TEST METHOD 21

TEMPERATURE CORRECTIONS TO RESISTANCE MEASUREMENTS

21.1 GENERAL. The resistance of a conductor varies with the temperature. The resistance of metals and most alloys increases with the temperature, while the resistance of carbon and electrolytes decreases with the temperature.

21.2 PROCEDURE. When the resistance R_t of a winding has been determined by test at a winding temperature T_t, the resistance may be corrected to a specified temperature Ts by the following equation:

$$R_S = R_t \left[\frac{T_S + k}{T_t + k} \right] \text{ ohms.}$$

where R_S = winding resistance, corrected to specified temperature, T_S

T_S = specified temperature, ^{o} Celsius

R_t = test value of winding resistance

T_t = temperature of winding when resistance was measured, ^{o} Celsius

k = characteristic constant for the winding material

NOTE: For 100 percent pure copper k = 234.5;
For hard drawn 97.3 percent copper, k = 241.5.
Data for different materials may be found in various standard engineering handbooks.

Testing all values of observed resistance of windings shall be corrected to a standard temperature of 25 °C (77 ^{o}F) unless otherwise specified in the contract.

TEST METHOD 22

BATTERY SERVICING AND CONDITION ASSURANCE PRIOR TO "COLD STARTING" TESTS

22.1 GENERAL. Lead-acid or nickel-cadmium (NI-CAD) batteries are used to start some engine-driven electrical power generator sets. One of the purposes of this document is to provide guidance to assure that proper test conditions and preparations are accomplished prior to commencing any tests.

When provisions are made in advance to assure that adequate facilities, equipment and personnel will be available, battery servicing and condition assurance can usually be accomplished within a normal 5-day work-week. Planning and scheduling for testing should allow sufficient pre-test time for these tasks.

These tests, when used for first article or production acceptance, are to verify that generator sets have been properly manufactured, not to test batteries. Batteries are multi-use items tested and qualified under their own separate programs, prior to being specified for use on generator sets or various other equipment. Batteries that are used during first article or production acceptance testing are, in essence, "test support equipment". If full battery output capability is not assured prior to generator set testing, inadequate battery performance may cause abortion of an otherwise valid test sequence; this can result in waste of test facility and personnel resources, and risk failure to meet contract or program schedules. Operational experience with the procedures below is that they are highly effective in preventing such problems.

When these tests are used for evaluation during equipment research and development, the use or non-use of the procedures below depends upon the purpose for which the test data will be used. For example, total system reliability or operational readiness assessments, evaluations of component compatibility's, standardization studies and so forth, would probably not require the use of these battery conditioning procedures.

22.2 PREPARATION OF BATTERIES FOR CHARGING. It is strongly recommended that new batteries be used for the cold starting tests, to further minimize possibilities of test abortions due to improper battery conditions. Extreme care must be exercised to insure that NI-CAD batteries are not contaminated by tools, equipment, solutions or gases from lead-acid batteries. Such contamination can destroy NI-CAD batteries. Refer to the NI-CAD battery technical manual or manufacturer's data for further guidance about this.

Batteries may be received in either the "wet" or "dry" condition. Wet battery cells already contain the electrolyte solution, whereas dry batteries require filling with electrolyte solution after receipt. Some batteries may have sealing devices over each cell for shipment and storage, which must be dislodged (and can be discarded or left inside the cells) prior to filling. Wet batteries may require "topping off" with distilled water to bring the electrolyte to its correct level, but neither topping off of wet batteries nor filling of dry batteries should be attempted until the battery has stabilized at a temperature between 60 ➡F (15.6 °C) and 100 ➡F (37.8 ➡C). Stabilization should be verified by 3 consecutive checks of the battery or electrolyte temperature, 10 minutes apart and varying within +5 ➡F (2.8 °C) of each other, within the 60 ➡F to 100 ➡F range. Final check

and adjustment of the electrolyte level should then be made 30 minutes after any previous additions of distilled water or electrolyte.

The electrolyte for dry lead-acid batteries is a solution of sulfuric acid (H_2SO_4) and distilled water having a specific gravity between 1.260 and 1.280 at 80 ➞F (26.7 °C). Wet lead-acid batteries contain the same solution, but normally only distilled water is added to them after receipt. For temperatures below 0 ➞F (-17.7 ➞C), battery performance is better when 1.280 specific gravity solution is used.

NI-CAD batteries use potassium hydroxide (KOH) electrolyte. Unlike lead-acid battery electrolyte, the specific gravity of potassium hydroxide in NI-CAD batteries does not vary with the state of charge of the battery; however, the level of the electrolyte in NI-CAD batteries does vary extremely with the state of charge. NI-CAD batteries normally are shipped with the proper amounts of electrolyte already in the cells, but if the battery is in the discharged state when received, it may appear to be dry or low on electrolyte because the liquid has been absorbed by the cell plates. Because of this phenomenon, neither electrolyte nor distilled water should be added to NI-CAD batteries until they have been fully recharged (see Para 22.3 below). After recharging, the level may continue to vary for another two hours; therefore, final level determination should be made two hours after completion of recharging. Distilled water may then be added if needed. If it is suspected that a totally dry NI-CAD battery has been received, the condition can be confirmed by checking for absence of voltage across the individual cells or between the terminal posts, or by observing the charger meter immediately after charging current is applied to the proper connections; if there is no electrolyte in the battery, it will not take a charge, and the charger should be stopped. Electrolyte should then be added, not to full level, but to just above the plates in each cell. Charging may then be resumed and continued, provided battery temperature does not rise above that specified in the battery Technical Manual or manufacturer's data, and the charger meter or other device indicates the battery is taking the charge. Final electrolyte level should be verified or corrected two hours after completion of charging.

All battery electrolytes are highly corrosive and can severely damage human eyes, skin, and other body tissues; therefore, protective clothing, gloves and goggles should be worn when handling these chemicals and while near any battery charging operations.

