METHOD 71

REVERSE BATTERY POLARITY TEST

71.1 General. Batteries are items that are normally installed in the field since they are shipped dry and must be activated before use in the generator set. Little control is available over the installation of the set batteries or the connection of slave batteries, therefore it is important that a mistake in the battery connections will not cause damage to the generator set.

71.2 Apparatus. A slave battery cable and slave batteries of the proper voltage and size to start the set shall be required.

71.3 Procedure.

a. With the set batteries installed in their normal operating position in accordance with the instructions on the set or in the technical manual, start and operate the generator set at rated voltage, rated frequency (speed) and no load for a period of 5 minutes. The set instruments will be sufficient to indicate voltage and frequency.

b. After the 5 minute operation, shut the set down. Reverse the polarity of the set batteries and attempt to start the set following the instructions on the set or in the technical manual. Record the results of the starting attempt on the data sheet (see figure 71-I).

c. Open the control panel and visually check for damage to any component. Record observations on the data sheet. Replace fuse, if applicable.

d. Record operation of reverse polarity malfunction indicator, if so equipped.

e. Correct the polarity of the set batteries and attempt to start the set in accordance with the instructions on the set on the data sheet.

f. If the generator set is equipped with a battery slave receptacle, disconnect the set batteries and using a slave cable and slave batteries, repeat steps a thru d above.

g. Perform any other checks as specified in the contract.

71.4 Results. Compare the operation or non-operation of the generator set with the requirements of the contract.

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

a. The requirements of the reverse battery polarity protection.

b. Any additional checks on the battery polarity other than those specified in 71.3.

c. Reverse polarity malfunction indicator requirements, if applicable.

TEST METHOD 72

PARALLELING AID DEVICE TEST

72.1 General. The paralleling aid device is designed to prevent the paralleling of a generator set with another generator set or operating system unless the voltage and phase relations are within certain limits to prevent damage to either the generator set or the system.

72.1.2 Apparatus. Instrumentation for measuring load conditions of the generator set acting as the system, and voltage and frequency of the generator set to be paralleled, shall be as described in EGSA 107T. In addition, a synchroscope or phase relationship indicating equipment as described in EGSA 107T, Test Method 17, to detect the phase relationship between the system and the generator set, shall be required.

72.3 Procedure. The generator set acting as the "system" shall be designated as set No. 1. The generator set with the paralleling aid device under test shall be designated as set No. 2.

72.3.1 Preparation for test.

a. Connect the load and instrumentation to set No. 1 for a voltage connection and frequency specified in the contract.

b. Connect the voltage and frequency sensing instruments to the line side of the circuit interrupter of set No. 2 for the same voltage connection and frequency used in step a above.

c. Connect the output terminals of set No. 2 to the output terminals of set No. 1 with the correct phase relationship (L1-L1; L2-L2; L3-L3; L0-L0).

d. Connect the synchroscope, or phase relation indicating equipment, in accordance with the manufacturer's instructions in such a manner that the same phase voltage of each set (No. 1 and No. 2) is sensed and the phase difference, in degrees, can be readily determined.

72.3.2 Test.

a. Start and operate set No. 1 at rated voltage, rated frequency and rated load.

b. Start and operate set No. 2 with the frequency difference between the two sets within the limits specified in the contract for the paralleling aid device to activate and with The Kellough Group, Inc. voltage 10 percent below the voltage of set No. 1.

c. With the operator selector switch of set No. 2 in the "Parallel Operation" position, slowly raise the voltage of set No. 2. Record the voltage of both sets and the phase difference in degrees at the time the sets are paralleled.

d. Repeat steps b and c above with the operator selector switch in the "Single Unit Operation" position and the circuit interrupter control switch held in the "closed" position.

e. Repeat steps b and c above except that the voltage of set No. 2 shall be 10 percent above the voltage of set No. 1 and the voltage of set No. 2 shall be slowly lowered.

f. Repeat step e above with the operator selector switch in the "Single Unit Operation" position and the circuit interrupter control switch held in the "closed" position.

g. Operate set No. 2 such that the voltage difference between the two sets is within the limits specified in the contract for the paralleling aid device to activate and the frequency is 2.5 percent below the frequency of set No. 1.

h. With the operator selector switch of set No. 2 in the "Parallel Operation" position, slowly raise the frequency of set No. 2. Record the frequency of both sets and the phase difference in degrees just prior to the time the sets are paralleled.

i. Repeat steps g and h above with the operator selector switch in the "Single Unit Operation" position and the circuit interrupter control switch held in the "closed" position.

j. Repeat steps g and h above except that the frequency of set No. 2 shall be 2.5 percent above the frequency of set No. 1 and the voltage of set No. 2 shall be slowly lowered.

k. Repeat step j above with the operator selector switch in the "Single Unit Operation" position and the circuit interrupter control switch held in the "closed" position.

1. Shut down set No. 1. With set No. 2 operator selector switch in the "Parallel Operation" position, record the operation of set No. 2's circuit interrupter.

m. Repeat steps a thru 1 above for any other voltage connection(s) and frequency(ies) specified in the contract.

72.4 Results. Compare the parallel and device activation readings with the limits as specified in the contract.

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

a. Voltage tolerance in percent of rated voltage beyond which the paralleling aid device must not permit paralleling.

b. Frequency tolerance in percent of rated frequency beyond which the paralleling aid device must not permit paralleling.

c. Phase angle tolerance in degrees beyond which the paralleling aid device must not permit paralleling.

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

METHOD 73

VOLTAGE WAVEFORM TEST

73.1 General. Voltage waveform is the value of voltage as a function of time. A graphic representation of a voltage waveform may be obtained using an oscillograph.

Generally, the voltage waveform produced by alternating-current generators is approximately sinusoidal; however, since the design of generators varies, the voltage waveform also varies or deviates differently for each generator design. The term deviation factor is used to describe the maximum deviation of a generator voltage waveform from that of a true sine wave. The deviation factor of a wave is defined as the ratio of the maximum difference between corresponding ordinates of the wave and the equivalent true sine wave to the peak value of the equivalent true sine wave when the two waves are superposed in such a manner as to make this maximum difference as small as possible.

Since some equipment powered by a generator set may not function properly if the voltage waveform deviates too much from a true sine wave, it is important that the deviation factor be maintained within practical limits.

73.2 Apparatus. Instrumentation for measuring load conditions shall be as described in EGSA 107T . In addition, a data acquisition instrument or system capable of digitizing, storing, and displaying one cycle of the voltage waveform in an x-y format will also be required. Data acquisition instruments are described in EGSA 107T , Test Method 6. Also a noninductive voltage divider may be required to reduce the generator line voltage to a voltage compatible with the instrumentation input.

73.3 Procedure.

73.3.1 Preparation for test. Connect the load and instrumentation, following the data acquisition instrument manufacturer's instructions, and the instructions given in this method for one voltage connection and frequency specified in the contract.

73.3.2 Test.

a. Connect the voltage waveform measuring system to one of the line connections (L1-L2, L1-L0, etc.) specified in the contract.

c. Start and operate the generator set at one of the load conditions specified in the contract.

d. Adjust the peak-to-peak amplitude of the voltage trace to a minimum of 4 inches (approximately 10 centimeters).

e. Adjust the test recording equipment such that the per cycle time base of the voltage trace is a minimum of 4 inches (approximately 10 centimeters).

f. After the conditions of steps d and e above have been obtained, stored the voltage waveform.

g. Read and record the load instrumentation, line connection and waveform number (see figure 73-I).

h. Repeat steps b thru g above for each of the other line connections specified in the contract.

i. Repeat steps b thru h above for each of the other voltage connections, frequencies, and load conditions specified in the contract.

73.4 Results.

a. The equivalent sine wave shall be determined by the following method (see figures 73-II and 73-III):

1. Construct the zero potential line of the voltage trace midway between the positive and negative peaks, being careful to use the center of the trace width.

2. Using one complete cycle of the trace, divide the zero potential line into at least 36 equal parts beginning and ending at the points where the trace crosses the zero potential line.

3. Construct line (ordinates) perpendicular to the zero potential line at each of the points established in step 2 above.

4. Measure the length of each ordinate from the zero potential line to the center of the trace width, to the nearest millimeter.

5. Square each measured ordinate and sum the squares. Divide this sum by the total number of equal parts.

6. Take the square root of the value obtained in step 5 above and multiply this value by the square root of 2.

7. Using the value obtained in step 6 above as the peak value of the equivalent sine wave, calculate the lengths of the remaining ordinates using the sine of the electrical degree angles at each of the remaining points established in step 2 above.

8. Construct the equivalent sine wave with a time base equal to the complete cycle of the generator voltage waveform trace used in step 2 above. This construction must be on a separate sheet of paper in order to proceed with part b below.

b. Comparison of waves:

1. Superpose the complete cycle used in 73.4a.2 over the equivalent sine wave constructed in 73.4a.8 so that the maximum vertical difference between the two traces is as small as possible. Accomplish this by shifting one trace with respect to the other, keeping the zero potential lines of the two traces superposed.

2. Determine, to the nearest 0.25 millimeter, the maximum vertical difference between the two traces.

3. Divide the result of step 2 above by the peak value obtained in 73.4a.6, then multiply by 100. This is the deviation factor of the generator waveform, in percent.

c. Compare the deviation factor determined in 73.4b.3 above with the requirement of the contract.

