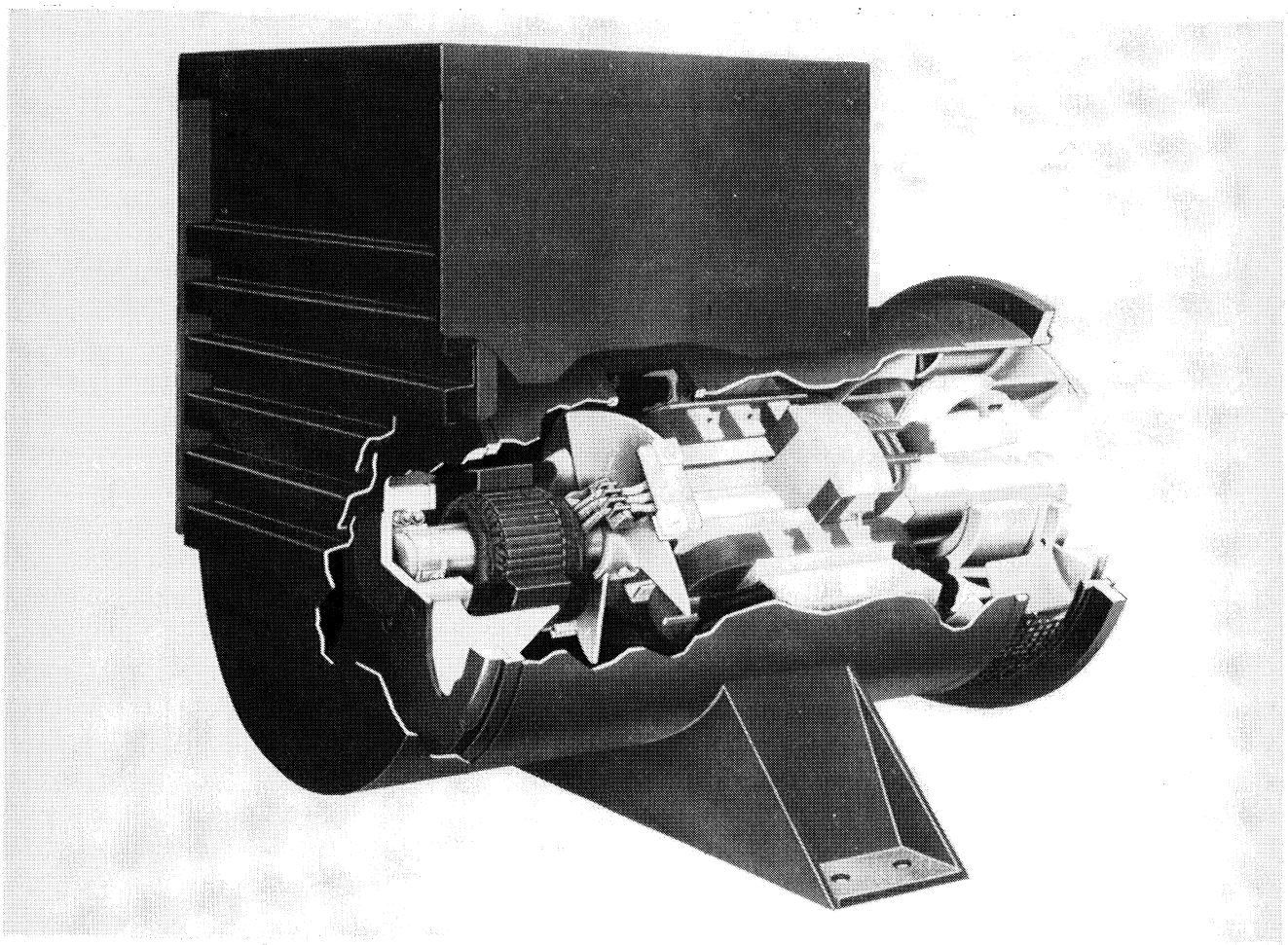
CATERPILLAR®

Special Instruction

Cleaning and Drying of Electric Set Generators 4450

All Caterpillar Generator Sets



SEHS9124-01 (5/93)

Introduction

Many electrical failures in generators are a result of a breakdown in the insulation. These breakdowns normally occur in specific locations. Current leakage through these locations causes a deterioration in the insulation. This deterioration causes a lower resistance to high voltage that eventually allows a short circuit.