After adjusting electrolyte levels, battery tops and cases should be thoroughly washed, neutralized and dried. Use washing and neutralizing solutions recommended in the applicable technical manuals or manufacturer's data. Do not allow washing or neutralizing solutions to enter the battery cells. After drying, the battery should be placed on a dry wooden board or similar material that will electrically and chemically isolate the battery case from ground and surrounding material. The battery should remain so insulated throughout charging and storage operating prior to use for cold starting tests. Avoid allowing sparks, lighted cigarettes, pipes, cigars, excessive heat, or flame near batteries, especially during charging operations. Hydrogen and oxygen gases from the batteries can ignite and explode. Charging and storage areas must allow for adequate ventilation and dilution of these gases.

22.3 <u>BATTERY CHARGING EQUIPMENT AND CONNECTIONS</u>. Charging equipment for lead-acid batteries can consist of any suitable DC power source with the necessary metering and instrumentation. NI-CAD batteries generally require their own special charging equipment as well as special discharging fixtures, which will be identified in the applicable technical manual or

manufacturer's data. Improper charging or discharging of NI-CAD batteries can result in a condition called "thermal runaway", which is dangerous to personnel and destructive to the battery.
When more than one battery is to be charged or discharged simultaneously, connect the batteries in series or use isolated circuits. Do not connect the batteries in parallel because the charge or discharge rate of an individual battery is extremely difficult to control that way.

22.4 STANDARD BATTERY RATING . "Battery Rating" normally means the total number of ampere-hours that can be expended during a specified period of continuous discharging at a specified constant temperature and at a specified constant discharge rate. This rate, also referred to as "rated output", is not the maximum discharge rate; most batteries used to start engines are required to discharge at rates many times their standard rated output. When the actual hourly rate of a battery is unknown, an 8 hour rate must be assumed; for example, a 32 amp-hour battery is capable of supplying 32 - 8 = 4 amps to the load for 8 hours before becoming fully discharged. Additional examples for two commonly used lead-acid batteries are given in the table below.

Battery Designation	Ampere-hour Rating	Calculation	8 Hour Rate
MS3500-1 Type 2HN	45 Ampere-hours	45 / 8 = 5.62	5.62 Amperes
MS3500-3 Type 6TN	100 Ampere-hours	100 / 8 = 12.5	12.5 Amperes

"Rated capacity" of a battery is the number of amps the battery will supply at a specified temperature. The capacity of lead-acid batteries decreases with temperatures below 80 ➡F (26.7 °C). At -40 ➡F (-40 °C), the loss can be as much as 75 percent. Capacity can be improved and returned to normal, but only by increasing the temperature.

22.5 STATE-OF-CHARGE ASSURANCE. The state-of-charge of a battery at any point in time may be determined by various methods, but these methods may not accurately establish the length of time the battery will continue to operate at that state. Presently, the best assurance that a battery is in its optimal state-of-charge is obtained by subjecting the battery to cycles of charging and discharging (preconditioning) determined from previous experience to produce maximum output for the longest period of time. A general rule is to charge or recharge a battery in the final cycle so that the ampere hours put into the battery by charging are at least 1.25 times the battery's rated capacity in ampere-hours.

22.5.1 PRECONDITIONING OF LEAD-ACID BATTERIES

a. Charge the batteries with a constant current* at the 8 hour rate (see 22.3) until the specific gravity of the electrolyte becomes constant for three consecutive 30-minute readings. Use a suitable hydrometer or optical tester to obtain the readings of each cell. A difference in readings between any two cells of .05 or more indicates a battery usually unsuitable for cold starting tests.

* Constant potential may be used provided battery electrolyte temperature is maintained below 130 ➡F (54.7 °C), or provided violent gassing is controlled by interrupting charging or by lowering the charging voltage. Violent gassing is evident if bubbles in the electrolyte occur at a rate of more than two per second, or if the diameter of any bubble exceeds 1/8 inch (3.2 mm).

b. The batteries shall then be discharged continuously at the 8 hour rate to a final terminal voltage equivalent to 1.75 volts per cell (1.75 x 6 = 10.5 volts for a 12-volt battery). At this point, specific gravity of each of the cells should be checked again, and readings should not differ by more than .05.

c. Repeat a.

d. Repeat steps b and a two additional times.

22.5.2 CHARGING OF BATTERIES IN PREPARATION FOR COLD TEMPERATURE USE. There are two different methods to charge the batteries. One method is Constant Voltage, the other is Constant Current.

22.5.3 PRECONDITIONING OF NI-CAD BATTERIES. NI-CAD Batteries generally are not affected by lower temperatures as much as lead-acid batteries are; however, NI-CAD batteries have other characteristics that, without preconditioning, can significantly reduce their performance at all temperatures.
Preconditioning of NI-CAD batteries prior to testing differs considerably from the procedures used for lead-acid batteries. NI-CAD preconditioning consists of assuring that the process commonly referred to as "equalization" has been performed immediately prior to charging or recharging. Equalization corrects the condition referred to as "memory effect" and also corrects any imbalance among individual cells allowed or caused by the memory effect. Any voltage difference between cells of more than 0.10 volts indicates that equalization is not accomplished and may indicate the need for battery repair or replacement, if subsequent or repeated equalization does not correct the imbalance.
NI-CAD equalization procedures, as well as charging and discharging rates and equipment, differ among the models, types and styles of batteries. The applicable technical manual(s) or manufacturer's data or both should be consulted to determine proper procedures and equipment.

22.6 STABILIZATION PERIOD AFTER CHARGING. Batteries should be allowed to "sit" for approximately 24 hours after final charging and prior to use. Final state-of-charge determinations should also not be made until after this stabilization period. Throughout the stabilization period, the battery should be kept on a dry wooden board or similar material that electrically and chemically isolates the battery case from ground and surrounding material; battery terminals should be kept covered with suitable plastic caps, grease or wax; temperatures around the battery should be kept between 60 ➡F (15.6 °C) and 80 ➡F (26.7 ➡C); the battery exterior should remain dry, and the relative humidity around the battery should not exceed 65 percent.

