the requirement document, 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 to the load, voltage or frequency has been made.

c. Starting with the rated load, voltage and frequency record all instrument readings. Then, reduce the load to zero in one step.

d. Record all instrument readings. Then, reapply rated load in one step.

e. Repeat steps c and d above two additional times.

f. Repeat 82.3 above, for ac sets only, using a rated kilowatt and unity power factor load.

82.3.3 Repeat procedure. Repeat 82.3 for all other voltage connections and frequencies specified in the contract.

82.4 Results.

82.4.1 Voltage regulation.

a. Obtain the average of the no-load and rated-load voltages individually. Do this for both line-to-line and line-to-neutral voltages.

Sample Computations
From data sheet - Figure 82-I

Rated Load

		Reading No. 116	Reading No. 118	Reading No. 120
L1-L2	(volts)	208	208	208
L2-L3	(volts)	208	208	208
L3-L1	(volts)	208	208	208
Total		624	624	624

Average of three trials =

$$\frac{624 + 624 + 624}{9} = 208 = V_{r1}$$

		Reading No. 116	Reading No. 118	Reading No. 120
L1-L0	(volts)	120.4	120.4	120.4
L2-L0	(volts)	120.1	120.0	120.0
L3-L0	(volts)	120.2	120.2	120.2
Total		360.7	360.6	360.6

Average of three trials =

$$\frac{360.7 + 360.6 + 360.6}{9} = 120.2 = V_{r1}$$

No Load

		Reading No. 116	Reading No. 118	Reading No. 120
L1-L2	(volts)	210	211	212
L2-L3	(volts)	210	211	212
L3-L1	(volts)	210	211	212
Total		630	633	636

Average of three trials =

$$\frac{630 + 633 + 636}{9} = 211 = V_{n1}$$

		Reading No. 116	Reading No. 118	Reading No. 120
L1-L0	(volts)	121.4	121.8	122.2
L2-L0	(volts)	121.4	121.6	122.2
L3-L0	(volts)	121.6	122.0	122.4
Total		364.4	365.4	366.8

Average of three trials =

$$\frac{364.4 + 365.4 + 366.8}{9} = 121.8 = V_{n1}$$

b. Substitute the average values of the three trials in the following formula:

$$\text{Voltage regulation (in percent)} = \frac{V_{n1} - V_{r1}}{V_{r1}} \times 100$$

Where: V_{n1} is the average voltage at no load.

V_{r1} is the average voltage at rated load.

Sample Computation Line-to-Line

Average voltage regulation =

$$\frac{211 - 208}{208} \times 100 = \frac{3}{208} \times 100 = 1.44\%$$

Sample Computation Line-to-Line

Average voltage regulation =

$$\frac{121.8 - 120.2}{120.2} \times 100 = \frac{1.6}{120.2} = 1.33\%$$

82.4.2 Frequency (speed) regulation.

a. Obtain the average of the no-load speeds individually. On ac generator sets, frequency may be used instead of speed.

Sample Computation

Reading No.	Frequency
116	399.4
118	400.0
120	400.0

Average of three trials = $\frac{1199.4}{3} = 399.8 = X_{r1}$

117	408.5
119	408.0
121	408.0

Average of three trials = $\frac{1224.5}{3} = 408.2 = X_{n1}$

b. Substitute the average values in the following formula:

Frequency (speed) regulation (in percent) =

$$\frac{X_{n1} - X_{r1}}{X_{r1}} \times 100$$

Where X_{n1} is the average frequency (speed) at no load

X_{r1} is the average frequency (speed) at rated load

Sample Computation

Average frequency (speed) regulation =

$$\frac{408.2 - 399.8}{399.8} \times 100 = \frac{8.4}{399.8} \times 100 = 2.10\%$$

82.4.3 Compare the results of the computations with the values given in the contract.

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

a. Allowable voltage regulation.

b. Allowable frequency regulation.

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

TEST METHOD 83

INHERENT VOLTAGE REGULATION TEST

83.1 General. The inherent voltage regulation is used by design engineers to aid in the selection of the voltage regulator and overvoltage safety equipment. It is important that the inherent voltage regulation of production generator(s) remains approximately the same as the regulation for the first article generator(s).

83.2 Apparatus. Instrumentation for measuring load conditions, field voltage and current, and ambient temperature shall be as described in EGSA 107T . In addition a variable dc source for external excitation shall be required. If this method is not performed as a set test, a prime mover capable of meeting the speed requirements as specified in the contract will be required.

83.3 Procedure.

83.3.1 Preparation for test.

a. Connect the load and field for one voltage connection and speed specified in the contract and provide the external excitation supply to the generator.

CAUTION: When operating the generator under manual voltage control care must be exercised in going from rated load to no load. The terminal voltage may rise to 150 percent of rated terminal voltage and exceed the voltage ratings of test instruments connected in the circuit.