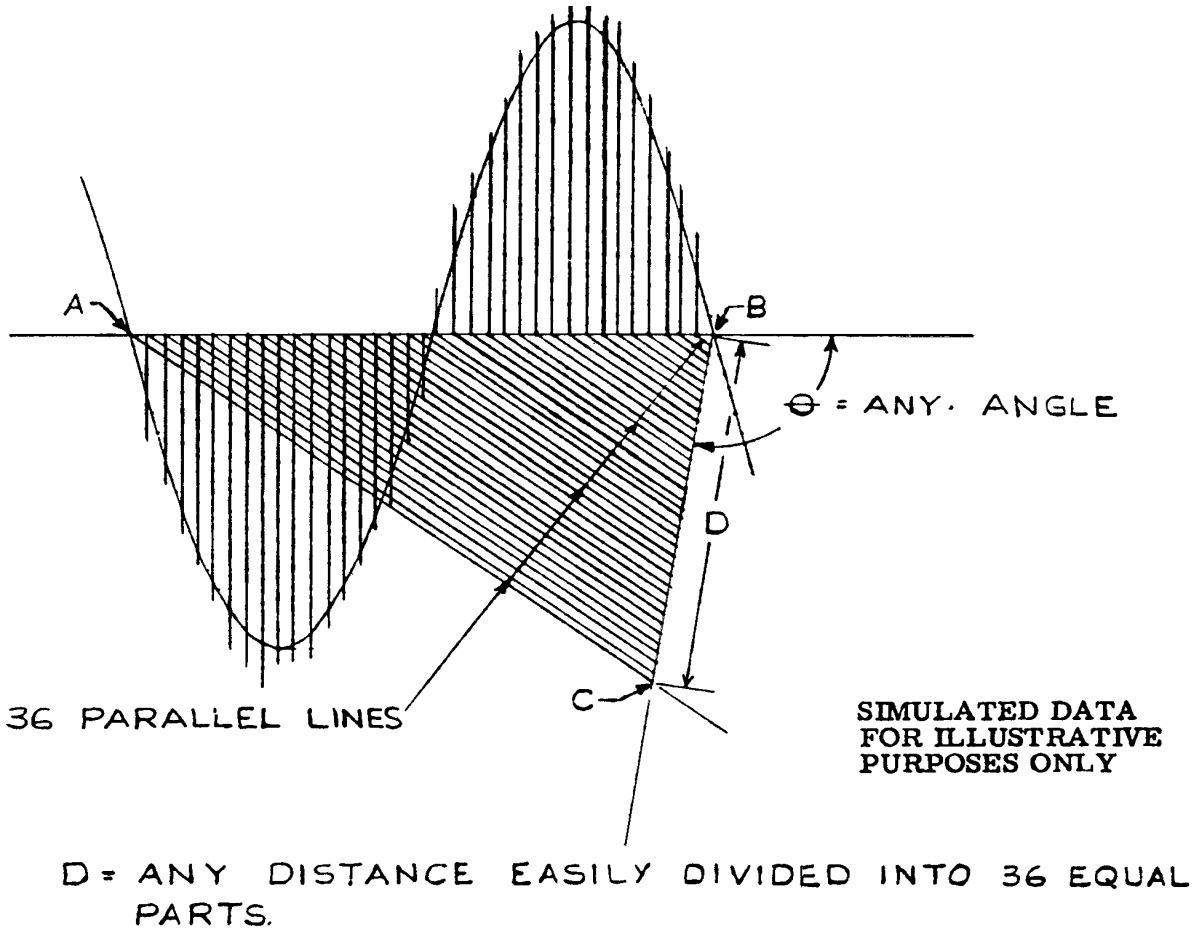
73.5 Contract requirements. The following items must be specified in the individual contract:

a. Maximum allowable deviation factor.

b. Load conditions at which this method is to be performed.

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

d. Line connections (L1-L2, Ll-L0, etc.) for which this method is to be performed.



NOTES:

1. (A) is the intersection of the zero potential line with the voltage trace and shall be the start of the complete cycle.
2. (B) is the second intersection of the zero potential line with the voltage trace counting from (A) and shall be the end of the complete cycle.
3. (C) is 36 equal distances from (B) along any line starting at (B).
4. Line A-C is the direction of the 36 parallel lines dividing the zero potential line into 36 parts. These lines start at each of the 36 equal divisions of line B-C

FIGURE 73-II. TYPICAL CHART OF A VOLTAGE WAVEFORM (NOT TO SCALE)

ORDINATE NO.	ORDINATE LENGTH (mm)	ORDINATE SQUARED $(mm)^2$	ANGLE ELECTRICAL DEGREES	SINE OF ANGLE	ORDINATE LENGTH EQUIV. SINE WAVE
0	0	0	0	0	0
1	10	100	10	0.174	9
2	20	400	20	0.342	18
3	29	841	30	0.500	26
4	35	1225	40	0.643	34
5	41	1681	50	0.766	40
6	45	2025	60	0.866	45
7	49	2401	70	0.940	49
8	51	2601	80	0.985	51.5
9	52	2704	90	1.000	52
10	51	2601	100	0.985	51.5
11	50	2500	110	0.940	49
12	46	2116	120	0.866	45
13	42	1764	130	0.766	40
14	37	1369	140	0.643	34
15	30	900	150	0.500	26
16	23	529	160	0.342	18
17	15	225	170	0.174	9
18	6	36	180	0	0
19	- 2	4	190	-0.174	- 9
20	-12	144	200	-0.342	-18
21	-21	441	210	-0.500	-26
22	-31	961	220	-0.643	-34
23	-37	1369	230	-0.766	-40
24	-42	1764	240	-0.866	-45
25	-47	2209	250	-0.940	-49
26	-50	2500	260	-0.985	-51.5
27	-52	2704	270	-1.000	-52
28	-51	2601	280	-0.985	-51.5
29	-50	2500	290	-0.940	-49
30	-46	2116	300	-0.866	-45
31	-41	1681	310	-0.766	-40
32	-35	1225	320	-0.643	-34
33	-26	676	330	-0.500	-26
34	-19	361	340	-0.342	-18
35	-10	100	350	-0.174	- 9
36	0	0	360	0	0
	TOTAL	49,374			

SIMULATED DATA FOR ILLUSTRATIVE PURPOSES ONLY

Peak Value of Equiv. Sine Wave = $\sqrt{\frac{49,374}{36}} \times \sqrt{2}$

= 52 mm

Typical Equivalent Sine Wave Ordinate Calculation:
Ordinate at 10 Degrees = Sine 10° x 52 (Peak value of equiv. sine wave)
= 0.174 x 52 = 9 mm

FIGURE 73-III. SAMPLE CALCULATION OF EQUIVALENT SINE WAVE

TEST METHOD 74

VOLTAGE WAVEFORM TEST

(HARMONIC ANALYSIS)

74.1 General. The voltage waveform of a generator set may be analyzed by determining the magnitude of the specific frequency components, other than the fundamental, contained in the waveform. The method of analysis is called harmonic analysis. A harmonic is defined as a frequency component whose frequency is an integral multiple of the fundamental frequency of the waveform.

74.2 Apparatus. Instrumentation for measuring load conditions shall be as described in EGSA 107T. In addition, a waveform analyzer (or similar test recording equipment) and digital oscilloscope as described in EGSA 107T, Test Method 6 (unless otherwise specified in the contract) will also be required.

74.3 Procedure.

74.3.1 Preparation for test.

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

b. Connect the waveform analyzer (or similar test recording equipment) and digital oscilloscope signal inputs directly to the generator set output terminals, for one of the line connections (L1-L2, L1-L0, etc.) specified in the contract.

NOTE: If the generator set output voltage magnitude will be greater than the voltage input ratings of either the waveform analyzer (or similar test recording equipment) or digital oscilloscope, use a voltage divider of noninductive-resistive components to lower the input voltage such that it is compatible with the signal input voltage ratings of the waveform analyzer (or similar test Recording equipment) or digital oscilloscope. For the digital oscilloscope, a probe may be used but care must be exercised to insure that it is properly adjusted in accordance with the manufacturer's instructions.

74.3.2 Test.

a. Start and operate the generator set at rated voltage, rated frequency, and at one of the load conditions specified in the contract.

b. Operate the waveform analyzer (or similar test recording equipment) in accordance with the manufacturer's instructions and read and record, as a percentage of the fundamental, the magnitude of each harmonic in excess of 0.05 percent. On preproduction generator

sets, read and record all the harmonics thru the 50th, fractional order harmonics and slot harmonics. Scan the frequencies thru 50 kHz, noting and recording any harmonics greater than 0.05 percent. On production generator sets, read and record the harmonics thru the 20th.

NOTE: The calibration of the waveform analyzer must be checked, using the internal calibrator, before proceeding to the next condition (e.g. load condition, line connection, etc.).

c. Adjust the voltage trace on the digital oscilloscope screen such that the complete cycle of the voltage covers approximately both the full vertical and full horizontal dimensions of the graduated portion of the viewing screen. The digital oscilloscope controls need not be in their calibrated position unless measurements of discontinuities in the waveform are desired.

d. With the digital oscilloscope adjusted as in step c above, store or save the voltage waveform.

e. Repeat 74.3 for each of the other load conditions, line connections, voltage conditions and frequencies specified in the contract.

74.4 Results. The data sheet (see figure 74-I) shall show in addition to the load instrumentation readings, the values of the harmonics in percent of the fundamental for each line connection, load condition, voltage connection and frequency. Compare these results with the requirements of the contract.

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

a. Maximum allowable value of a single harmonic, in percent of the fundamental.

b. Line connection(s) at which this method is to be performed.

c. Load conditions(s) at which this method is to be performed.