22.7 INSTALLING BATTERIES IN GENERATOR SETS. Clean the battery posts and cable terminals thoroughly in accordance with the applicable technical manual(s) or manufacturer's data. Do not use a wire brush or other metal cleaning tools on NI-CAD battery posts. Nylon brushes, sand paper or emery cloth are recommended for cleaning NI-CAD battery posts.

After installation, apply approximately 1/8" (3 mm) thick coating of petroleum jelly, GAA compound or similar, completely covering the battery posts and cable terminals.

22.8 SOURCES OF ADDITIONAL INFORMATION ON BATTERIES. The following publications contain additional information and guidance on battery installation and maintenance. They are listed here for information only;

- DA Pamphlet 750-34 Preventive Maintenance of Lead-Acid Batteries

- TM 11-6140-203-14-3 Technical Manual Nonaircraft Nickel-Cadmium Batteries

TEST METHOD 23

THERMAL INSTRUMENTATION

23.1 GENERAL. Thermal instrumentation includes instructions for locating various measuring devices for determining temperature of components and materials, and the surrounding (ambient) air.

The usual methods of obtaining temperatures at the various locations are: contact, resistance, or embedded detector. Each of these temperature measurement methods are discussed in detail in Test Method 10.

23.2 GENERATOR SET COMPONENTS:

23.2.1 CONTACT METHOD. The contact method of temperature measurement is used in the following locations: generator bearing housing or housings, generator frame, stator coils, intake and exhaust cooling air, collector rings, commutator, pole tips, rotor windings, and engine coolant and lube oil (by immersing the detector). Temperature measurements on moving components must be attached immediately once the moving part is at rest.

23.2.2 RESISTANCE METHOD. This method is applicable for measuring the temperature of the generator output winding, the generator field and exciter field. It shall not be used on a rotating winding whose resistance at ambient temperature is less than 1.0 ohm.

The application of the devices and the formula for calculating the temperature rise are given in Test Method 10.

23.2.3 EMBEDDED DETECTOR METHOD. Usually, only generator sets rated at 500 kW, or larger, are equipped with embedded detectors for the determination of the temperature of the electrical windings. The temperature of stationary windings will be measured periodically by this method during a test, while that of rotating windings will be taken at a standstill, immediately following shutdown.

Embedded detectors are of two types: the thermocouple type and the resistance type. Either of these types may be employed as stationary or rotating detectors.

Before measuring temperatures by the embedded detector method, make sure that the detectors have been properly located in accordance with the applicable contract.

23.3 ENGINE COMPONENTS. All temperature measurements of the engine components normally use the contact method. The contact detector can be either the thermocouple type or the resistance type.

23.4 AMBIENT AIR TEMPERATURE.

23.4.1 APPARATUS. Ambient air temperature measurements shall be made with of thermometers or thermocouples. These devices shall be exposed directly to the ambient air. When chambers are used, the thermal sensing devices used for controlling the chamber temperature shall be separate from the apparatus used for measuring and recording the chamber ambient.

23.4.2 LOCATION.

23.4.2.1 ENVIRONMENTAL CHAMBERS. Precautions will be taken to insure that none of the thermometers or thermocouples are located in either "hot" or "cold" spots in the chamber. The thermometers or thermocouples shall be placed at the following positions:

Unhoused generator set - The ambient air temperature shall be measured at a distance of approximately 2 feet diagonally outboard from the corners of the generator set as the air approaches the set. A minimum of 2 thermometers or thermocouples shall be recorded and averaged to establish the ambient air temperature specified in the applicable test document. The distance from walls or obstructions shall be 1 foot minimum. The temperature measurement devices shall not be located near the engine exhaust outlet or in the cooling air exhaust from the generator set.

Housed generator sets - The ambient air temperature shall be measured at the generator air intake to the housing. This measurement shall be taken by a minimum of 2 thermometers or thermocouples. The outputs shall be recorded and averaged to establish the ambient air temperature specified in the appropriate test document.

23.5 CONTROL PANEL TEMPERATURES. The temperature within the control panel enclosure shall be taken by means of a thermocouple. The thermocouple shall be mounted in the space behind the control panel and shall be so located that it is surrounded only by air and is not in contact with any object. When testing a generator set on which the control panel has been opened for inspection, always close the control panel before measuring the temperature of the enclosure behind it.

23.6 BATTERY ELECTROLYTE AND BATTERY BOX AMBIENT AIR TEMPERATURES.

23.6.1 BATTERY ELECTROLYTE TEMPERATURES. The battery electrolyte temperature shall be taken by a thermometer or thermocouple in the opening to a central battery cell in all batteries, if there is more than one. When a thermocouple is used, it shall be enclosed with a corrosion resistant material which is flexible and sealed on the end in the battery. One such corrosion resistant material is "Teflon". To install the thermocouple halfway down the plates, a wooden separator about the thickness of the thermocouple can be carefully forced down between the plates, then the thermocouple installed and the separator removed. The thermocouple junction shall be located so that it is completely immersed in the electrolyte. The plates will hold

the thermocouple in place. If a thermometer is used, it shall be located so that its bulb is completely immersed in the electrolyte.

23.6.2 BATTERY BOX AMBIENT AIR TEMPERATURES. The battery box ambient air temperatures shall be measured by means of two thermocouples located at opposite sides of the battery box, approximately halfway up the inside wall, and free from contact with any object other than the ambient air.

23.7 WINTERIZATION HEATER TEMPERATURES

23.7.1 COOLANT TYPE HEATERS. For winterization heaters that heat and circulate the engine coolant, the temperature of the coolant shall be measured at both its inlet and outlet to the heater. The temperature shall be taken by thermometers or thermocouples located in the piping at these points.

23.7.2 HOT AIR TYPE HEATERS. For heaters that heat and circulate uncontaminated hot air, the temperature of the air shall be measured at its inlet and outlet to the heater. The temperatures shall be measured by thermocouples located in the heater ducts at these points.