83.3.2 Test.

a. Start and operate the generator set and allow it to stabilize at rated load, rated voltage and rated speed. During this period record all instrument readings at minimum intervals of 10 minutes. If necessary, adjustments to the load, voltage and speed may be made to maintain rated load at rated voltage and speed. On sets utilizing a droop-type speed control system as the prime speed control, the speed and droop portions of the control may be adjusted. No other adjustments to the voltage and speed control systems shall be made unless permitted by the requirement document. Adjustments to load, voltage or speed 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 to the load, voltage or frequency has been made.

b. After stabilization has occurred apply and drop rated load several times (3 should be sufficient) to assure that the no load and rated load voltage and speed values are repeatable and that the voltage and speed regulation is within the limits specified in the contract. If any adjustments are necessary, step a must be repeated.
Reapply rated load. No further adjustments of the field voltage shall be made for the remainder of this method.

c. Starting with rated load, obtain the following load conditions in one step from the previous load step. During each step record all instrument readings (see figure 83-I).

1. Rated load
2. No load
3. Rated load
4. No load
5. Rated load
6. No load

d. Repeat steps a thru c above for all other voltage connection(s) and frequency(ies) specified inthe contract.

83.4 Results.

a. Obtain the average of the three no load voltage readings and the average of the three rated load voltage readings.

b. Substitute the averages obtained in step a above in the following formula to obtain the inherentvoltage regulation:

$$\text{Inherent voltage regulation (in percent)} = \frac{V_{n1} - V_{r1}}{V_{r1}} \times 100$$

Where: V_{n1} is the average no load voltage.

V_{r1} is the average rated load voltage.

c. Compare the computed inherent voltage regulation with the requirements of the contract.

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

a. Upper and lower limits of acceptable inherent voltage regulation in percent of rated voltage.

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

c. Allowable speed regulation.

TEST METHOD 84

VOLTAGE DIP FOR LOW POWER FACTOR LOADS TEST

84.1 General. Waveforms of the output voltage made during the sudden application of low power factor loads indicate the ability of a generator set to start motors.

84.2 Apparatus. Instrumentation for measuring load conditions, field voltage and current, and ambient temperature shall be as described in EGSA 107T . In addition, the test recording equipment shall be described in EGSA 107T , Test Method 1, 4, and 6 (unless otherwise specified in the contract); and a voltage-linear, non-saturating reactive load of 0.4 (or less) power factor lagging will also be required.

84.3 Procedure.

84.3.1 Preparation for test.

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

b. Unless otherwise specified connect the voltage measuring equipment across any line-to-neutral(phase) connection which provides the input to the voltage regulator sensing circuit. Make this connection at the generator output terminals.

c. Connect the current measuring equipment across a shunt in the line associated with the voltage measuring galvanometer.

d. If the set contains an internal load bank, it shall be disconnected. If a voltage regulator reactive droop compensator is installed on the set, it shall be made inoperative.

84.3.2 Test.

a. Start and operate the generator set under control of the voltage regulator and allow the set to stabilize at rated load, rated voltage and rated frequency. During this period readings of the load and field instrumentation and ambient temperature shall be recorded at minimum intervals of 10 minutes. I f necessary, adjustments to the load, voltage and frequency may be made to maintain rated load at rated voltage and rated frequency. However, adjustments to the voltage or frequency shall be limited to those adjustments available to the operator, specifically, adjustments to the voltage or frequency adjust devices. On sets utilizing a droop-type speed.control system as the prime speed control, the speed and droop portions of the control may be adjusted. No other adjustments to the voltage and frequency control systems shall be made unless permitted by the contract. Adjustments to load, voltage or frequency shall be recorded on the stabilization

data sheet. 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 to the load, voltage or frequency has been made. (see figure 84-II).

b. Adjust the peak-to-peak voltage trace amplitude to a minimum of 3 inches (approximately 75millimeters) as viewed on the test recording equipment. Set the test recording equipment such the individual waveform peaks will be clearly visible. Set the test recording equipment time marker to at least 0.01 seconds per line or use a 60 Hertz timing trace.

c. Immediately after the generator set has stabilized and the test recording equipment has been adjusted, reduce the load to zero.

d. Adjust the terminal voltage and frequency to their rated values (generator nameplate values at the voltage connection and frequency used).

e. Apply the 0.4 or less power factor load (or as specified) and adjust this load to draw twice rated current (this will be a 1/2 per unit (P.U.) load impedance at the rated voltage connection used in step b above). A balanced three phase reactive load is required for three phase machines. If, while the applied load is drawing twice rated current, the set output voltage as measured on rms meter differs by more than two percent from the rated value, the reactive load shall be readjusted to compensate for this voltage difference.

NOTE: Several trial runs and readjustments may be necessary to insure that the equation is satisfied for the measured values of I_{ZPF} and E_{ZPD}.) The new equivalent load current required shall be calculated from the following equation:

$$I_{ZPF} = \frac{2\, I_R \;\; X \;\; E_{ZPF}}{E_R}$$

Where: I_{ZPF} = The new equivalent load current.

E_{ZPF} = The resultant. voltage at the low power factor load coincident with I_{ZPF}.

I_R = Rated current
(from the generator nameplate data at the specified voltage connection).