Another problem is the potential risk of stator failure for generators stored or operated in contaminated and/or humid environments. Problems can develop in the generator windings when dust, water, salt, or grease is present, or any time the generator windings are below the dew point.

Contaminants such as dirt, dust, grease, oil films, salt and water should not be allowed to accumulate on the stator windings. These conditions increase the risk of moisture collecting in the windings. Moisture can provide a conductive pathway between bundles of wire. When this occurs, current will leak from the higher voltage bundle to the lower voltage bundle. The current leak produces heat and causes a breakdown and charring of the winding insulation. If the problem goes undetected, the windings may be severely damaged.

This publication will give some testing and maintenance procedures that may be carried out in the field that will remove or reduce potential problems with insulation as well as some preventative maintenance activities that will reduce the risk of stator failure for generators stored or operated in contaminated and/or humid environments.

REFERENCE: Service Manual, Operation & Maintenance Manual, *Operating Manual for 4C4213 Insulation Tester,* Form NEHS0528; Caterpillar Engine Data Sheet 78.3 *(Generator Space Heaters),* Form LEKX6351; AIEE STD #43 *Recommended Practice for Insulation Testing of Rotating AC Machinery. Form SEBD0660; Operating Environment-And Its Effect on SR4 Generators.*

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Safety

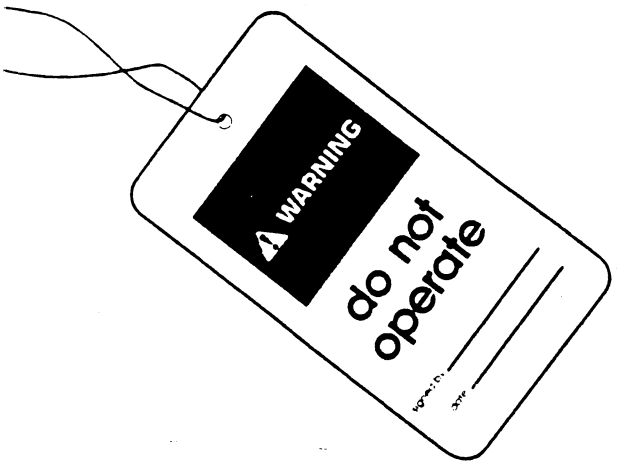
⚠ WARNING

When servicing or repairing electric power generation equipment:

Make sure the unit is off-line (disconnected from utility and/or other generators power service), and either locked out or tagged DO NOT OPERATE. * Remove all fuses.

- **Make sure the generator engine is stopped.**
- **Make sure all batteries are disconnected.**
- **Make sure all capacitors are discharged.**
- **Failure to do so could result in personal injury or death.**
- **Make sure residual voltage in the rotor, stator and the generator is discharged.**

Attach a "DO NOT OPERATE" or similar warning tag to start switch or controls before performing any service or repairs.



NOTE: "DO NOT OPERATE" tags are available from Caterpillar. Order Form SEHS7332.

⚠ WARNING

When power generation equipment must be in operation to make tests and/or adjustments, high voltage and current are present.

• Improper test equipment may fail and present a high voltage shock hazard to its user.

• Make sure the testing equipment is designed for and correctly operated for high voltage and current tests being made.

Necessary Tools

Use a megohmeter ("megger") such as the 4C4213 Insulation Tester, or equivalent, for checking insulation resistance.

This tester applies a nominal insulation testing voltage of 500 VDC, which is recommended, to test insulation resistance for most applications of Caterpillar Generator Sets.

New Equipment

Storage

After a new generator arrives on site it should be protected against moisture until it is installed.

When a generator is in storage, moisture condenses in the windings. To minimize condensation, always put the generator in a dry storage area.

When the generator is placed in storage, it is necessary that a megger insulation resistance check be performed and the results recorded. The temperature and level of humidity should also be recorded. This check will provide a baseline for future reference.

NOTE: It is important that this baseline be established when the unit is dry.

To guard against collective contaminants, the generator should be covered with a plastic cover or similar type of protective cloth. The protective cover should extend to the ground, but remain loose around the generator in order to allow the generator to properly breathe.

Caterpillar recommends maintaining the insulated parts and the air surrounding them at a temperature of at least 5° C (9°F) higher than the room temperature in which the equipment is located. This will prevent condensation. Normal methods of providing the heat required are:

1. Space heaters.

2. Warm air blower. Do Not exceed 206.7 kPa (30 psi).

3. Light bulb (60 Watt minimum) installed inside the generator in proximity to the stator core at the lowest possible location.