23.7.3 EXHAUST GAS MEASUREMENTS (BOTH TYPES OF HEATERS). The heater exhaust gas temperature shall be measured by a thermocouple located as close as possible to the point at which the exhaust gases leave the heater. When the exhaust gas is used in heating the oil pan, the temperature of the exhaust gas, after passing through or around the oil pan, shall also be measured.

TEST METHOD 24

DATA SHEETS AND RECORD ENTRIES

24.1 GENERAL. Tests do not fulfill their purpose unless complete and accurate data are recorded.

When the data are compared directly with the requirements of the requirement documents, or when calculations are made from the information on the data sheets, and the results compared to the requirements of the requirement documents, the acceptance or rejection of the set under test is dependent upon the data obtained.

To avoid accepting equipment which fails to meet the requirements of the requirement documents, and to be absolutely certain that any rejects fail to meet these requirements, repeat any test procedure if there is any doubt as to the accuracy of the recorded data.

Each data sheet must be trackable to a complete series of information which will identify the set under test and the test method, in addition to the data. The following is a list of information each data sheet shall be trackable to or will be included on the data sheet:

1. The make, rating, model number, and serial number of the set under test.
2. The name and number of the test method.
3. Columns for all instrument readings, with the serial number of the instruments used, and the multiplying factor.
4. The date on which the test is performed and the time of each reading.
5. The names of the personnel performing the test and the observer.
6. Notes as necessary to clarify the conditions of the test.
7. The name or designation of the agency responsible for inspection of the unit under test.
8. Data sheet number. If more than one data sheet is used to record data at the same time, each data sheet used shall be numbered, e.g., sheet 2 of 3.
9. The ambient temperature reading.
10. References by reading number to attached charts.
11. A series of instrument readings taken within five minutes after starting the set (only for tests requiring stabilization of the set).

NOTE: Zero instrument readings will be recorded as such. Do not leave the space blank.

All instruments shall be carefully read. The readings shall be recorded directly on the data sheet and not multiplied by the multiplying factor before recording. Both maximum and minimum readings for cyclic values shall be recorded on the data sheets.

When making readings for steady-state conditions, be certain that these conditions have been reached before recording the readings.

No erasures of readings shall be made. Errors shall be neatly crossed out with a single straight line. Consecutive reading numbers will begin with the first test conducted during first article (preproduction) tests and shall be continued throughout these tests.

Individual tests requiring a series of data points shall be repeated if an interruption occurs during the test (e.g., data points being taken for plotting a curve, etc.).

Complete, accurate and neat data are essential when performing these tests.

TEST METHOD 25

INSULATION RESISTANCE TEST

CAUTION: OBSERVE SAFETY REGULATIONS. The voltages used in this method are dangerous to human life. Contact with the leads or the windings under test may cause severe, and possibly fatal, shock. Arrange the high voltage leads so that they are not in a position to be accidentally touched. Keep clear of all energized parts. Always reduce the test voltage to zero and ground the winding under test before making any mechanical or electrical adjustments on the equipment. When grounding windings which have been tested, always-connect the connection wire to ground first, and then to the winding. Never perform this test without at least one other person assisting. The generator frame shall be securely grounded to the building ground or earth ground.

25.1 General. To assure that the current leakage is kept to a minimum, the insulation resistance must be as high as practicable.

25.2 Apparatus. Instrumentation shall be as described in Test Method 5, para 5.5.2 (unless otherwise specified in the contract).

25.3 Procedure.

25.3.1 Preparation for test.

a. Disconnect the circuit under test from all other circuits. Each circuit of each generator presents an individual problem and no specific instructions can be given here.

b. Disconnect all radio suppression capacitors from the circuit to be tested.

c. In the case where several windings constitute a circuit, all leads of the circuit may be connected together and the resistance measured between this connection and ground.

d. Ground all circuits except the one being tested.

e. When testing a stator element, connect the ground lead from the test apparatus to the generator frame (ground). When testing elements that rotate, connect the test apparatus ground lead to the shaft.

f. Connect the other lead to the circuit under test.

25.3.2 Test.

a. Operate the test apparatus in accordance with the manufacturer's instructions.

b. Record the insulation resistance after one minute of operation. Also record ambient temperature.

c. Turn off test apparatus. Ground the winding under test and the test lead before disconnecting apparatus leads or touching circuit under test.

d. Remove the leads to the circuit under test and repeat the procedure for all other circuits to be tested.

e. After all circuits are tested, reconnect all circuits to original configuration.

25.4 Results. Compare the results with the requirements of the contract.

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

a. Minimum allowable insulation resistance.

b. Circuits to be subjected to this method.

TEST METHOD 26

HIGH POTENTIAL TEST

CAUTION: OBSERVE SAFETY REGULATIONS. The voltages used in this method are dangerous to human life. Contact with the leads or the windings under test may cause severe, and possibly fatal, shock. Arrange the high voltage leads so that they are not in a position to be accidentally touched. Keep clear of all energized parts. Always reduce the test voltage to zero and ground the winding under test before making any mechanical or electrical adjustments on the equipment. When grounding windings which have been tested, always connect the connection wire to ground first, and then to the winding. Never perform this test without at least one other person assisting. The generator frame shall be securely grounded to the building ground or earth ground.

26.1 General. The generator insulation materials must be capable of withstanding, without damage, voltages higher than rated for definite periods of time to preclude damage during transient loading and short circuit conditions. This test should be performed after the equipment is completely assembled so that damage to the insulation which might have occurred during manufacture and assembly will be detected.

26.2 Apparatus. A variable alternating current, high voltage, current-limited power source shall be required (unless otherwise specified in the required document).