E_R = Rated voltage (at the specified voltage connection).

f. Adjust the peak-to-peak current trace amplitude to a minimum of 1.5 inches (approximately 40 millimeters).

g. Reduce the load to zero.

h. Read the load and field instrumentation and record the steady-state readings.

i. With the test recording equipment adjusted as above, operate the test recording equipment and apply the low power factor load in one step. After allowing the voltage and frequency to return to steady-state conditions after the transient period, stop the test recording equipment, read the load and field instrumentation and record the readings.

j. Repeat steps g thru i above two additional times allowing the voltage and frequency to return to steady-state conditions after each load application.

k. Repeat steps a thru j above for each additional voltage connection and frequency specified in the contract.

84.4 Results.

a. From the wavefroms, check to insure that the load reactance was not saturated and introducing excessive harmonics by determining that the ratios of the peak-to-peak voltage to peak-to-peak current remain constant from the instant the reactive load is first applied until steady-state conditions are reached (see figure 84-I).

b. Using the waveforms and the corresponding voltmeter readings, determine the voltage dip in percent using the following equation:

$$\text{Voltage Dip, in percent} = \frac{V_{NL} - V_D}{V_{RATED}} \times 100$$

Where: V_{NL} = Voltmeter reading at no load prior to applying load.

V_{RATED} = Rated voltage for which the generator is connected.

V_D = Calculated voltage dip during the transient period where:

$$VD = \frac{DV_L}{L}$$

V_L = Steady-state voltmeter reading after application of load.

D = Measured minimum peak-to-peak amplitude of the voltage trace during the transient period following load application.

L = Measured peak-to-peak amplitude of the steady-state voltage after load application.

c. Calculate the minimum voltage, in percent of rated voltage, during the transient period after the application of the low power factor load by subtracting the voltage dip, in percent, obtained in b above from 100 percent.

d. From the waveforms, use the timing lines or the 60 Hertz timing trace and determine the recovery time (no load to load) to the nearest 0.01 second. The recovery time is the time from the application of load until the voltage reaches the voltage value specified in the contract.

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

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

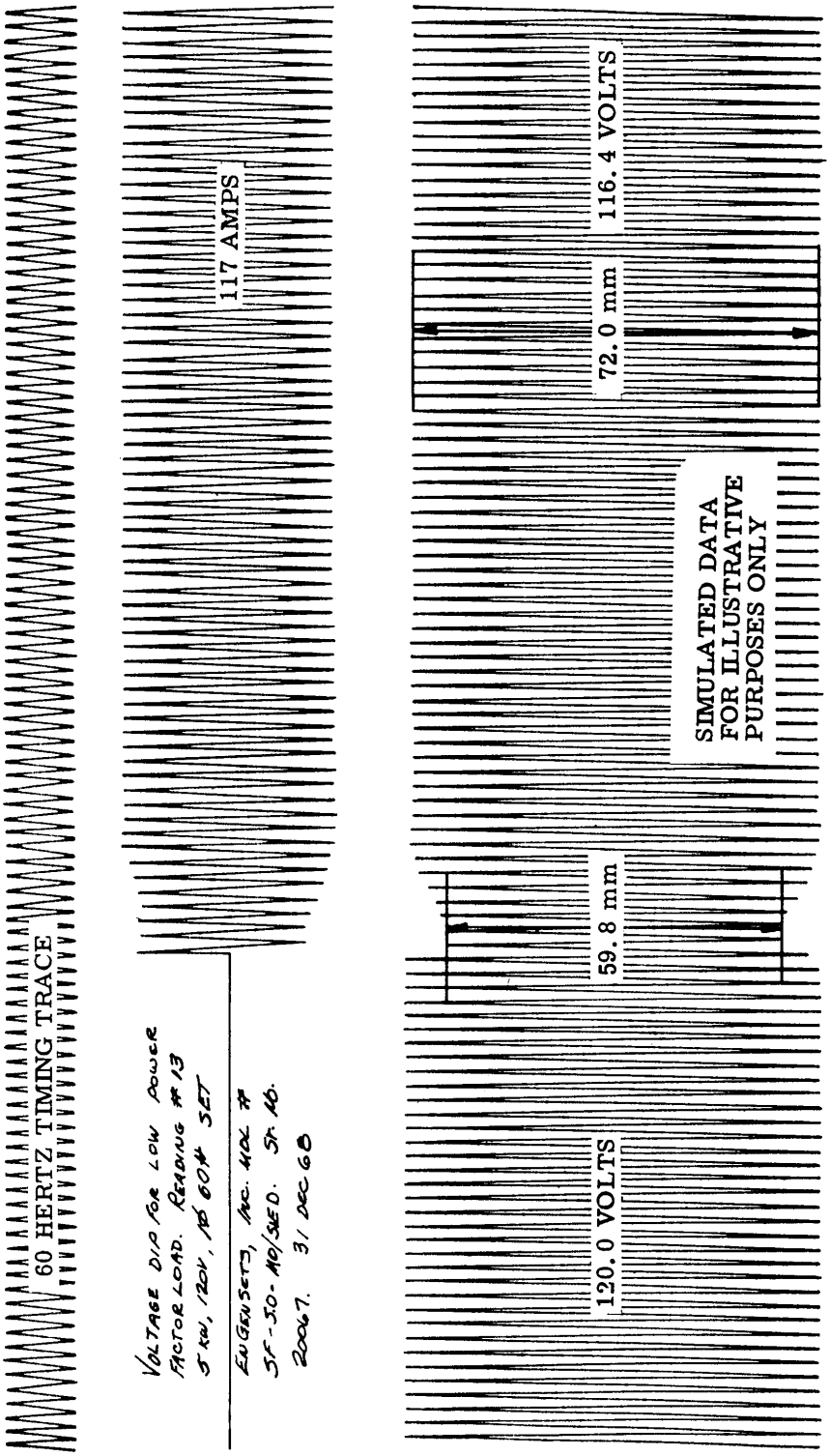
a. Allowable voltage dip (no load to load), in percent of rated voltage or the minimum value of voltage, in percent of rated voltage, permitted during the transient period.