It is important that the shaft be rotated 10 revolutions every 60 days throughout the storage period. This process helps to insure that grease continues to cover all bearing surfaces.

Removal from Storage

Operate space heaters for at least 24 hours prior to removing covers.

Remove all protective covers. Reseat the brushes on the slip ring for SRCR generators.

Before startup of a generator, visually inspect the generator for any foreign material such as rodents, etc. that may have nested in the generator. Use a megohmeter to check insulation resistance for moisture and/or foreign material. Refer to the Service Manual for the procedure.

A resistance reading with a 50% reduction from the reading recorded when the unit was placed in storage, or 30 megohms for a new unit is an indication that the winding has absorbed too much moisture. Clean as necessary according to the instructions in this Special Instruction.

Checking the Equipment

While there are many different types of checks that may be performed on generators to determine their condition, the ones outlined in this publication are relatively easy to do and offer a good evaluation.

Visual Checks

The generator should be checked periodically for any accumulation of dust, water, salt, grease, or oil films. Clean as necessary according to the instructions included in the topic entitled *Normal Cleaning.*

NOTE: Windings must be kept clean and dry. Any accumulation of dirt will trap moisture. This moisture will reduce the insulation's dielectric strength, causing the insulation to fail.

Insulation Resistance Checks

The environmental and operating conditions in which the generator is operating will determine how often the megger insulation resistance checks should occur. You must be confident the readings are not changing more rapidly than the frequency selected before determining a preventative maintenance schedule. Megger insulation resistance check must be performed a minimum of once a year.

Generators that work seasonally should be tested and inspected prior to being placed back in service.

If the generator is installed in an enclosed building with relatively low humidity and minimal temperature variations, test the insulation every year.

If the above conditions are not met, the insulation tests should be made every three months.

If the generator is in or near a sea water environment, or in a high humidity (above 75% relative humidity) environment, test the insulation every month.

If the most recent test results were less than 3 megohms, increase the frequency of the insulation test.

The use of a space heater is recommended whenever the unit is not running. Even generators that cycle on and off within a 24 hour period should use space heaters during the off hours.

Things to Consider when Making the Tests

Good results from the insulation resistance tests do not guarantee that the unit will not fail. Certain conditions will give acceptable (or even high) insulation resistance values but the unit may still fail. These tests do, however, give a good indication of when cleaning and/or repairing is becoming more critical.

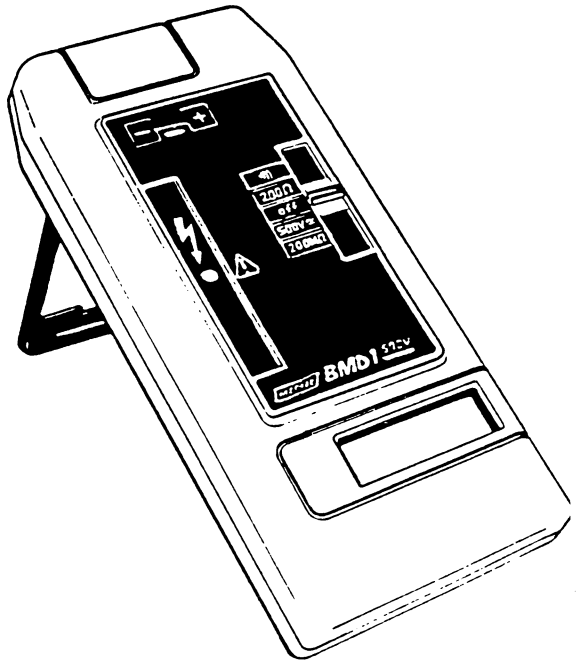
Generally insulation resistance will vary greatly with temperature. Tests should be made at the same temperature and humidity (as near as possible) each time.

A permanent record of the temperature of the unit should be kept along with the values of the insulation readings.

Making the Insulation Resistance Tests

⚠ WARNING

An incompletely discharged capacitor can cause a spark. This can result in personal injury or property damage. Do not use the 4C4213 Insulation Tester in an explosive atmosphere.



Caterpillar recommends the 4C4213 (or an equivalent) Insulation Tester for checking insulation resistance on Caterpillar Generator Sets. Refer to NEHS0528, *Operating Manual for 4C4213 Insulation Tester* for operating instructions.