26.3 Procedure.

26.3.1 Preparation for test.

a. Adequately ground the high potential apparatus to a solid electrical ground in accordance with instructions accompanying the apparatus. Also, connect the main frame of the generator set and all windings of the generator, not under test, to the same ground.

b. Unless rectifiers and semiconductors are specifically designed to withstand the specified test voltage they should be removed or disconnected from the circuit along with any radio suppression capacitors prior to conducting the tests.

c. Raise, or remove, brushes from commutator and slip rings, if applicable.

d. Isolate the generator power output windings, the generator field windings, and the exciter armature and field windings if a part of the set. This is accomplished by disconnecting the various windings from the associated control circuits or other connections. Static excitation systems feeding the field excitation from the ac generator shall be tested with all rectifiers and capacitors disconnected, unless such rectifiers and capacitors are designed to withstand the specified test voltage.

e. Connect the high voltage lead from the test apparatus to the winding or circuit under test. All other windings and circuits must be securely connected to ground

26.3.2 Test.

a. Turn on the test apparatus in accordance with the manufacturer's instructions, after making sure that the initially applied voltage will not be greater than 600 volts.

b. The test voltage shall then be raised approximately uniformly to the required value. This increase shall be accomplished in not less than 10 seconds nor more than 30 seconds. Unless otherwise specified in the contract, the maximum test voltage for power output windings shall be equal to 1,000 volts plus twice the highest rated voltage of the generator. The test voltage for field windings shall be equal to 10 times the exciter ceiling voltage but in no case less than 1,500 volts nor more than 3,500 volts. Record on the data sheet the maximum voltage reached during this method.

c. Apply the maximum voltage for 1 minute. Record the voltage applied, including any breakdown in insulation observed.

d. After 1 minute the voltage shall be reduced gradually to the voltage initially applied. This reduction shall not be accomplished in less than 5 seconds.

e. Turn off the test apparatus.

CAUTION: Ground the high voltage lead of the test apparatus to make sure that no charge remains on the windings which have been under test.

f. Remove the high voltage lead from the winding and proceed with the tests of the remaining circuits to be tested. Make sure that all the circuits not under test are securely grounded.

g. After test is completed, reconnect all circuits to original configuration.

26.4 Results. Compare the results with the requirements of the requirements document.

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

a. Test value of applied voltages, if different than those specified in para 26.3.2.

b. Windings to be tested, other than those specified in para 26.3.

c. Definition of insulation breakdown.

TEST METHOD 27

WINDING RESISTANCE TEST

27.1 General. Winding resistance measurements are commonly used to determine temperature rises; to compare winding resistance with design data; to compare production models against first article models; and to detect defective windings.

27.2 Apparatus. Instrumentation for measuring winding resistances shall be as described in Test Method 5 (unless otherwise specified in the required document).

27.3 Procedure.

27.3.1 Preparation for test.

a. Isolate the winding whose resistance is to be measured by disconnecting one end from all other circuits..

b. Winding resistance measurements shall be made by methods described in Test Method 5.

c. Connect the measuring apparatus across the winding in accordance with the apparatus manufacturer's instructions. If the drop-in potential or comparison methods are employed, measure the voltage only on the portion of the circuit to be included in the resistance measurements. Since these measurements are used in comparing one reading against another, care should be taken to measure the voltage at the same location during each measurement of like windings.

d. Cold resistance measurements shall be made with the generator set at approximately the generator set has been inoperative for a sufficient time (approximately 12 hours) to bring the major generator mass temperature to within 3 °C of the ambient temperature.

27.3.2 Test. Operate the test apparatus in accordance with the applicable method selected and record the resistance value for the winding(s) under test. The resistance values shall as a minimum be recorded to four significant digits.

When this test method is used for temperature change determination, speed in taking the measurements is essential (see Test Method 10). The ambient temperature at which the resistance readings are taken shall also be recorded.

27.4 Results. The corrected (see Test Method 17) values determined by these measurements shall be compared with contract or design requirements, or shall be used in other computations.

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

a. The minimum and maximum allowable resistance values for each component tested, if applicable.

b. The standard temperature to which these measurements are to be corrected, if applicable.

TEST METHOD 27

WINDING RESISTANCE TEST

27.1 General. Winding resistance measurements are commonly used to determine temperature rises; to compare winding resistance with design data; to compare production models against first article models; and to detect defective windings.

27.2 Apparatus. Instrumentation for measuring winding resistances shall be as described in Test Method 5 (unless otherwise specified in the required document).

27.3 Procedure.

27.3.1 Preparation for test.

a. Isolate the winding whose resistance is to be measured by disconnecting one end from all other circuits..

b. Winding resistance measurements shall be made by methods described in Test Method 5.

c. Connect the measuring apparatus across the winding in accordance with the apparatus manufacturer's instructions. If the drop-in potential or comparison methods are employed, measure the voltage only on the portion of the circuit to be included in the resistance measurements. Since these measurements are used in comparing one reading against another, care should be taken to measure the voltage at the same location during each measurement of like windings.

d. Cold resistance measurements shall be made with the generator set at approximately the generator set has been inoperative for a sufficient time (approximately 12 hours) to bring the major generator mass temperature to within 3 °C of the ambient temperature.

27.3.2 Test. Operate the test apparatus in accordance with the applicable method selected and record the resistance value for the winding(s) under test. The resistance values shall as a minimum be recorded to four significant digits.

When this test method is used for temperature change determination, speed in taking the measurements is essential (see Test Method 10). The ambient temperature at which the resistance readings are taken shall also be recorded.

27.4 Results. The corrected (see Test Method 17) values determined by these measurements shall be compared with contract or design requirements, or shall be used in other computations.

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

a. The minimum and maximum allowable resistance values for each component tested, if applicable.

b. The standard temperature to which these measurements are to be corrected, if applicable.

TEST METHOD 28

OPEN CIRCUIT SATURATION CURVE TEST

28.1 General. The open circuit saturation curve is used by design engineers in conjunction with the short circuit and zero power factor saturation curves to determine certain performance characteristics of the generator under various load conditions. It is used also in comparison with data obtained from tests on production models as a check to ascertain that the quality of the iron or the length of the air gap in the production generators has not been changed from that of the first article model.