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

e. Discontinuities in the voltage waveform allowed, if any.

TEST METHOD 75

VOLTAGE WAVEFORM TEST (DEVIATION FACTOR)

75.1 General. Voltage waveform is the value of voltage as a function of time. The deviation factor of a wave is the ratio of the maximum difference between corresponding ordinates of the wave and of the equivalent sine wave to the maximum ordinate of the equivalent sine wave when the waves are superposed in such a way as to make this maximum difference as small as possible. Since some equipment powered by a generator set may not function properly if the voltage waveform deviates too much from a true sine wave, the deviation factor must be maintained within practical limits.

75.2 Apparatus. Instrumentation for measuring load conditions shall be as described in EGSA 107T. In addition, a data acquisition instrument or system capable of digitizing, storing, and displaying one cycle of the voltage waveform in an x-y format will also be required. Data acquisition instruments are described in EGSA 107T , Test Method 6. Also a noninductive voltage divider may be required to reduce the generator line voltage to a voltage compatible with the instrumentation input.

753 Procedure.

75.3.1 Preparation of test. Connect the load and instrumentation, following the data acquisition instrument manufacturer's instructions, and the instructions contained herein for one voltage connection and frequency specified in the contract.

75.3.2 Test.

75.3.2.1 Waveform acquisition.

CAUTION: Some digital equipment may have single-ended inputs; that is, one input load is connected to the chassis ground. This chassis ground is electrically the same as "House Power" ground and the engine generators utilized during this test may have their neutral tied to earth ground. This condition presents no problem for phase-to-neutral (L-N) voltage waveform measurements. For phase-to-phase (L1-L2,L2-L3, etc.) measurements however, it may be necessary to "float" the instrument (Lift the chassis ground). A phase-to-phase noninductive voltage divider may be used to reduce the signal voltage to the instrument.

a. Connect the voltage waveform deviation measurement system to one of the line connections (L1-L2, L1-L0, etc.) specified in the contract.

b. Start and operate the generator set at one of the load conditions specified in the contract. Read and record load instrumentation, line connection and voltage connection on the data sheet. (See figure 75-I).

d. Store the sampled waveform in memory.

e. Record the voltage waveform in an x-y format. An image of an oscilloscope display of each sample waveform or an x-y presentation shall be supplied for record purpose.

f. From the stored digital waveform data, analyze the waveform for deviation from a true sine wave. If the data acquisition system has the capability of storing the data on magnetic tape, the waveform analysis may be performed after all waveform samples are obtained.

g. Repeat steps a through f for each of the other line connections, load conditions, voltage outputs, and frequencies specified in the contract. Once the waveform is digitized, the waveform deviation should be processed by calculator or computer on a numerical basis.

75.3.2.2 Waveform analysis. The mathematical data reduction techniques described herein require the accurate shifting of the theoretical sine wave in 0.25 degree increments. Therefore, the shifting operation should be performed on a numerical basis utilizing a computer or a programmable calculator.

a. From the recorded waveform, establish the zero potential line midway between the positive and negative peaks of the voltage waveform.

b. Divide the zero potential line into at least 36 parts for 1 complete waveform.

c. Determine the voltage waveform amplitude at each of these points.

d. Square each value in step c and sum the squares. Divide this sum by the total number of sample points used in step b.

e. Take the square root of the value obtained in step d and multiply this value by the square root of two.

f. Using the value obtained in step e as the peak value of the equivalent sine wave, calculate the lengths of the remaining ordinates using the sine of the electrical degree angles at each of the remaining points established in step b above.

g. Compare sample waveform actual values versus theoretical values.

h. Determine the maximum difference at each ordinate.

i. Divide the results of step h above by the peak value obtained in step e above. This is the deviation factor.

j. Shift the ordinates established in step f above by a maximum of +0.25 degrees steps. Recalculate the amplitude of these ordinates.

k. Repeat steps h, i, and j until the deviation factor is minimized. This is the deviation factor of the generator in percent. Record the deviation factor on the data sheet.

1. Compare the minimum deviation factor determined in step k above with the requirements of the contract.

75.4 Results. The data required from this test shall include:

a. Data sheet showing line connection, load instrument readings, frequency, etc. (figure 75-I).

b. x-y graph presentation of each sample generator waveform for each line connection, load condition, voltage connection and frequency specified in the contract.

c. Maximum deviation in percent from a true sine wave.

d. An equipment list showing all load measuring equipment, data acquisition system components, and data analysis equipment utilized.

e. Data analysis program utilized. For example, if a computer based data reduction system is used, the computer program listing shall be supplied.

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

a. Maximum allowable deviation factor.

b. Load conditions at which this method is to be performed.

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

d. Line connections (L1-L2, L1-L0, etc.) for which this method is to be performed.

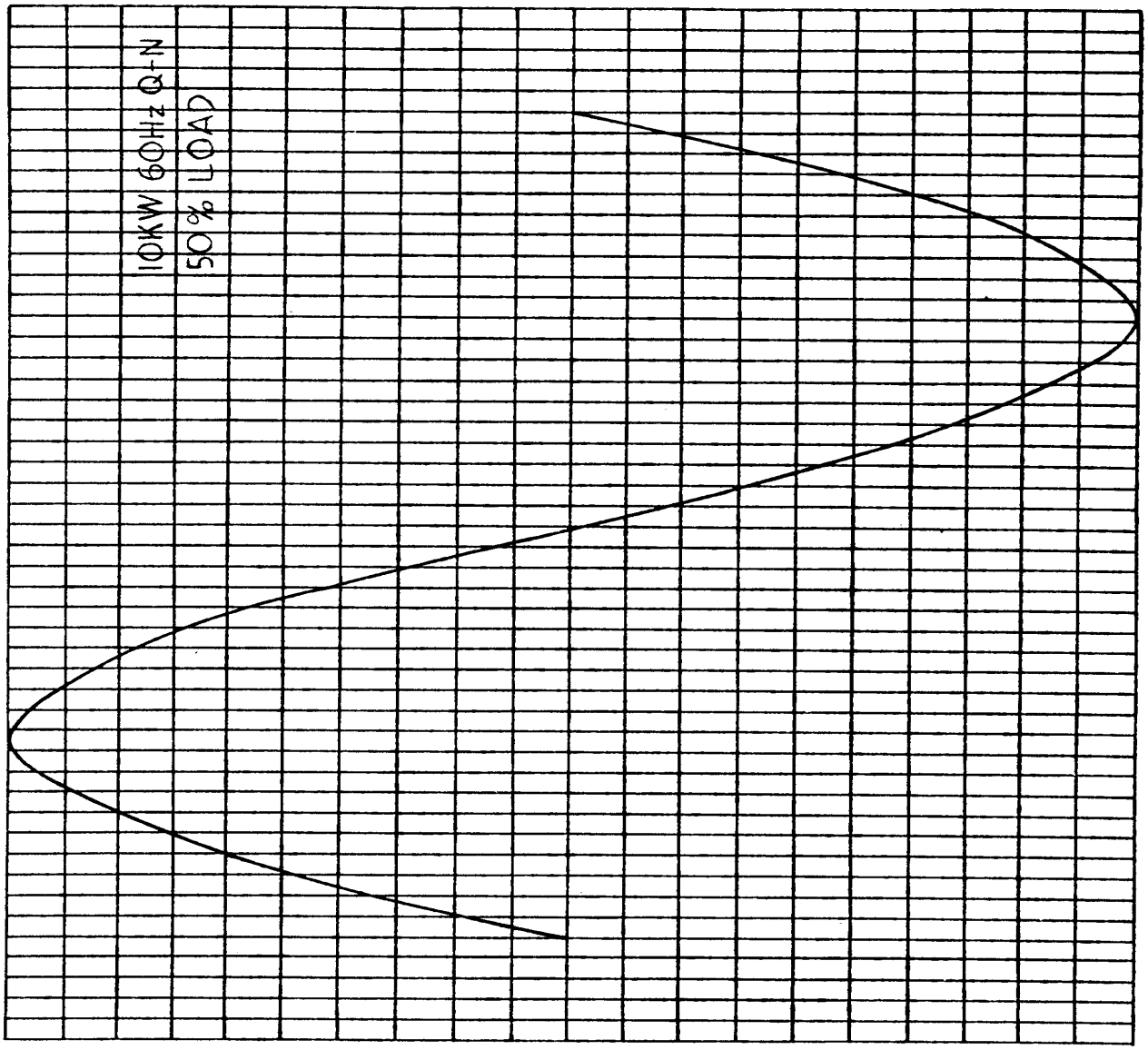


FIGURE 75-II. Typical x-y graph of voltage waveform.

TEST METHOD 76

VOLTAGE MODULATION TEST

76.1 General. If the peak value of a voltage wave is not constant but varies with time, the wave is considered to be voltage modulated. In many cases, the rate at which the peak value varies is so rapid or the magnitude of variation so small that the modulation cannot be detected by observation of a voltmeter. Voltage modulation can affect the operation of the generator set as well as some types of electrical equipment.

76.2 Apparatus. Instrumentation for measuring load conditions shall be as described in EGSA 107T . In addition, a fast writing digital oscilloscope having a flat bandwidth of dc to 5 MHz, minimum, and single sweep features equipped with a centimeter marked graticule. The circuit illustrated in figure 76-I will also be required. The two zener diodes CR 1 and CR 2 are a matched pair with nominal rating of 170 volts; zener voltage of the two diodes shall be determined by test and shall not differ by more than 0.3 volts. A continuously variable autotransformer and isolation transformers will be needed. The continuously variable autotransformer shall be selected such that the following will apply:

a. There will be negligible saturation of the magnetic circuits. To achieve this requirement, the autotransformer rated input voltage shall be at least 125 percent of the maximum voltage which will be applied to its input terminals during this test.

b. The distortion of the output shall not be more than 0.5 percent higher than at the input.

c. The winding resistance will be not greater than 50 ohms.