- Carefully follow the manufacturer's instructions for connecting any megohmeter to the electrical system.

The circuit which is to be the subject of the test must be switched off before connecting the test leads.

Disconnect any grounds, loads, meters, and controls before performing a megohm check. Connect all the sections of the stator windings together in the normal high or low voltage connections.

Connect one lead of the megohmeter in turn to each of the stator windings, with the other megohmeter lead on the generator frame.

NOTE: If the voltage regulator is connected, and a resistance problem is found, disconnect the regulator to verify that it is not affecting the readings.

⚠ WARNING

The megohmeter is applying a high voltage to the circuit. To avoid serious injury or death by electrocution, do not touch the instrument leads without first discharging them. When finished testing also discharge the generator windings.

Before checking the exciter field winding;

- disconnect the exciter field leads, F1 and F2, from the regulator.
- Connect one megohmeter lead to either the F1 or the F2 field lead and ensure the other lead, F1 or F2, is not touching anything.
- Connect the other megohmeter lead to the generator frame.

Recommended Megger Insulation Test Procedure for Main Stator

1. Take generator out of service.

2. Visually inspect for moisture. If moisture exists, do not megger. Dry unit first. Refer to the drying procedure in this Special Instruction.

3. Inspect installation to determine what equipment will be tested by the 4C4213 Megger.

4. Discharge the capacitance of the windings.

5. Disconnect T0 from ground.

6. Disconnect regulator sensing lead wires 20, 22, 24.

7. Connect megger tester RED lead to ground (+).

8. Connect megger tester BLACK lead T0 (–).

9. Set voltage for 500 Volts for units that are 600 volts or less.

Set voltage for 1000 Volts for units that are 600 volts or more.

10. Use the 30 – 60 time resistance method.

(a) Apply voltage.

(b) Observe the readings at 30 seconds and again at 60 seconds.

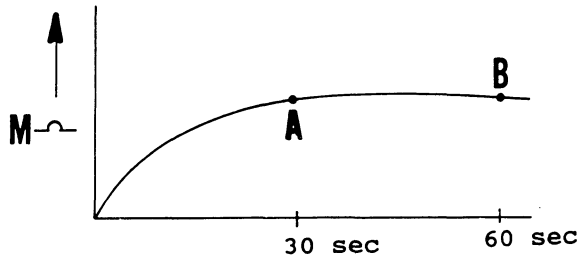
(c) Record the 60 second reading. This reading must be corrected for temperature.

(d) Record temperature.

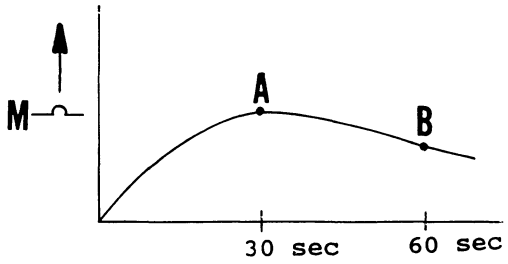
(e) Record humidity.

(f) Remove voltage.

11. Evaluate readings. The actual value of the resistance may vary greatly from one generator to another. For this reason, the insulation condition must be evaluated based on how the 60 second resistance readings compare to the readings taken on previous dates (under similar conditions). A 60 second resistance reading with a 50% reduction from the previous reading, indicates that the insulation may have absorbed too much moisture.



The illustration above shows the resistance curve of normal high resistance windings over a period of one minute. The resistance after one minute will be greater than or equal to the resistance after 30 seconds.



The illustration above shows the resistance curve decaying over a period of one minute. If the insulation resistance after one minute is not higher than the resistance after 30 seconds, the windings should be cleaned and thoroughly dried. Refer to the methods covered in the topics on cleaning and drying.

12. Discharge leads and windings before disconnecting megger leads by switching megger to "off".

NOTE: Results from the insulation resistance checks give a good indication of when cleaning and/or repairing is becoming more critical.

Generally insulation resistance will vary greatly with temperature. Tests should be made at the same temperature and humidity (as near as possible) each time.

Evaluating the Test Readings

The actual value of the resistance may vary greatly from one generator to another. For this reason, the insulation condition must be evaluated based on how the resistance readings compare to readings taken on previous dates (under approximately the same conditions of temperature and humidity) for the same generator.

The cause should be determined if the measurements show a wide variation from previous readings (under similar test conditions). The abnormal conditions should be corrected before an insulation failure occurs.