28.2 Apparatus. Instrumentation for measuring terminal voltage, generator speed, exciter field voltage and current (generator field voltage and current, if applicable) shall be as described this standard (unless otherwise specified in the contract). In addition, a prime mover having a steady state speed regulation not greater than ±1 percent of rated speed and a separate, variable dc source for excitation shall be required. A voltmeter or digital measuring equipment having an accuracy of ±0.5 percent of the reading or better shall be required for measuring the terminal voltage.

28.3 Procedure.

28.3.1 Preparation for test.

a. Mechanically connect the generator to the prime mover and provide the external excitation supply to the generator. Observe correct polarity when connecting the dc supply to field windings.

b. Connect the instrumentation for the applicable voltage connection.

28.3.2 Test.

a. Start and operate the prime mover such that the generator is operating at rated speed, open-circuited and zero excitation. Read and record all instrumentation.

b. Increase the applied voltage to the field to increase the field current in steps from zero upward to give approximately 20, 40, 60, 80, 90, 95, 100, 105, 110, 120, and 130 percent of rated generator voltage (unless otherwise specified in the contract). Read and record all instrumentation at each step. All readings must be taken with rising field current and without interruption (see figure 28-I).

NOTE: Should it become necessary to decrease the excitation, the field current must be reduced to zero and then increased to the desired value.

c. When performing this test on three phase machines, readings should be taken of the terminal voltage (line-to-line) of all three phase to check phase balance. These readings should be made under constant conditions of excitation and speed, and with the same voltmeter.

28.4 Results. A curve of generator terminal voltage (vertical axis) versus exciter field current (and generator field current, if applicable) (horizontal axis) shall be plotted. If the knee of the curve is not well defined, repeat 28.3.2 taking additional readings as needed to better establish this portion of the curve. This curve is defined as the open circuit saturation curve (figure 28-II). Compare the results with the requirements of the requirements document.

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

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

b. Maximum value of no load exciter field current, if applicable.

c. Maximum value of no load generator field current, if applicable.

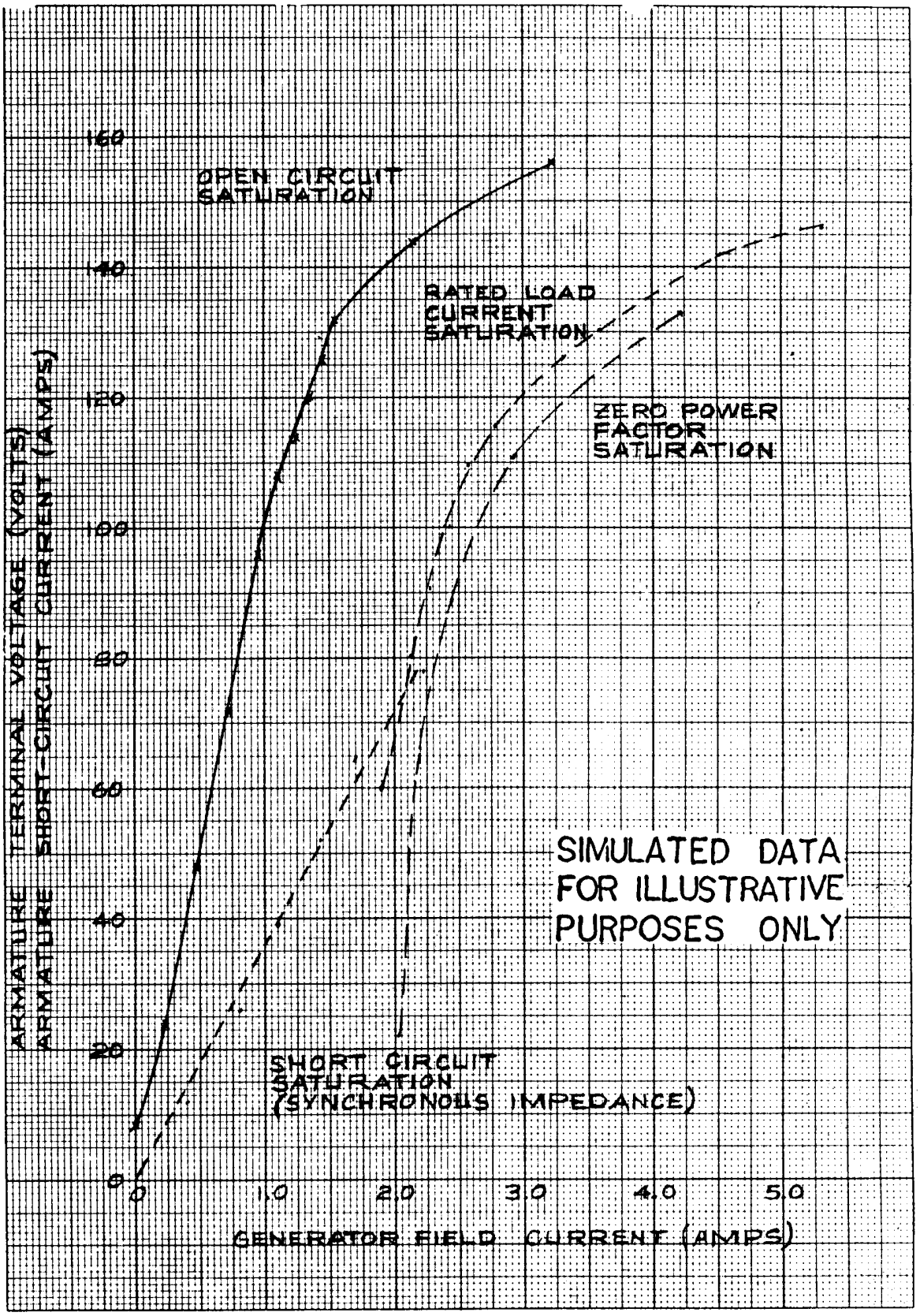

Figure 28-II: Family of saturation curves.