The same requirements shall apply for the isolation transformers at the input voltages indicated in figure 76-II.

76.3 Procedure.

76.3.1 Preparation for test.

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

b. Operate the set at rated frequency and voltage at no load.

c. Connect the specific voltage(s) to be tested to the modulation test box as shown in figure 76-II. The voltmeter shown shall be a rms indicating meter in accordance with EGSA 107T , Test Method 1.

d. Compensate the digital oscilloscope probe in accordance with the manufacturer's instructions.

e. Verify the accuracy and frequency response of the digital oscilloscope by inserting a square wave signal of known value into the probe. Check all calibrated ranges to be used in this test.

76.3.2 Test.

a. With rated voltage at the generator output and with the digital oscilloscope vertical gain control set to measure at least 2.0 volts/cm, adjust the autotransformer such that the zener voltage is exceeded slightly and a display is seen on the screen of the digital oscilloscope. Adjust the horizontal sweep until approximately six voltage peaks per centimeter appear. Adjust the autotransformer output voltage until the smallest voltage peaks are a minimum of 0.5 volts above or below zero voltage. This minimum voltage level must be maintained for all of the readings. Increase the scope vertical gain (using the calibrated positions of the gain selector switch) to the maximum possible without causing any peak to go off the screen. Adjust vertical position of the display, if necessary, to help obtain this condition. The display will then be similar to figure 76-III.

b. Record the digital oscilloscope display with the digital oscilloscope in its single sweep mode. Record the reading of the voltmeter at the input to the test circuit, the digital oscilloscope gain and sweep calibration, the probe multiplier, and the load instrumentation.

c. Repeat a and b above, for each of the conditions specified in the contract.

76.4 Results.

a. Examine the positive peaks on each digital oscilloscope stored waveforms and determine from the centimeter graticule scale the difference in deflection of the highest and lowest peaks; convert this deflection to volts by multiplying by the volts/cm calibration of the digital oscilloscope vertical gain selector (taking into account the probe multiplier); designated as Vp. Calculate voltage modulation as follows:

$$\text{Percent modulation} = \frac{Vp}{V \nearrow 2} \times 100$$

Where V is the reading of voltmeter shown in figure 76-II.

b. Repeat 76.4.a for the negative peaks on the picture.

c. Select the larger of the values obtained from 76.4.a and b. This larger value is the voltage modulation for the particular conditions tested.

d. Determine on each of the oscilloscope stored waveforms if any repetitive pattern is present in the positive or negative peak pattern and the number of positive or negative peaks between the repetition if it exists. Divide this number into the frequency meter reading at the time the waveform was taken. This value is the frequency of the modulation in the picture examined.

e. Compare the results with requirements of the contract.

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

a. Allowable voltage modulation.

b. Frequency limitations (if any) on modulation.

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

d. Load conditions at which this method is to be performed.

e. Individual generator coils to be tested, if required.

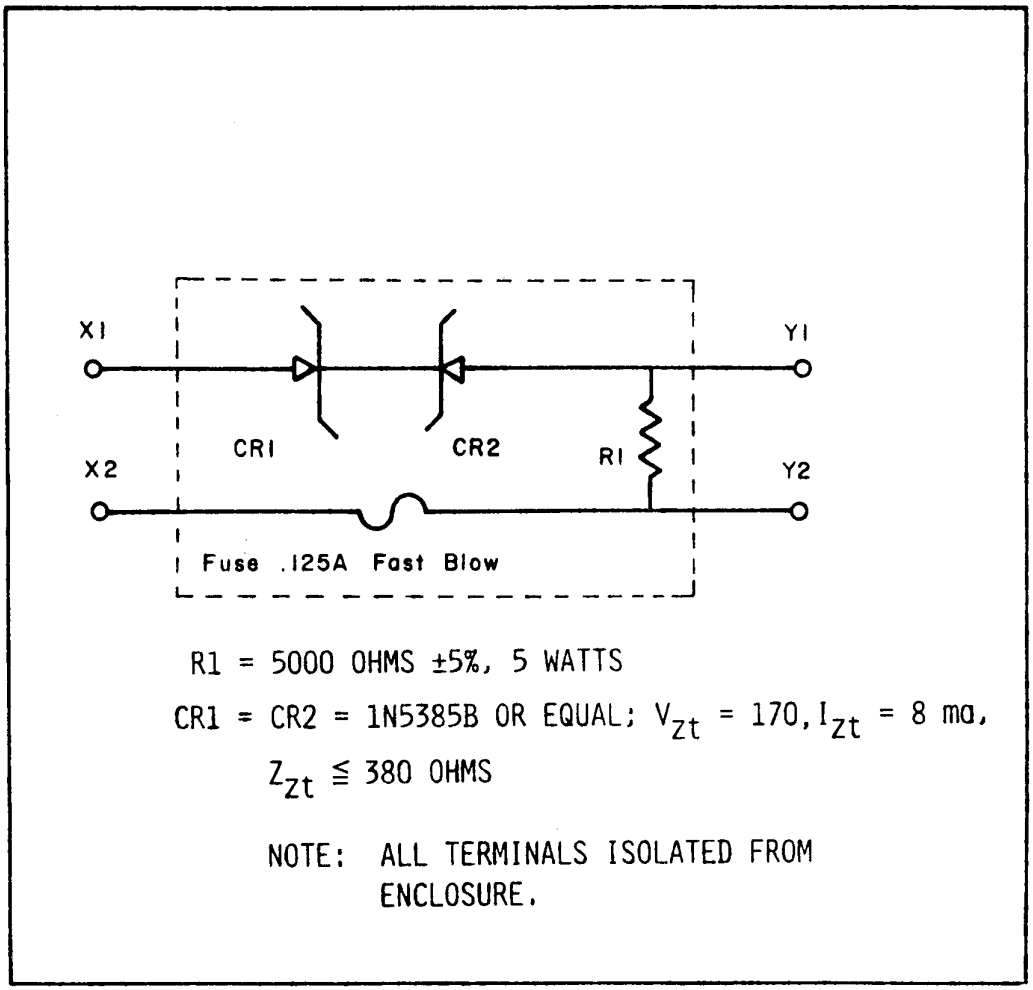
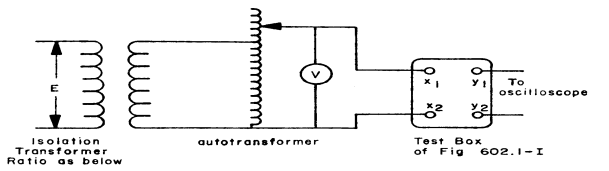


FIGURE 76-I. Schematic Diagram Of The Voltage Modulation Test Box.



E = GENERATOR LINE TO LINE, LINE TO NEUTRAL OR COIL OUTPUT
V = VOLTMETER

E	ISOLATION TRANSFORMER RATIO
120	1:1
208-240	2:1
416	4:1
2400	20:1
4160	40:1

Figure 76-Ii. Voltage Modulation Test Connection Diagram.