If the resistance levels can be brought up to acceptable levels, the windings can then be resealed by dipping them in a tank of insulation varnish.

NOTE: Caterpillar recommends that the minimum acceptable insulation resistance, for operating generators with less than 1000 volts of operating or rated voltage, is one megohm.

Operating generators, with more than 1000 volts of operating or rated voltage, should have a minimum insulation resistance of **at least (Rated V/1000) + 1 megohm** . These values are approximate; it may be possible to operate a generator with less resistance.

For new units being placed into service, the resistance reading should be greater than 30 megohms.

Periodic megger readings should establish a trend in insulation deterioration. Resistance readings that trend downwards greater than 50% of prior readings may indicate an abnormal condition. Even though the resistance reading is greater than Caterpillar acceptable insulation resistance criteria, an abnormal condition may exist.

If the Caterpillar minimum acceptable insulation resistance readings cannot be obtained after cleaning and drying the generator windings, the insulation has probably deteriorated and should be reconditioned by a qualified electrical shop.

Normal Cleaning

Contaminants such as dirt, dust, grease, salt or oil films should not be allowed to accumulate on the windings.

Before cleaning, test to see if the insulation is in good condition. See the previous topic entitled *Making the Insulation Resistance Tests.*

Generators may be cleaned by normal methods such as; wiping, vacuuming, washing, steam cleaning or with filtered pressure air, 135 - 205 kPa (20 - 40 psi). Generators that have been submerged, flooded, or completely filled with dirt may be cleaned by the methods covered in the topic *Extreme Cleaning.*

⚠ WARNING

Regardless of the cleaning method used; to avoid serious injury or death, be sure there is no voltage applied to the windings and the engine can not be started. Serious injury or death may result.

Wiping

1. If the unit is small enough and the dirt on the exposed parts is dry, wiping with a dry lint-free cloth is acceptable.

NOTE: The cloth must be lint-free or the lint will adhere to the insulation and collect dust, moisture and oil. This is particularly unacceptable on high-voltage insulation.

2. Completely dry the unit according to the topic entitled *Drying* in this publication.

Vacuuming

1. Dry contaminants may be removed by vacuuming. A soft-bristle brush may be used to loosen the dirt before or during vacuuming.

2. Completely dry the unit according to the topic entitled *Drying* in this publication.

Washing

While a shop environment is more desirable, this may be done in a dealer shop (or in the field), if drying equipment is available. See the topic entitled *Drying*, in this publication, to determine what equipment is needed.

⚠ WARNING

Because of the volatile nature of many cleaning solvents, extreme caution must be exercised when using them. If unsure about a particular cleaning fluid, refer to the manufacturer's instructions and directions. Always wear protective clothing and eye protection when working with cleaning solvents.

NOTICE

Read and understand the information on the container label before using. A cleaner that is nonflammable and safe for all ferrous and nonferrous parts should be used. The cleaner should be readily removable with water.

A water soluble liquid emulsion cleaner such as Hydrosolv 67® may be used to clean generators. The concentration level (of Hydrosolv 67®) may be varied from 5 to 100% as needed to remove all foreign material.

NOTE: Other solvents (such as Stoddard solvents) may be used. Refer to National Institute of Standards and Technology, a United States Government Agency. Telephone (301) 975-2000. The N.I.S.T standard is NBS Standard P-D-680 entitled *Dry Cleaning and Degreasing Solvent.*

1. Cleaning should be done as rapidly as possible to avoid long periods of exposure of the insulation to the solvent. Rinse with fresh warm water.

2. Wipe off excess moisture with a clean dry cloth.

3. Bake dry in an oven before placing back in service. See the topic entitled *Drying* in this publication.

Steam Cleaning

Steam cleaning should only be done in the case of very dirty and greasy windings.

1. Clean the generator with a steam cleaning unit operating at a pressure of 0.1 - 0.2 MPa (15 - 30 psi) and a temperature of 121 - 149°C (250 - 300°F).

NOTICE

After steam cleaning, a complete drying and revarnishing are required before the unit is placed back into service. Use a qualified electrical rebuild shop.

2. Bake the unit in an oven to remove moisture before revarnishing.

3. The windings must be revarnished.

4. Bake dry in an oven before placing back into service. See the topic entitled *Drying* in this publication.

Pressure Air

This is the least desirable method of cleaning. It can, in some instances, relocate the dirt rather than remove it.