TEST METHOD 29

SYNCHRONOUS IMPEDANCE CURVE TEST

(SHORT-CIRCUIT SATURATION CURVE)

29.1 General. Synchronous impedance curves assist in determining the performance of an alternating current generator during periods of short circuit. The is information is needed to properly design protective devices and to assure designers that the air gap, coils and steel meet requirements.

29.2 Apparatus. Instrumentation for measuring line current, field voltage and current and generator speed shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, a prime mover capable of driving the generator at rated speed with the short-circuit applied and having a speed regulation not greater than ±1 percent of rated speed and a separate dc source for excitation shall be required. Instruments for measuring the field and short circuit currents shall have an accuracy of ± 0.5 percent of reading or better.

29.3 Procedure.

29.3.1 Preparation for test.

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

b. Connect the instrumentation for the applicable voltage connection.

c. Apply the short-circuit to the generator terminals through the ammeters.

NOTE: The short-circuit leads shall be as short as possible to reduce heating effects.

29.3.2 Test.

a. Start and operate the prime mover such that the generator is operating at rated speed, short-circuited and zero excitation. Read and record all instrumentation.

b. Increase the field current until 100 percent of rated current exists in each phase. Read and record the current in all three phases to check current balance. If the current is not balanced within ±1 percent of each other, or within the tolerance specified in the contract, the cause of the unbalance shall be located and corrected before proceeding with the test.

c. After the phase balance is determined to be satisfactorily within tolerance, increase the field excitation until 150 percent of rated current is present in each phase.

CAUTION: Do not maintain overload current long enough to cause generator overheating.

d. Record all instrument readings.

e. Reduce the field excitation in steps to obtain 125, 100, 75, 50 and 25 percent of armature current in each phase. Read and record instrument indications at each step. All readings shall be taken without interruption.

29.4 Results. A curve of generator armature short-circuit current (vertical axis) versus generator or exciter field current (horizontal axis) shall be plotted. This curve is defined as the synchronous impedance, or short-circuit saturation curve (figure 29-I). Compare the results with the requirements of the contract

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

a. The voltage connections) and speed(s) at which this method is to be performed.

b. The allowable current variation, if other than as specified herein.

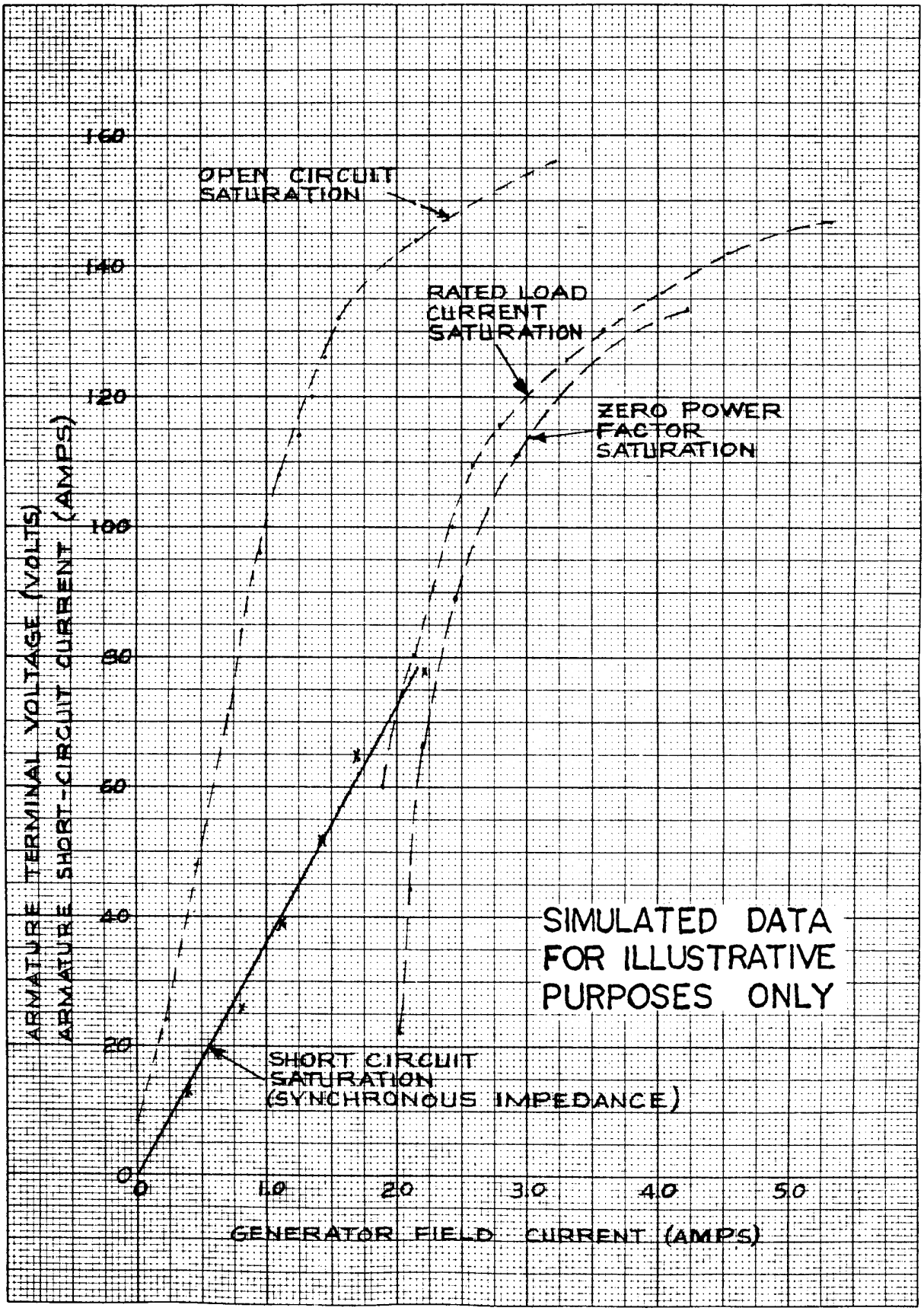

Figure 29-I - Family of saturation curves.