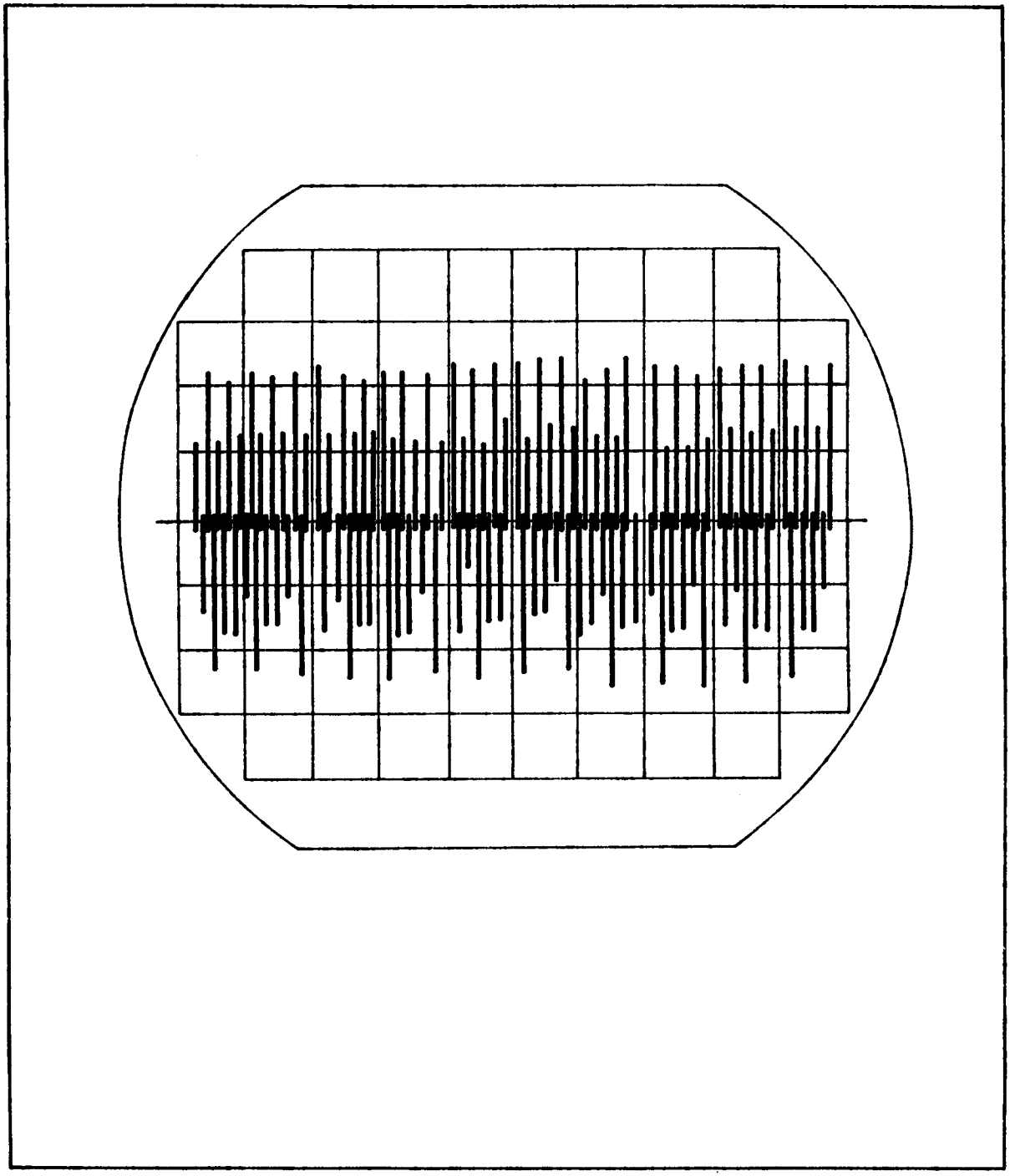


Figure 76-Iii. Typical Oscilloscope Display.

TEST METHOD 77

FREQUENCY AND VOLTAGE REGULATION, STABILITY AND TRANSIENT RESPONSE TEST (SHORT-TERM)

77.1 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 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.

Frequency transient response describes the reaction of the frequency to a sudden change in some condition; such as, a load change on a generator set. This response consists of the amount of excursion beyond the mean of the new operating band, and the recovery time. The recovery time is the interval beginning at the point where the frequency leaves the original prescribed operating band and ending at the point where it enters and remains within the new prescribed operating band. The amount of surge is expressed as a percentage of the rated frequency of the generator set. The recovery time is expressed in seconds. The voltage transient response is described similarly.

77.2 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 methods 1, 4 and 6 (unless otherwise specified in the contract).

77.3 Procedure.

77.3.1 Preparation for test.

a. Connect the load and field instrumentation for one voltage connection and frequency specified in the contract. Unless otherwise specified, connect the signal input of the test recording equipment to the convenience receptacle of the set or to the generator coil which is used as the voltage sensing input to the voltage regulator.

b. Turn on the test recording equipment (if using recording meter(s), set the chart speed(s) to a minimum of 6 inches per hour). The following items shall be recorded on both data sheets and test measuring equipment:

1. The date
2. The serial number(s) of the test equipment(s)
3. Generator set identification
4. If using a chart recorder, recording chart speed(s)
5. The data reading number

(Refer to figures I, II, and III)

c. Place all instrumentation referred to in Test Method 130 in operation.

77.3.2 Test.

a. Start and operate the generator set and allow the set to stabilize at rated load, rated voltage and rated frequency. Record all instrument readings including thermal instrumentation at minimum intervals of 10 minutes (if using recording meter(s), the chart speed shall not be less than 6 inches per hour). 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 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 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 77-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. During this period, adjust the amplitude of the voltage and current traces to minimums of 75 and 40 millimeters respectively. Adjust the chart speed such that individual waveform peaks will be clearly visible. Use a 60 or 400 Hertz (depends on the operating frequency of the generator) timing trace or set the chart recorder time marker to at least 0.01 seconds per line.

c. 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 frequency values are repeatable and that the frequency and voltage regulation is within the limits specified in the contracts (do not use set circuit breaker to remove or apply load). If any adjustments are necessary, paragraph a above must be repeated. Reapply rated load.

d. If using recording meter(s), the chart speed(s) shall be 12 inches per minute throughout the remainder of this test. At each of the following load conditions (one step) operate the set for a minimum of 40 seconds (or the short-term stability period plus the allowable recovery time as specified in the contracts). Approximately 10 seconds during each load condition, record all instrument readings except thermal instrumentation (for three-phase sets it is not necessary to record line-to-line voltages). Each load condition shall be applied to the generator set in one step at the end of the short-term stability period for the previous load condition (do not use set circuit breaker to remove or apply load). The load conditions are:

1. Rated load
2. No load
3. Rated load
4. No load
5. Rated load
6. No load
7. Rated load
8. Adjust load to 3/4 load and check for the accuracy of the load until the load is equal to 3/4 load. No adjustments to either voltage or frequency shall be made. Drop the load to no load and hold for 40 seconds.
9. 3/4 rated load
10. No load
11. 3/4 rated load
12. No load
13. 3/4 rated load
14. No load
15. Apply load and repeat step 7 except at 1/2 load.
16. 1/2 rated load
17. No load
18. 1/2 rated load
19. No load
20. 1/2 rated load
21. No load
22. Apply load and repeat step 7 except at 1/4 load.
23. 1/4 rated load
24. No load
25. 1/4 rated load
26. No load

27. 1/4 rated load
28. No load
29. Apply load and repeat step 7 except at rated load.
30. Rated load
31. No load
32. Rated load
33. No load
34. Rated load
35. No load

d. Repeat steps a thru c for any other voltage connection(s) and frequency(ies) specified in the contract.

77.4 Results.

77.4.1 Prepare a data sheet (use the data sheet in figure 77-VI as a reference) in giving for each load change the momentary frequency overshoot or undershoot and the recovery time. For each constant load, give the maximum frequency variation.

a. Determine the voltage and frequency regulation for all load changes (e.g. rated load to no load, 1/2 rated load to no load, no load to 1/4 load, etc.) as follows:

   1. Using the indicating voltmeter readings subtract the load value of voltage from the no load value for each load changes (e.g. step 1 to step 2). (For voltage regulators utilizing single-phase voltage sensing, the value of voltage in the sensed phase only shall be used in the above calculations. For voltage regulators utilizing multiphase voltage sensing, the average value of the sensed voltage shall be used.)

   2. Convert each of the values obtained in step 1 above to a percentage of rated by dividing by the rated voltage and multiplying by 100. This is the voltage regulation expressed in percent.

   3. Repeat 1 and 2 substituting frequency for voltage.

b. For reference, refer to figure 77-V, begin by determining the observed B, and steady state D frequency bandwidths.

   1. Mark numerically the stabilization's occurring after each load change, starting with the stabilization obtained before the first load change.

   2. Determine the observed frequency bandwidth B by marking the maximum trace excursion and minimum trace excursion in the stabilized portion. Draw two lines parallel to the axis of chart movement, one each passing through these maximum and minimum trace excursions respectively.

3. Draw a line C parallel to and equidistant from the edges of the observed frequency bandwidth, determined in step 2 above.

4. Using the rated frequency of the generator and given contract requirements, calculate the steady state frequency bandwidth D. Draw this steady state frequency bandwidth as two parallel lines, parallel to and equidistant from the median C at the observed frequency bandwidth.

5. At the point where the trace initially leaves the prescribe bandwidth, draw T_G, the maximum allowable recovery time as specified in the contract.
Repeat steps 2 thru 4.

c. To determine the maximum frequency variation at constant load:

1. One-half the observed frequency bandwidth B is the plus or minus value of voltage deviation at constant load.

2. Divide each of the values obtained in step 1 by the rated frequency of the generator and multiply by 100 to convert to percentage.

d. To determine the maximum overshoot and undershoot at each load step, and express this as a percentage of its rated frequency, proceed as follows:

1. From the meter recording charts or digital measuring devices, determine the maximum amount that the frequency trace goes beyond the line C of the observed frequency band following the load change (see figure 77-V for illustration of overshoot and undershoot).

2. Divide the result obtained in step 1 by the rated frequency (as given on the generator nameplate), then multiply by 100 to convert to percentage.

CAUTION: Do not use the constant operating frequency at each load as the divisor in the computation. Use only the rated frequency of the generator.

e. To determine the time required to restore stable frequency conditions after each load change (recovery time):

1. The prescribed steady state frequency bandwidth, extended to the point at which the frequency trace leaves the prescribed steady state band, shall be considered as the time at which the transient conditions begin. The point at which the frequency trace enters and remains within the prescribed band after a load change shall be considered as the point at which stabilization begins.

2. Measure the distance (in millimeters) from the point where the frequency trace leaves the prescribed steady state band to the point where it reenters and remains within the prescribed frequency band for the next load condition.

3. Divide this distance by chart speed (in millimeters per second). This will give the frequency recovery time, in seconds.

f. Repeat 77.4.1b and c substituting ac voltage for frequency.

g. Repeat 77.4.1 substituting dc voltage for frequency.

77.4.2 Use the chart in figure77-IV as a reference in calculating for each load change the voltage dip and rise.

a. From the charts or stored waveforms 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 the peak-to-peak current remain constant from the instant the load is first applied until steady-state conditions are reached.

b. Using the no load to load charts or stored 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

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

V_L = Steady-state voltmeter reading after application of load.
D = Measured minimum peak-to-peak amplitude of the ac voltage trace during the transient period following load application. (For dc sets use the minimum trace excursion from the zero reference line).
L = Measured amplitude, peak-to-peak for ac of the steady-state voltage after load application.