b. Required recovery time (no load to load) and the voltage value to which it is to be measured.

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

d. Load conditions, if other than 1/2 P.U. impedance at 0.4, or less, power factor lagging (twice rated current).

e. Phase connections for voltage measurement, if other than as specified herein.



$V_{NL} = 120.0V$ $D = 59.8mm$ $V_D = \frac{DV_L}{L} = \frac{(59.8V/in.)}{72.0} = 96.7V$ VOLTAGE DIP = $\frac{V_{NL}-V_L}{V_{RATED}} \times 100 = \frac{120.0-96.7}{120} \times 100 = 19.4\%$

$V_{RATED} = 120V$ $L = 72.0mm$

$V_{LOAD} = 116.4V$

FIGURE 619.11. PORTION OF AN WAVEFORM SHOWING VOLTAGE DIP CALCULATIONS FOR APPLICATION OF LOAD.

Figure 84-I Voltage Dip Calculations for Application of Load

TEST METHOD 85

VOLTAGE UNBALANCE WITH UNBALANCE LOAD TEST

(LINE-TO-NEUTRAL LOAD)

85.1 General. A generator set must have the capability to maintain a reasonably balanced voltage among the phases when an unbalanced load is applied. Line-to-line voltage unbalance has a serious effect on polyphase motor load. The negative sequence voltages cause heating of the windings and loss of torque. Line-to-neutral voltage deviations from rated voltage affect single phase loads. Lights and single phase motors may have either too low or too high a voltage impressed on them for either efficient or safe operation.

65.2 Apparatus. Instrumentation for measuring load conditions and ambient temperature shall be as described in EGSA 107T .

85.3 Procedure.

85.3.1 Preparation for test. Connect the load instrumentation for one voltage connection and frequency specified in the contract. Note that only one voltmeter shall be used to measure all voltages and this voltmeter shall have an accuracy of +0.5 percent of the reading or better.

85.3.2 Test.

a. Start and operate the generator set at rated voltage, no load, rated frequency, and under control of the voltage regulator. Record all instrument readings.

b. Apply the specified load between terminals L1-L0, L2-L0, and L3-L0 in turn. Record all instrument readings at each. l me-to-neutral condition (see figure 620.1-I).

c. Repeat 85.3 for each of the other specified voltage connection(s) and frequency(ies).

85.4 Results.

a. Express the greatest difference between any two of the line-to-line voltages and any two of the line-to-neutral voltages as a percent of rated voltage.

b. Compare the largest differences expressed in percent with the maximum allowable difference specified in the contract.

85.4.1 Sample calculations.

L1-L2 = 200.0 volts
L2-L3 = 203.0 volts
L3-L1 = 210.0 volts

Maximum difference = 10.0 volts

Rated Voltage = 208.0 volts

$$\frac{10.0}{208.0} \times 100 = 4.81 \text{ percent}$$

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

a. Load(s) to be applied as unbalanced loads in percent of rated line-to-neutral load.

b. Maximum acceptable values of line-to-line voltage unbalance expressed as percent of rated voltage.

c. Maximum acceptable values of line-to-neutral voltage unbalance expressed as a percent of rated voltage.

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

TEST METHOD 86

VOLTAGE UNBALANCE WITH UNBALANCE LOAD TEST

(LINE-TO-LINE)

86.1 General. A generator set must have the capability to maintain a reasonably balanced voltage among the phases when an unbalanced load is applied. Line-to-line voltage unbalance has a serious effect on polyphase motor load. The negative sequence voltages cause heating of the windings and loss of torque.

86.2 Apparatus. Instrumentation for measuring load conditions and ambient temperature shall be as described in EGSA 107T

86.3 Procedure.

86.3.1 Preparation for test. Connect the load instrumentation for one voltage connection and frequency specified in the contract. Note that only one voltmeter shall be used to measure the line-to-line voltages and this voltmeter shall have an accuracy of +0.5 percent of the reading or better.

86.3.2 Test.

a. Start and operate the generator set at rated voltage, no load, rated frequency, and under control of the voltage regulator. Record all instrument readings.

b. Apply the specified load between terminals L1-L0, L2-L0, and L3-L0 in turn. Record all instrument readings at each. l me-to-neutral condition (see figure 86-I).

c. Repeat 86.3 for each of the other specified voltage connection(s) and frequency(ies).