TEST METHOD 30

ZERO POWER FACTOR SATURATION CURVE TEST

30.1 General. The zero power factor saturation curve is used by design engineers in conjunction with the short-circuit and open-circuit saturation curves to determine certain performance characteristics of the generator under various load conditions. The family of generator saturation curves can be used to approximate the generator field current for any load condition.

30.2 Apparatus. Instrumentation for measuring load conditions and generator field voltage and current shall be as described in EGSA 107T (unless otherwise specified in the required document). In addition, a prime mover capable of maintaining constant rated speed of the generator under all load conditions of this method within ±1 percent and a source of dc power for generator excitation shall be required. Instruments for measuring the field current and terminal voltage shall have an accuracy of ±0.5 percent of reading or better. The power factor meter used shall be capable of indicating power factor to 0.3 lagging.

30.3 Procedure.

30.3.1 Preparation for test.

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

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

30.3.2 Test.

a. Start and operate the prime mover such that the generator is operating at rated speed with zero excitation. Adjust the low power factor load to minimum reactance.

NOTE: During all portions of this method the power factor of the load shall not exceed 0.40 and shall not be less than 0.30. Load current on polyphase generators shall be balanced.

b. Increase the field current until the generator is supplying rated load current.

c. Record all instrument readings.

d. Increase the load slightly, then increase the field current until the generator is again supplying rated load current.

e. Record all instrument readings.

f. Repeat steps d and e above to obtain at least seven equally spaced steps of terminal voltage up to and including 130 percent of rated voltage (unless otherwise specified in the contract). All readings shall be taken without interruption.

30.4 Results. A curve of terminal voltage (vertical axis) versus generator or exciter field current (horizontal axis) shall be plotted. This curve is defined as the zero-power-factor saturation curve (figure 30-II). Compare the results with the requirements of the contract.

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

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

b. The limiting terminal voltage, if other than as specified herein.

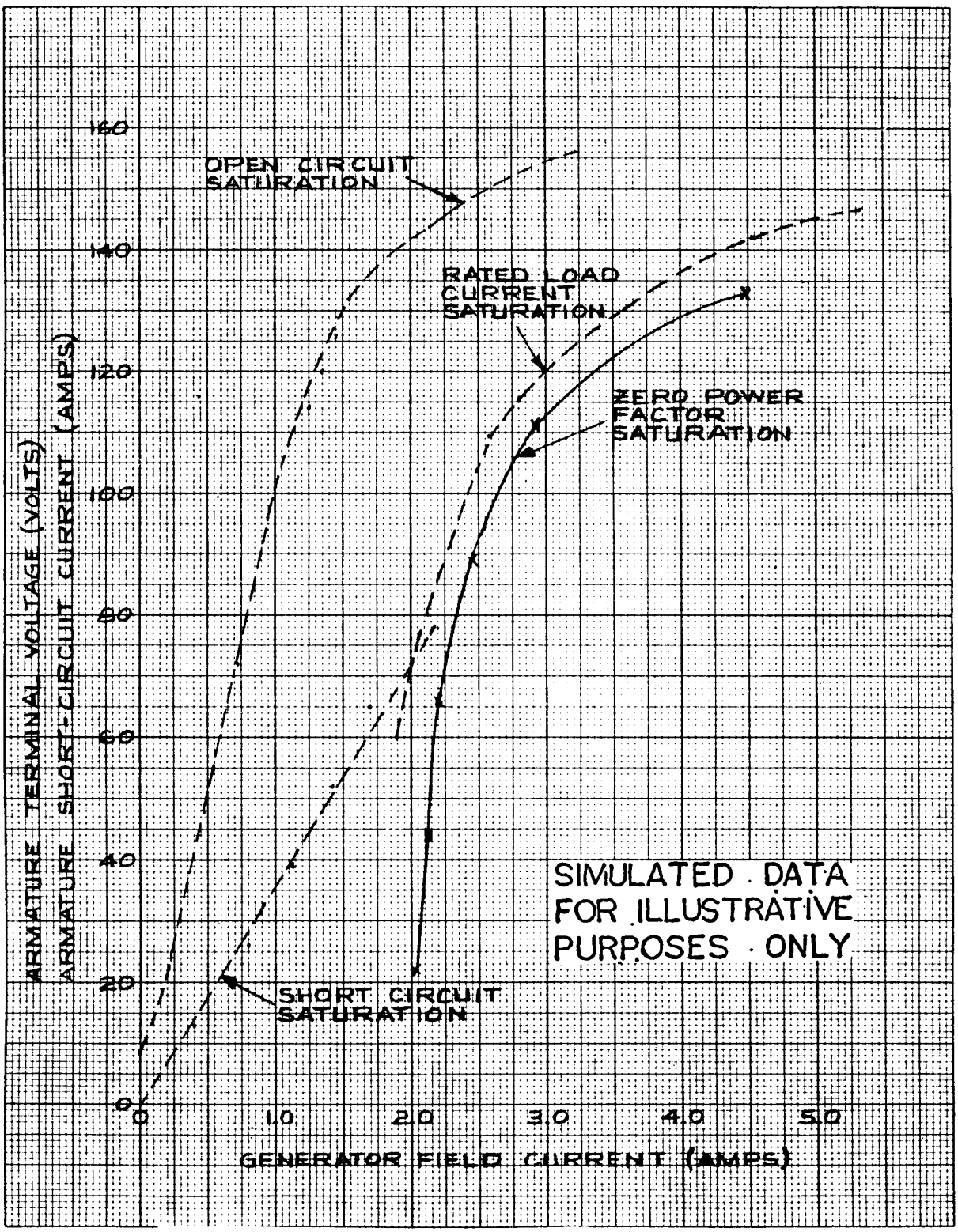

Figure 30-I - Family of saturation curves.