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

d. From the charts or stored waveforms use the 60 or 400 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 stable voltage value as specified in the contract.

e. Using the load to no load charts or stored waveforms and the corresponding voltmeter readings determine the voltage rise in percent using the following equation:

$$\text{Voltage Rise, in percent} = \frac{V_R - V_L}{V_{RATED}} \times 100$$

Where V_R = Calculated voltage rise during the transient period

$$\text{where } V_R = \frac{RV_{NL}}{NL}$$

R = Measured maximum peak-to-peak amplitude of the ac voltage trace during the transient period following load removal. (For dc sets use the maximum trace excursion from the zero reference line).

NL = Measured amplitude, peak-to-peak for ac, of the steady-state voltage after removing load.

V_{NL} = Steady-state voltmeter reading after removing load.

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

V_L = Steady-state voltmeter reading prior to removing load.

f. Calculate the maximum voltage in percent, during the transient period after removal of load by adding the voltage rise, in percent, obtained in step e above to 100 percent.

g. From the charts or stored waveforms, use the timing lines or the 60 Hz timing trace and determine the recovery time (load to no load) to the nearest 0.01 second. The recovery time is the time from the removal of load until the voltage reaches the stable voltage value as specified in the contract.

77.4.3 Compare the results tabulated in 77.4.1 and 77.4.2 with the requirements of the contract.

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

a. Frequency

1. Maximum allowable short-term stability bandwidth or deviation in percent of rated frequency.
2. Maximum allowable recovery time.
3. Maximum allowable overshoot and undershoot.
4. Frequency(ies) at which this method is to be performed.
5. Maximum allowable regulation.

b. Voltage

1. Maximum allowable short-term stability bandwidth or deviation in percent of rated voltage.
2. Allowable voltage dip, no load to rated load, in percent of rated voltage, or the minimum value of voltage, in percent of rated voltage permitted during the transient period after applying load.
3. Required recovery time, no load to rated load, and the stable voltage value, in percent of rated voltage, to which it is measured.
4. Allowable voltage rise, rated load to no load, in percent of rated voltage or the maximum value of voltage, in percent of rated voltage permitted during the period after removal of load.
5. Required recovery time, rated load to no load, and the stable voltage value to which it is to be measured, if different from item 3 above.
6. Voltage connection(s) at which this method is to be performed.
7. Maximum allowable regulation.

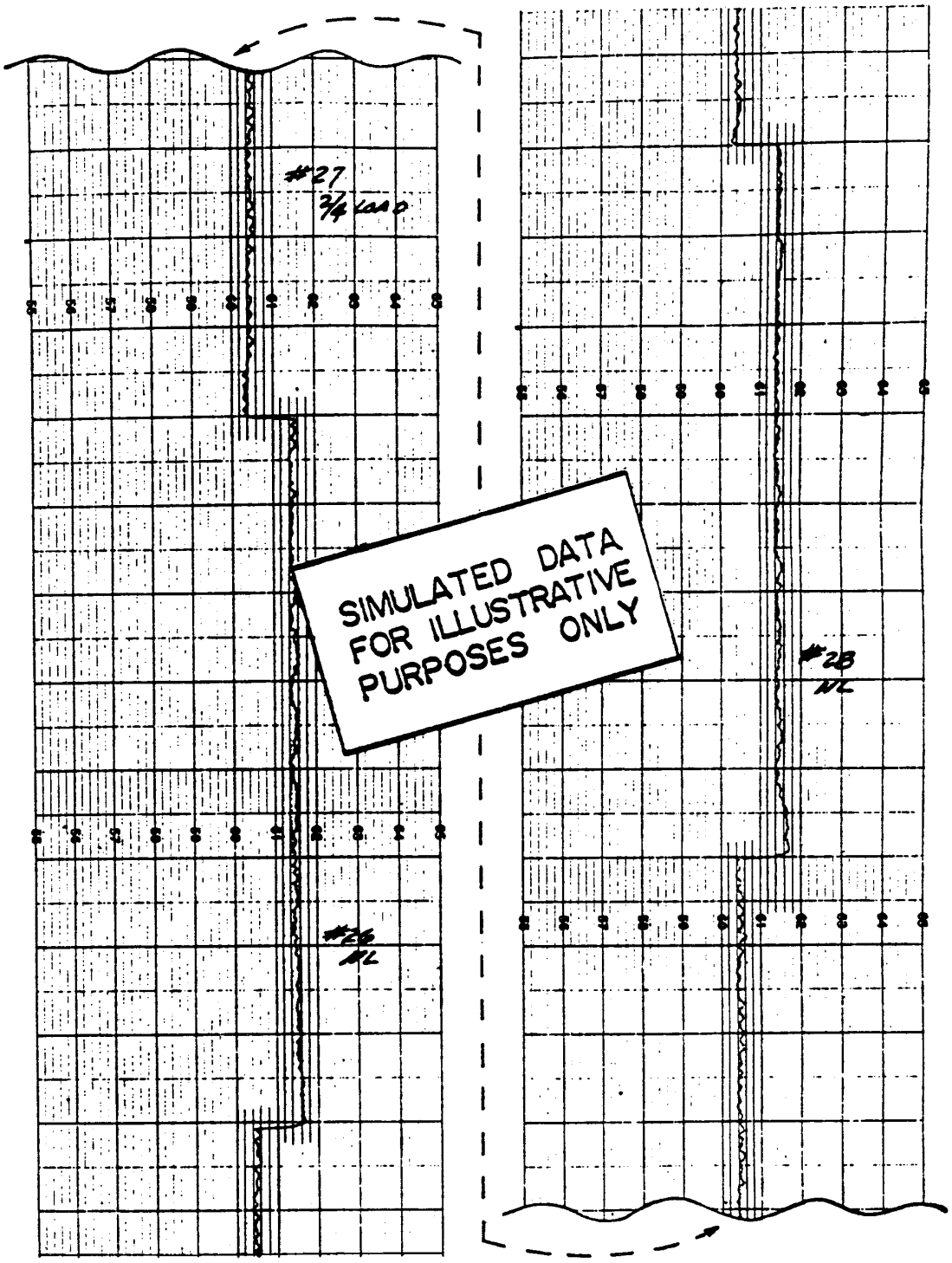
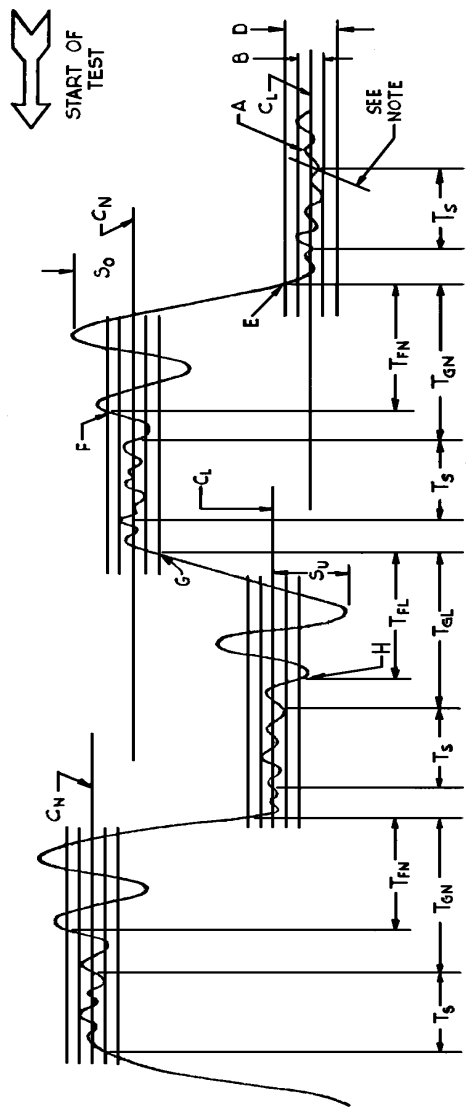


FIGURE 77-III. PORTION OF A FREQUENCY RECORDING CHART SHOWING LOAD CHANGES.



Trace and definitions apply to either voltage or frequency.

Note: Chart marked at start of test.

A Actual instrument trace of function.

B Observed steady state band (two lines parallel to the axis of chart movement. one each passing through the center points of maximum and minimum trace excursion respectively during the short-term stability sample period, T_S).

C Mean of observed band.

C_L Mean value at selected load.

C_N Mean value at no-load.

D Prescribed steady state band.

E Point at which trace initially leaves prescribe load band under condition of decrease in load.

F Point at which trace enters and remains within prescribe no-load band.

G Point at which trace initially leaves prescribed no-load band.

H Point at which trace enters and remains within prescribed load band.

S Surge after a load change.

S_O Overshoot.

S_U Undershoot.

T_{FL} Observed recovery time, no-load to load.

T_{FN} Observed recovery time, load to no-load.

T_G Maximum allowable recovery time.

T_{GL} Maximum allowable recovery time-No-load to load.

T_{GN} Maximum allowable recovery time-Load to no-load.

T_S Prescribed short-term sample time for determining stability.

FIGURE 608.1-IV. DIAGRAMMATIC REPRESENTATION OF STABILITY AND TRANSIENT RESPONSE TERMS.