86.4 Results.

a. Express the greatest difference between any two of the line-to-line voltages and any two of the line-to-neutral voltages as a percent of rated voltage.

b. Compare the largest differences expressed in percent with the maximum allowable difference specified in the contract.

86.4.1 Sample calculations.

Reading No. 222	L1-L2	= 200.0 volts
	L2-L3	= 203.0 volts
	L3-L1	= 210.0 volts

Maximum difference = 10.0 volts

Rated line-to-line voltage = 208.0 volts

$$\frac{10.0}{208.0} \times 100 = 4.81 \text{ percent}$$

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

a. Load(s) to be applied as unbalanced loads in percent of rated line-to-neutral load.

b. Maximum acceptable values of line-to-line voltage unbalance expressed as percent of rated voltage.

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

METHOD 87

VOLTAGE UNBALANCE TEST

(THREE WIRE, SINGLE PHASE)

87.1 General. A generator set must have the capability to maintain a reasonably balanced voltage to the system when an unbalanced load is applied. Voltage deviations from rated voltage affect single phase loads. Lights and single phase motors may have either too low or too high a voltage impressed on them for either efficient or safe operation.

87.2 Apparatus. Instrumentation for measuring load conditions and ambient temperature shall be as described in EGSA 107T .

87.3 Procedure.

87.3.1 Preparation for test. Connect the load instrumentation for one voltage connection and frequency specified in the contract. Note that only one voltmeter shall be used to measure all voltages and this voltmeter shall have an accuracy of +0.5 percent of the reading or better.

87.3.2 Test.

a. Start and operate the generator set at rated voltage, no load, rated frequency, and under control of the voltage regulator. Record all instrument readings.

b. Apply the specified load between terminals L1-L0, L2-L0, and L1-L2 in turn. Record all instrument readings at each. l me-to-neutral condition (see figure 87-I).

87.4 Results.

a. Express the greatest difference between the two of the line-to-neutral voltages as a percent of rated voltage.

b. Compare this difference expressed in percent with the maximum allowable difference specified in the contract.

87.4.1 Sample calculations.

L1-L0 = 118.0 volts
L2-L0 = 122.0 volts

Voltage difference = 4.0 volts

Rated Line-to-Neutral Voltage = 120.0 volts

$$\frac{4.0}{120.0} \times 100 = 3.33 \text{ percent}$$

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

a. Load(s) to be applied as unbalanced loads in percent of rated line-to-neutral load.

b. Maximum acceptable value of line-to-neutral voltage unbalance in percent of rated voltage.

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

TEST METHOD 88

UNBALANCED LOAD HEATING TEST

88.1 General. The generator set must be capable of withstanding without damage unbalanced loads for long periods of time.

88.2 Apparatus. Instrumentation for measuring load conditions, field conditions, field voltage and current, temperature of the generator windings and ambient temperature shall be as described in EGSA 107T .

88.3 Procedure

88.3.1 Preparation for test.

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

b. Connect switch(es) to the generator armature winding(s) for which the temperature rise is to be determined, such that the winding(s) may be isolated for resistance measurements (if rapid access is available to isolate the individual winding(s) this step may be omitted).

c. Attach the necessary thermal instrumentation in accordance with Test Method 20 and make the necessary winding resistance measurements in accordance with Test Method 58.

88.3.2 Test.

a. Start and operate the generator set at rated voltage, no load, rated frequency, and under control of the voltage regulator.

b. Apply the specified unbalanced load.

c. Add balanced load at rated power factor, until rated current is recorded at one or the other of the two terminals to which the single phase load is connected.

> **NOTE**: The current will not be the same in the lines to which the single phase load is applied, if the power factor of the three phase load is other than unity. As soon as the current at either terminal is at rated value, discontinue adding three phase load.

d. Allow the generator set to stabilize at the above conditions. During this period record all instrument readings including ambient temperature at minimum intervals of 10 minutes. If

necessary adjustments to the voltage and frequency may be made to maintain rated conditions. Adjustments to the voltage and frequency shall be limited to those adjustments available to the operator, specifically adjustments to the voltage and frequency adjust devices. On sets utilizing a droop type speed control system as the prime speed control, the speed and droop portions of the control may be adjusted. No other adjustments to the voltage and frequency control systems shall be made unless permitted by the contract. Adjustments to the voltage and frequency controls shall be recorded on the data sheets 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 to the load, voltage or frequency has been made (see figure 88-I).

e. After stabilization has occurred, stop the set so that temperatures of rotating components and windings may be taken. For application of the contact method to rotating parts, or the resistance method to the armature coils (see Test Methods 110.1 and 202.1); a quick shutdown of the set is mandatory.

CAUTION: Do not connect bridges, meters or temperature measuring equipment for measuring resistance or temperature to circuits which may still be energized, e.g., during the time that the set is coming to a stop.

f. Immediately after the shutdown, start to record the resistance bridge readings of the windings and the temperature of the components, where the contact method of measuring temperature rise is used.
Readings of resistance measurements shall be recorded in accordance with instructions given in Test Method 10
The first thermocouple reading shall be taken and recorded within 30 seconds after shutdown and additional readings taken and recorded at approximately 30 second intervals until one reading has been recorded after the temperature has begun to decrease, or three minutes has elapsed since set shutdown, whichever is longer, being certain that the maximum temperature reached by each component has been recorded. Continuous or multipoint temperature recorder(s) may be used to
record component temperatures as long as the above time requirements are met.

g. Repeat steps a thru f above for each of the windings specified in the contract.