⚠ WARNING

When using pressure air, wear a protective face shield and protective clothing. The maximum air pressure at the nozzle must be below 205 kPa (30 psi) for cleaning purposes.

NOTICE

Never aim the air directly against the insulation without first removing all of the moisture from the insulation.

Dirt blown into some areas of the generator may cause damage.

1. Using 135 - 205 kPa (20 - 30 psi) filtered dry air, carefully blow the dirt out of the windings

2. Completely dry the unit according to the topic entitled *Drying* in this publication.

Extreme Cleaning

This method is for electrical equipment that has been completely submerged, flooded or filled with dirt.

NOTE: Even with the best treatment and careful testing, a generator that has been submerged sometimes fails when put back into service.

NOTICE

The pressure of the water must not exceed 172 kPa (25 psi) when used for cleaning purposes.

1. Flush with fresh warm water to remove all traces of salt and silt. Washing should continue until salinity tests of the fresh water show the insulation to be free of salt.

NOTE: It may be necessary to disassemble the generator completely to accomplish proper cleaning.

2. Bake and dry the unit completely with externally applied heat before placing back into service. Revarnish, if necessary, to seal the windings.

NOTE: If the generator is used in or near a salt air and/or high humidity environment, special electric component cleaners and protectors may be needed to prevent corrosion. Contact your local dealer for recommendations.

Drying

Drying may be accomplished by external heat, internal heat, a combination of internal and external heat, or circulating current.

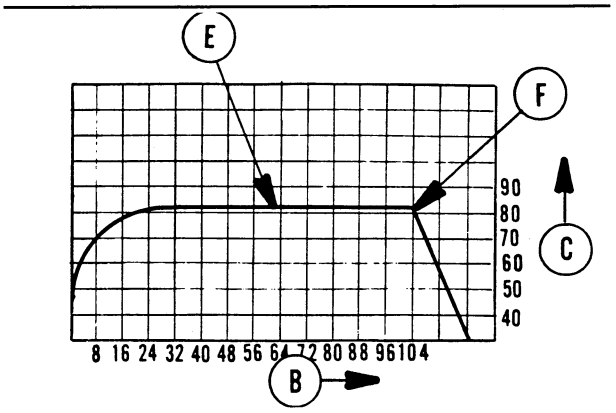
NOTICE

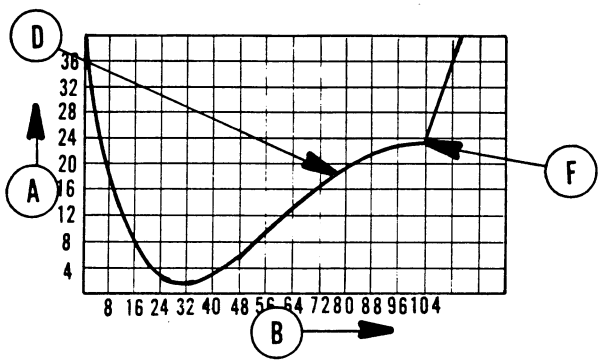
When using external heat to dry the generator, do not exceed 75°C (167°F).

External heat is the most desirable method. Insulation drying time can vary from a few hours to several days depending on the moisture content and the drying process used.

NOTE: Drying sometimes does not produce the required results. It may be necessary for the generator to be dipped and baked by a qualified rebuild shop.

Typical insulation drying curves are shown in the two illustrations below.





(A) Insulation Resistance in Megohms. (B) Hours Drying Time. (C) Temperature °C. (D) Insulation Resistance Curve. (E) Temperature Curve. (F) Heat Turned Off.

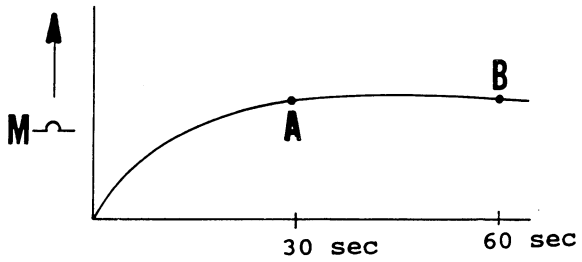
NOTE: When new (or very damp) insulation is being dried, the resistance will probably fall rapidly as the temperature is raised to a drying value. After reaching a minimum for a given temperature, the resistance will again rise as moisture is driven out of the insulation. The actual values will vary with each situation.