Figure 77-IV Diagramatic Representation of Stability and Transient Response Terms

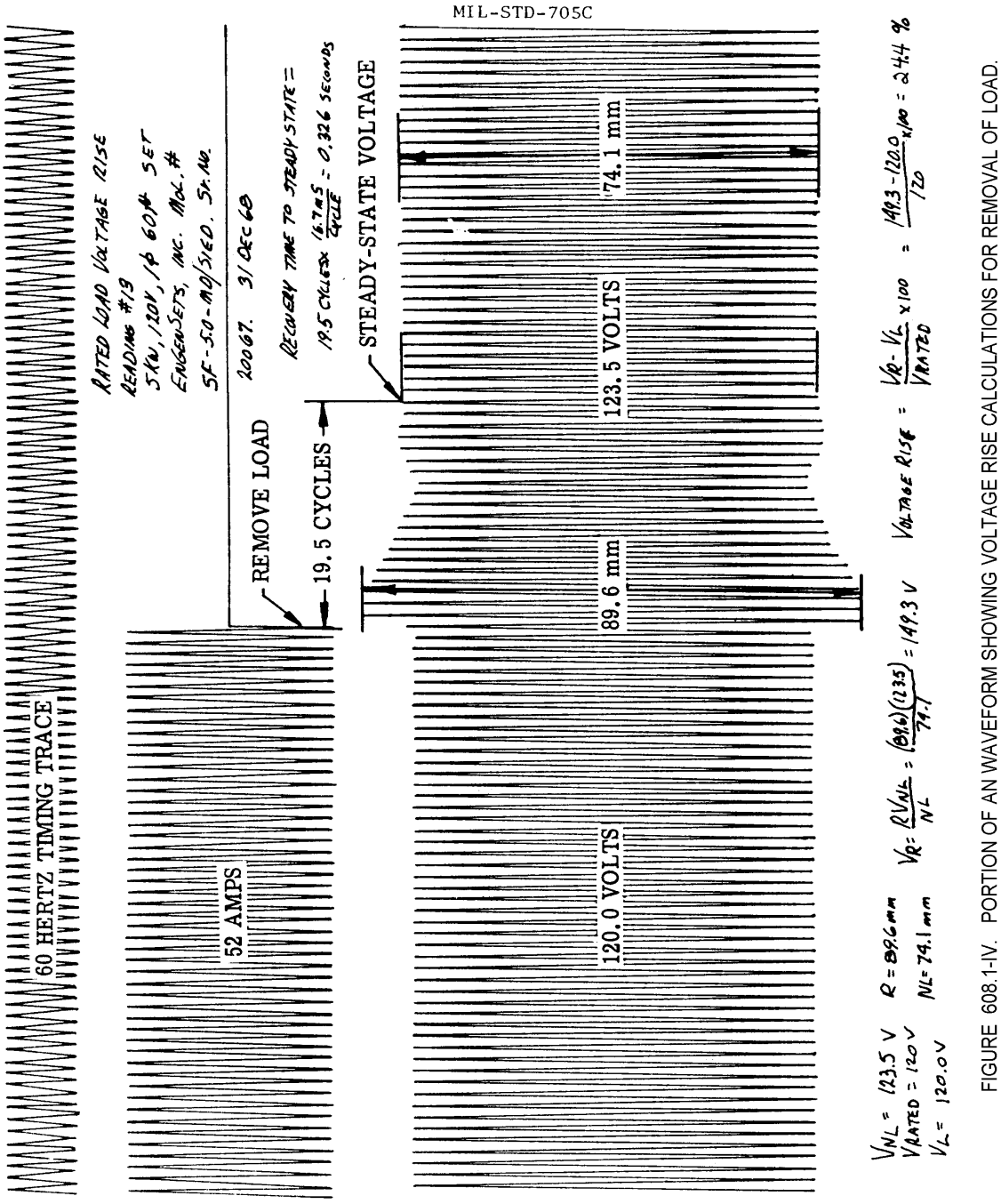


FIGURE 608.1-IV. PORTION OF AN WAVEFORM SHOWING VOLTAGE RISE CALCULATIONS FOR REMOVAL OF LOAD.

Figure 77-V Portion of a Waveform Showing Voltage Rise Calculations for Load Removal

TEST METHOD 78

FREQUENCY AND VOLTAGE STABILITY TEST

(LONG-TERM)

78.1 General. The generator-regulator-exciter combination must be capable of maintaining constant voltage and the engine-governor combination must be capable of maintaining constant speed for constant loads over long periods of time. 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 stability depending upon the length of time that the frequency is observed. Another term, bandwidth, describes the limits of these variation. Bandwidth is expressed as a percentage of rated frequency of the generator set. Voltage stability is described similarly.

78.2 Apparatus. Instrumentation for measuring load conditions and ambient temperatures shall be as described in EGSA 107T . In addition, the test recording equipment(s) shall be as described in EGSA 107T , Test Method 1 and 4 unless otherwise specified in the contract.

78.3 Procedure.

78.3.1 Preparation for test.

a. Connect the load instrumentation for the applicable voltage and frequency connection. Unless otherwise specified, connect the signal input of the test recording equipment(s) to the convenience receptacle of the set or to the generator coil which is used as the voltage sensing input to the voltage regulator.

b. Turn on the test recording equipment and the following items shall be recorded:

1. The date
2. The serial number(s) of the test equipment(s)
3. Generator set identification
4. If using a chart recorder, recording chart speed(s)
5. Data reading number

78.3.2 Test.

a. Start and operate the generator set and allow the set to stabilize at rated load, rated voltage and rated frequency. Record all instrument readings including thermal instrumentation at minimum intervals of 10 minutes (if using recording meter(s), the chart speed shall not be less than 6 inches per hour). 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 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 requirement document. Adjustments to load, voltage or frequency controls shall be recorded on both the data sheet and the test recording equipment(s) 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-alf the long-term voltage and frequencystability bandwidths with no evident continued increase or decrease in value after the last adjustment to the load, voltage, or frequency has been made.

b. After step a above, no further adjustments may be made to the voltage or frequency controls systems for the remainder of this test.

c. Determine the short-term stability prior to the start of the long-term rated load test by operating the test measuring for 40 seconds (if using recording meter(s), operate the chart speed at 12 inches per minute). During this 40 second period, record all instrument readings (if using recording meter(s), at the end of the 40 second period reduce the chart speed to 12 inches per hour). Continue to record and proceed with the test at rated load for a 4 hour period. During this period record all instrument readings at maximum intervals of 30 minutes.

d. Immediately after the long-term stability period, step c, reduce the load to zero and allow the set to stabilize at no load. During this period record all instrument readings including ambient temperature at minimum intervals of 10 minutes. No adjustments to the set shall be made before, during, or following this stabilization period. 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 voltage and frequency stability bandwidths with no evident continued increase or decrease in value.

e. Immediately after the set has stabilized at no load repeat step c above except at no load.

f. Immediately after the no load stability period (if using recording meter(s), operate the chart speed at 12 inches per minute) and in one step apply the following load conditions to the generator set. Each load condition shall last for a minimum of 40 seconds. No adjustments to the set shall be made before or during this portion of the method.

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

g. Repeat 78.3 for each voltage connection and frequency specified in the requirement document.

608.2.4 Results.

a. Determine the long-term rated load voltage stability as follows (see figure 78-I):

   1. Using the rated load short-term voltage stability trace run prior to the long-term rated load voltage stability test, determine the maximum and minimum trace excursions. The maximum trace excursion is the point of maximum voltage during the 40 second period prior to the start of the long-term stability test and the minimum trace excursion is the point of minimum voltage during the same time period.

   2. Calculate the middle of the observed steady state band by adding the values obtained in step 1 above and dividing by 2.

   3. Draw the center line of the observed steady state band at the value determined in step 2 above.

   4. Construct the prescribed steady state band by drawing two lines parallel to and equidistant from the center line of the observed band. Extend this band the entire length of the long-term steady state stability test.

b. Repeat step a for the long-term rated load frequency stability.

c. Repeat step a for the long-term no load voltage stability.

d. Repeat step a for the long-term no load frequency stability.

e. Analyze the data taken in 78.3.2f in accordance with Test Method 77, paragraph 77.4.

f. The tabulation sheet shall contain for each trace the observed maximum and minimum excursions during the short-term steady state stability period, and the observed maximum and minimum excursions during the long-term steady state stability tests.

g. Compare the tabulated results with the requirements of the contract.

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

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

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

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

d. Length of time for the long term stability runs, if other than four (4) hours at rated load and 4 hours at no load.