88.4 Results. Compare the temperature rise(s) with the requirements of the contract.

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

a. Allowable temperature rise for the windings, giving the method of measurement.

b. Unbalanced load to be applied, in percent of rated phase load.

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

TEST METHOD 89

PARALLEL OPERATING TEST

89.1 General. It is sometimes necessary to connect two or more generator sets (which are designed for parallel operation) in parallel to supply power requirements greater than the rating of an individual set. Generator sets may also be connected in parallel to assure an uninterrupted supply of power if it becomes necessary for one generator set to be shut down for maintenance or service. When two or more generator sets are connected in parallel, the capability should exist for supplying power equal to their combined ratings without overloading any one of the individual units. In order to do so, the sets must divide the system load in proportion to their individual set ratings, and power exchange between the sets so connected must be kept to a minimum. Power exchange is the difference between the maximum and minimum power output delivered by a set, for constant system load conditions. Power exchange may be determined by waveform measurements.

89.2 Apparatus. Instrumentation for measuring load conditions and phase rotation shall be as described and illustrated in EGSA 107T . In addition, the test recording equipment shall be described in EGSA 107T , Test Method 1,4,and 6 (unless otherwise specified in the contract), transducers for real and reactive power as described in Test Method , Test Method 3, and a non-inductive shunt will be required.

89.3 Procedure. The following instructions are for paralleling two sets of the same power (and frequency) rating. For paralleling more than two sets of different power ratings, this method may be followed by extension of the procedure.

CAUTION: Do not close any load switches or circuit interrupters until specifically directed to do so. Closing the load switches or circuit interrupters at any other time may damage both the equipment and the test apparatus.

89.3.1 Preparation for test.

a. Connect the generator sets to be paralleled for one of the voltage connections and frequencies specified in the contract.

b. Connect each of the sets, through individual load switches, to a common system load using the proper phase sequence (like output terminal numbers on each set are connected together on the same line). Connect the individual set instrumentation and system load instrumentation. The active power (watts) delivered by one set is recorded on the test recording equipment.

c. Using the operating instructions on the set or in the technical manual, check, and if necessary, initially adjust the governor and voltage regulator paralleling controls.

1. On sets that are paralleled with droop, check the frequency and voltage regulation while in the parallel operation mode (voltage droop compensator operative but the sets are not actually operating in parallel). If necessary, adjust both sets for identical regulation values. These regulation values must be within those values specified in the contract for parallel peration.

2. On sets that are paralleled without droop, the voltage at the parallel receptacle must be equal in both magnitude and polarity. Interconnect the sets utilizing the paralleling cable.

d. Unless otherwise specified, connect the signal input of the test recording equipment to the convenience receptacle of one of the sets or to a generator coil which is used as the voltage sensing input to the voltage regulator of one of the sets.

e. Use the phase sequence indicator to assure the phase rotation of each generator is the same.

f.. Open all circuit interrupters and load switches.

89.3.2 Test.

a. Operate the sets at rated voltage, rated frequency and at no load.

b. Close the circuit interrupter and turn on the paralleling circuits on set number 1.

c. Apply the minimum system load specified in the contract.

d. On set number 2, turn on the synchronizing lights and paralleling circuits. Adjust the frequency of set number 2 to a higher frequency than the bus frequency, then slowly reduce the frequency of set number 2 until the lights simultaneously brighten and go dark in approximately 5 second intervals.
(**NOTE**: If one light is bright while the other is dark, one of the sets is incorrectly wired and must be corrected before proceeding further. See 89.3..)

e. Close the circuit interrupter of set number 2 at the instant both synchronizing lights go dark.

CAUTION: Closing the switch under any condition other than with the synchronizing lights dark maycause severe damage to the generator sets and test apparatus.

f. With the generator sets operating in parallel, and with the system loaded to the minimum load of the frequency adjust device only) to equally divide the kW load between the sets. Make small adjustments to the voltage regulators (by means of the voltage adjust device only) to obtain a minimum and equal current, thereby dividing the reactive load equally between the sets.

g. Increase the system load in small increments and balance this load between each set using thereal and reactive load sharing controls until each set is carrying rated load. No further adjustments shall be made to either the load sharing controls or the voltage and frequency adjust devices for the remainder of this test unless specifically directed otherwise.

h. In one step, reduce the system load to the minimum value specified in the contract. Operate the sets at this system load condition for one hour. Read and record the load instrumentation readings for each set and the system load at 15 minute intervals. If using recording meter(s), adjust the voltage and frequency chart speed recording meter(s) to 12 inches per minute for the first 30 seconds and then to 12 inches per hour during the remainder of the one hour period. Adjust the waveform trace amplitudes such that periodic pulsations of power and current are clearly visible. Operate the test recording equipment for 30 seconds at 15 minute intervals during this one hour of operation.

i. Increase the system load in four approximately equal steps until the combined rating of the sets is applied. At each of the four load steps operate the sets for one hour taking readings and recordings as in step h above.

j. If using recording meter(s), adjust the recording meter(s) chart speed(s) to 12 inches per minute and the test recording equipment must sample at least twice the speed used in step h above.

k. With the sets operating at system rated load, reduce the load in one step to the minimum load value specified in the contract. Operate the sets at this load condition for a minimum of 30 seconds. (If the contract limits the transient load value, use the specified value). Read and record all load instrumentation readings and mark the recording charts.