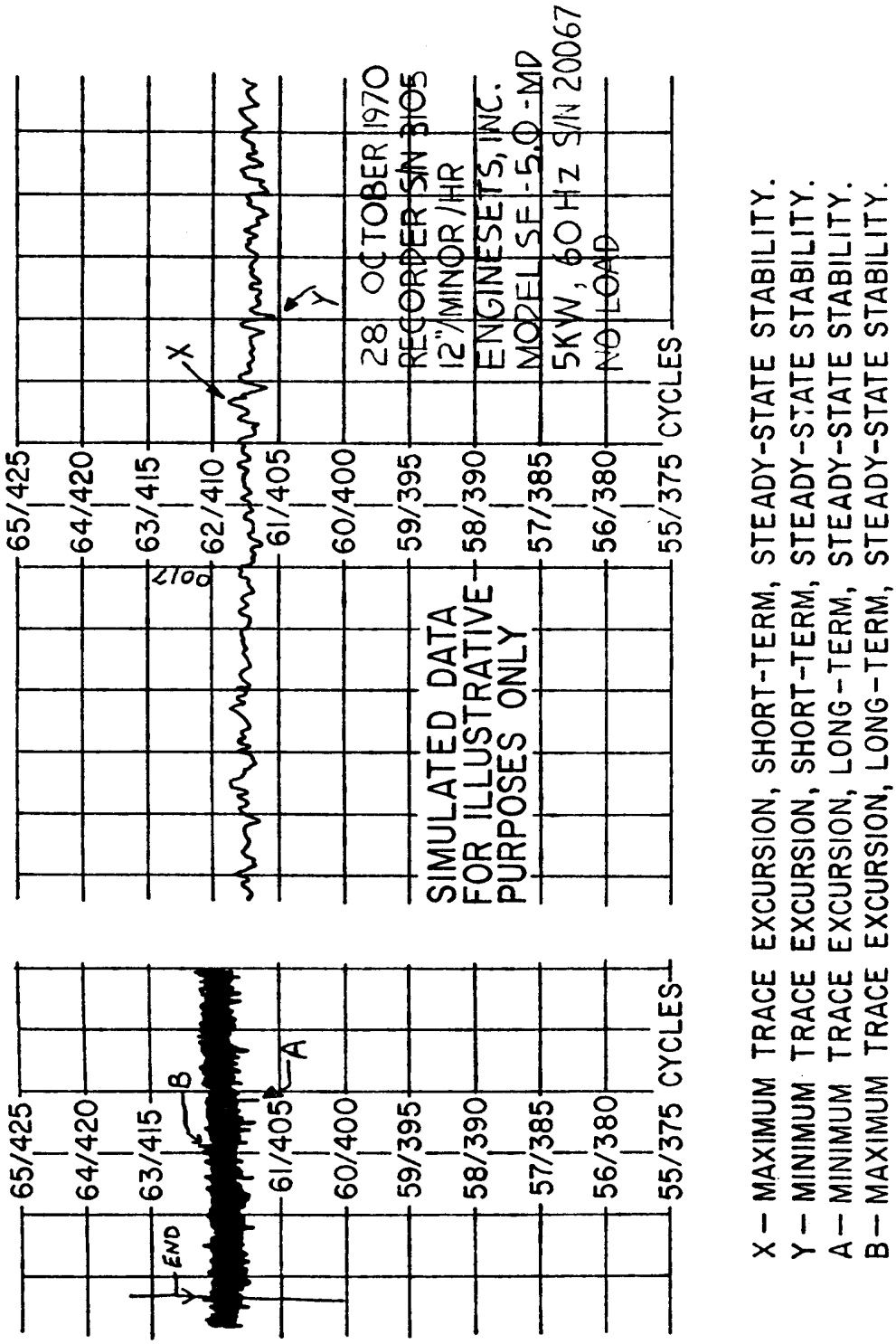


FIGURE 608.2-I. Portion of a four hour long-term stability run.

Figure 78-II Portion of Four Hour Stability Run

TEST METHOD 79

VOLTAGE AND FRQUENCY DROOP TEST

79.1 General. In a generator set in which the generator is equipped with a voltage regulator, the voltage regulator must be capable of maintaining a terminal voltage that falls within specified limits throughtout the load range of the generator. The engine governor also must be capable of maintaining speed within the specified range, under the same conditions. Terminal voltage and speed will vary as load is applied but shall not vary more than the specified limits.

79.2 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).

79.3 Procedure.

79.3.1 Preparation for test.

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

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

79.3.2 Test.

a. Start and operate the generator set and allow the set to stabilize at rated load, rated voltage and rated frequency. 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 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 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.

b. After temperature have stabilized, drop the load to no load and reapply rated load a number of times (three should be sufficient) to assure that the voltage regulator and governor return the terminal voltage and frequency to their rated values at rated load.

c. Reapplied rated load. Adjust the voltage regulator and engine governor to obtain rated values of terminal voltage and frequency. After governor adjustments, the frequency regulation shall be checked for compliance with the requirements of the requirement document.

NOTE: No further adjustments shall be made to the voltage regulator or engine governor.

d. Starting at rated load, rated voltage, and rated frequency, reduce the load to no-load in one step and record all instrument readings.

e. Gradually increase the load at rated power factor in approximately 10 percent steps, recording all instrument readings at each load step until the load reaches the specified overload condition. Then gradually decrease the load in approximately 10 percent steps until no-load is reached recording all instrument readings at each step.

f. On ac generator sets repeat step e above with a unity power factor load.

79.4 Results.

a. Plot voltage-droop and frequency-droop curves. The voltage-droop curve shall be plotted with the vertical axis as the "terminal voltage" and the horizontal axis as the total kilowatt load. The frequency-droop curve shall be plotted with the vertical axis as the "frequency" and the horizontal axis as the total kilowatt load.

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

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

a. Maximum voltage droop allowed.

b. Maximum frequency droop allowed.

c. Maximum overload condition at which this method shall be performed.

d. Short-term frequency stability requirement.

e. Maximum frequency regulation allowed.

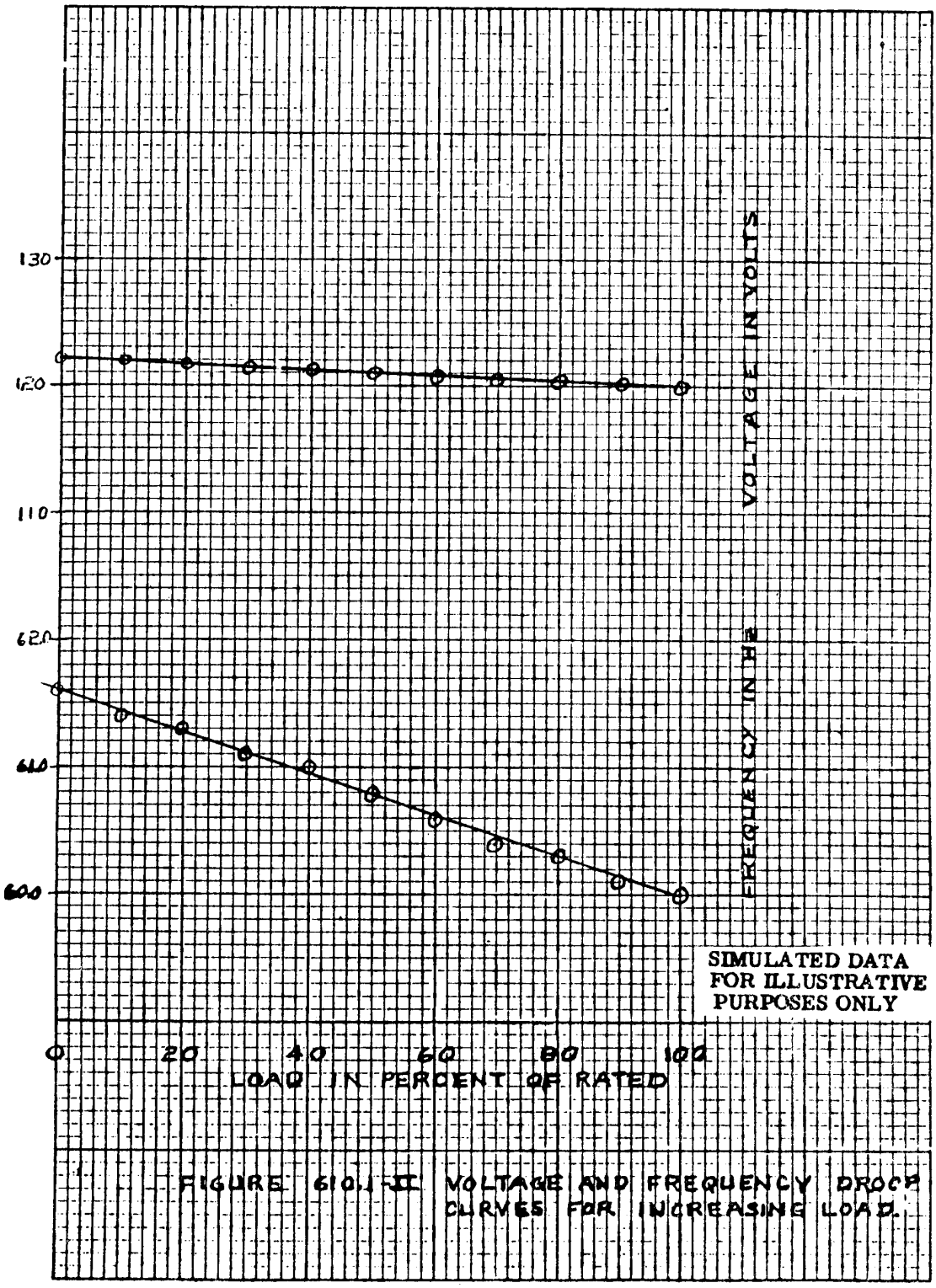


Figure 79-II Voltage and Frequency Droop Curve for Increasing Voltage.

TEST METHOD 80

PARALLEL OPERATING TEST

80.1 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.

80.2 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 EGSA 107T , Test Method 3 and a non-inductive shunt will be required.

80.3 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.

80.3.1 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 inthe 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 operation.

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.

80.3.2 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 80.3. lb.)

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 may cause 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 governors (by means 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 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 the real 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 requirement document. 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 pulsation's 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.

80.4 Results.

80.4.1 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.

80.4.2 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.

80.4.3 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.

80.4.4 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.

80.4.5 Voltage and frequency stability and transient response.

a. From the recording charts, determine the voltage and frequency stability bandwidths for each load condition of 80.3.1, steps h and i. Refer to Test Method 78.

b. For each of the load transients performed in 80.3.2, 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.

80.4.6 Compare these results with the requirements of the contract.

80.5 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.