1. In one step, reapply the system rated load in k above and operate the sets at this load condition for a minimum of 30 seconds. Read and record all load instrumentation readings and mark the data or recording charts.

m. Repeat steps k and l above two additional times; then reduce the system load to the minimum specified value.

n. On sets having a reverse power protective device, slowly adjust the frequency adjust device on one of the sets in such a manner as to increase the load on that set until the circuit interrupter on the other set opens or the specified value of reverse power is exceeded. Read and record the value of reverse power at which the circuit interrupter opens or record that the specified value of reverse power was attained without the circuit interrupter opening.
(Note and record the indication of the malfunction indicator as applicable).

o. Resynchronize the sets, parallel them again and repeat step n above using the other set.

p. On sets having permissive paralleling provisions, close the circuit interrupter on one of the sets and slowly adjust the frequency of the other set until the synchronizing lights simultaneously brighten and go dark in approximately 5 second intervals. At the onset of their peak brightness, momentarily close the circuit interrupter on the set. Record whether or not the circuit interrupter actually closed.

q. Repeat step p above except hold the circuit interrupter actuating switch closed until the circuit interrupter actually closes. Record whether or not the circuit interrupters on either set opened and any indication of the malfunction indicator, as applicable.

r. Repeat steps p and q above using the other set.

s. Repeat steps a thru r above for each of the other voltage connections and frequencies specified in the contract.

89.4 Results.

89.4.1 Active power division.

a. Using the individual set load instrumentation data, determine the kilowatt output for each set, in percent of its nameplate rating, at each load condition. This is the active power division for each set.

b. Determine the difference in the percentage of kilowatt load carried by each set by subtracting the values calculated in step a at each of the load conditions.

89.4.2 Active power exchange.

a. From the waveforms, determine at each load condition the maximum and minimum values of active power carried by one set.

b. Subtract the minimum value from the maximum value, divide by the nameplate rating of the set and multiply by 100. This is the active power exchange in percent of the nameplate rating of the individual set.

89.4.3 Reactive power division.

a. Using the individual set load instrumentation data, determine the KVAR output for each set at each load condition. This is the reactive power division for each set.

b. Determine the difference in the reactive power by subtracting the values calculated in step a above for each load condition. Divide the remainder by the individual set's KVAR rating. This is the percent unbalance in the reactive power division.

89.4.4 Load current pulsation.

a. From the waveforms, determine at each load condition the maximum and minimum values of load current carried by one set.

b. Subtract the minimum value from the maximum value, divide by the nameplate current rating of the set and multiply by 100. This is the load current pulsation in percent of the nameplate rating of the individual set.

89.4.5 Voltage and frequency stability and transient response.

a. From the recording charts, determine the voltage and frequency stability bandwidths for each load condition of 89.3.1, steps h and i. Refer to Test Method 78.

b. For each of the load transients performed in 89.3.2, steps h and m, determine the following (refer to Test Method 77):

1. Recovery times.
2. The overshoot.
3. The undershoot.
4. The regulation for voltage and frequency.

89.4.6 Compare these results with the requirements of the contract.

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

a. Voltage connection(s) and frequency(ies) at which the method is to be performed.

b. Minimum and maximum system load values.

c. Voltage and frequency droop control settings at which this method is to be performed, if applicable.

d. Maximum load transient, if other than specified in this method.

e. Active (kilowatt) power difference allowed, in percent of individual set rating.

f. Reactive power difference allowed, in percent of individual set rating.

g. Maximum active power exchange allowed, in percent of individual set rating.

h. Maximum load current pulsation exchange in percent of individual set rating, if applicable.

i. Maximum value of reverse power at which the circuit interrupter is to operate

if applicable.

j. Malfunction indicator requirements, if applicable.

k. Maximum allowable long-term voltage stability bandwidth or deviation in percent of rated voltage.

1. Maximum allowable long-term frequency stability bandwidth or deviation in percent of rated frequency.

m. Maximum allowable short-term voltage stability bandwidth or deviation in percent of rated voltage.

n. Maximum allowable short-term frequency stability bandwidth or deviation in percent of rated frequency.

o. Maximum allowable voltage time.

p. Maximum allowable frequency recovery time.

q. Maximum allowable voltage overshoot and undershoot, if applicable.

r. Maximum allowable frequency overshoot and undershoot.

s. Maximum allowable voltage regulation.

t. Maximum allowable frequency regulation.

TEST METHOD 90

MAXIMUM POWER TEST
(FOR GASOLINE AND DIESEL GENERATOR SETS)

90.1 General. The maximum power of a generator set is a function of the ambient conditions (temperature and altitude) and the mechanical condition of the engine at any particular time.

90.2 Apparatus. Instrumentation of measuring load conditions and temperatures shall be as described in EGSA 107T .

90.3 Procedure.

CAUTION: This procedure subjects the generator set to a severe overload which may be damaging if maintained for too long a period of time.

90.3.1 Preparation for test.

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

b. Install appropriate thermocouples to measure the following temperatures.

(**NOTE**: Not all sets will require instrumentation of all of the listed items. The list contains items normally instrumented. However, some sets may required additional thermal instrumentation).

1. Engine coolant (engine inlet and outlet).
2. Spark plug(s).
3. Exhaust gas(es) [the exhaust manifold(s) shall be drilled and tapped as close as possible to the combustion chamber(s).]
4. Lubricating oil sump.
5. Engine combustion air in (located at the inlet of the intake manifold).

c. Obtain and record the barometric and water vapor pressures.

d. On generator sets having more than one power output system; e.g. high voltage ac and low voltage dc (disregard the battery charging system) or two ac systems of different frequencies, maintain the system with the lowest power rating at rated load for all parts of this test. The load in the system with the highest power rating is then varied as indicated below to determine the maximum power of the set.

e. Bypass the set circuit interrupter if required.

f. Connect the set to a source of fuel containing a specified fuel required by the requirement document.

90.3.2 Test. Start and operate the generator set and allow the set to stabilize at rated load, rated voltage and rated frequency (speed). During this period, readings of all instruments including thermal instrumentation shall be recorded at minimum intervals of 10 minutes. If necessary, adjustments to the load, voltage and frequency may be made to maintain rated load at rated voltage and frequency. However, adjustments to the voltage and frequency shall be limited to those adjustments available to the operator, specifically adjustments to the voltage or frequency adjust devices. On generator sets utilizing a droop-type speed control system as the prime speed control, the speed and droop portions of the control may be adjusted. No other adjustments to the voltage and frequency control systems shall be made unless permitted by the contract. Adjustments to load, voltage or frequency controls shall be recorded on both the data sheet and the recording equipment 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 to the load, voltage or frequency has been made. Refer to figure 90 -I. If this test is performed immediately following another test which has established stabilization values, stabilization will be considered valid once all the previously established values and operating parameters are obtained (initial stabilization readings therefore must include all values needed for subsequent testing).

NOTE: Operation of the set must not be interrupted between this test and the test that established stabilization values.

b. Performed this test using resistive load only (on ac sets remove reactive load after stabilization).

c. For sets with droop-type governors (except turbocharged engine-driven generator sets):

1. Alternately increase the load, voltage and frequency in small increments until the fuel system controls are in the maximum fuel position as permitted by the governor control linkage and the voltage and frequency are within 1percent of their rated values. The maximum load should not exceed more than 2 percent above the specified maximum power requirement.

(**NOTE**: Small increments should be taken to avoid passing the maximum power at the rated voltage and frequency point and to avoid racing or bogging the engine).

2. Hold the conditions in step 1 above for two minutes. However, if the voltage and frequency cannot be maintained within 1 percent of their rated values, the load must be adjusted to the point at which the voltage and frequency can be maintained within 1 percent of their rated values for two minutes.

CAUTION: It may be necessary to reduce the load to a value below the rated kilowatt load for a short period of time to prevent serious overheating or damage to the generator set if the above conditions cannot be readily attained. (Monitor instrumentation).

3. During the two minute period record all instrument readings including thermal instrumentation. (On 3-phase sets it is not necessary to record line-to-line voltages).

4. Reduce the load to rated kilowatt load at unity power factor and allow the generator set to cool for 10 minutes.
5. Repeat steps 1 thru 4 above until three valid sets of maximum power data are obtained.

d. For set with isochronous-type governors (except for turbocharged engine-driven generator sets), perform step c above but do not adjust the frequency.

e. For turbocharged engine-driven generator sets with droop-type governors:

1. Load the set to 125 percent of rated load unless otherwise specified in the contract. Adjust the frequency to the rated value and maintain the load for 5 minutes unless otherwise specified in the contract.

2. Record all instrument readings including thermal instrumentation.

f. For turbocharged engine-driven generator sets with isochronous-type governors, perform step e above but do not adjust the frequency.

g. Repeat steps a thru f above as applicable in the contract.

90.3.3 Repeat procedure. Repeat 90.3 for all fuels specified in the contract.

90.3.4 Results.

a. Average the three valid maximum power readings for each load, voltage, frequency and fuel condition. This average is the observed maximum power value.

b. Except when performed as part of method 720.1, the Altitude Operation Test; if the requirement document specified a corrected value for maximum power then correct the observed maximum power value to standard conditions using the procedures in EGSA 107T , Test Method 20, paragraph 20.2.3. This is the corrected maximum power value.

(**NOTE**: The observed maximum power value for supercharged engine-driven generator sets, including turbocharged engines, is not to be corrected to standard conditions). Compare these results with the requirements of the contract.

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

a. Minimum value of maximum power required. (For turbocharged engine-driven generator sets: The value of load and length of time the set is to be operated at this load if other than specified herein).

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

c. Fuel(s) to be used in performing this method, if applicable..