When measuring resistance on wet windings or insulation use a five megohm protective resistor in series with red (+) lead to limit the voltage across the circuit under test. Use this method until drying is well under way and the resistance has reached an acceptable level.

During the drying period check the windings every four hours (every hour when using the circulating current method) with a 60 - second megohmeter test.

Observe each insulation resistance reading for at least one minute. If the resistance decays during that minute, the winding needs to be cleaned and thoroughly dried.

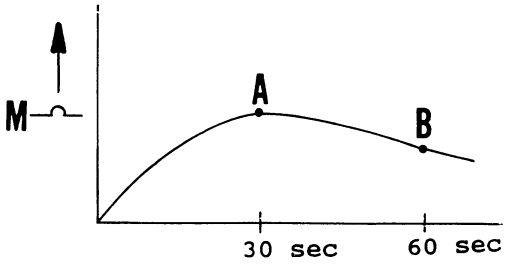
Drying is complete when the tests show no increase in resistance and the resistance is above the minimum. Record and compare these readings. Keep these records for future reference.



Windings in good condition.

The illustration above shows the resistance curve of normal high resistance windings over a period of one minute. The resistance after one minute will be greater than or equal to the resistance after thirty seconds.

NOTE: If the insulation resistance after one minute is not higher than the resistance after 30 seconds, the insulation may be weak.



Wet or dirty windings.

The illustration above shows the resistance curve decaying over a period of one minute.

In general, minimum acceptable insulation resistance for generators with less than 1000 volts of operating or rated voltage is one megohm.

Any generator with more than 1000 volts of operating or rated voltage should have a minimum insulation resistance of **at least (Rated V/1000) + 1 megohm** . These values are approximate; it may be possible to operate a generator with less resistance.

External Heat

Ovens

A forced air type oven is the best for drying electrical equipment. Radiant ovens sometimes cause localized overheating.

NOTICE

Do not heat the generator too quickly. Try to limit the temperature rise of the insulation and windings to 6.7°C (20°F) per hour.

NOTE: Many good electrical shops are equipped with baking ovens.

Heat the generator to approximately 75°C (167°F) [never exceed 75°C (167°F)] until it tests correctly for insulation resistance (at least four hours).

Alternate Method

Tarpaulins forming a tent in conjunction with heat lamps or a portable space heater may be used. A hole should be left in the top of the tarp to ensure proper circulation through the generator and to permit moisture to exhaust.

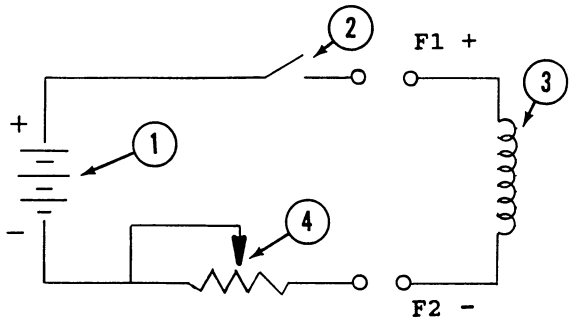
Heat the generator to approximately 75°C (167°F) [never exceed 75°C (167°F)] until it tests correctly for insulation resistance (at least four hours).

Internal Heating

If the generators are in damp environments and they go for long periods of time without operation; or, if they are operating regularly in a moisture-laden environment; they should have electric space heaters installed as part of the generator. Refer to Caterpillar Engine Data Sheet 78.3 Form LEKX6351 for additional information.

Circulating Current

Drying can be accomplished by circulating low voltage current through the windings. Since the voltage is low, insulation breakdown will not occur as it might with normal operation and wet insulation.



External Power Source Schematic. (1) Battery (12 Volt DC). (2) Switch. (3) L1 - exciter field being dried. (4) Rheostat -- 15 ohm, 25 watt.

1. Disconnect wires **F1 and F2** from the voltage regulator with the engine stopped.

2. Disconnect the generator load and open the breaker.

3. Connect the generator output leads **T1, T2 and T3** together.

4. Install a clamp-on type AC current probe to generator output lead **T1**.

5. Adjust rheostat (4) to give maximum resistance.

6. Connect the external power source to wires **F1+** (plus) and **F2-** (minus). [Switch (2) is open.]

7. Run the generator set at idle speed. (Residual voltage will cause current to circulate within the generator windings.)

NOTICE

Do not exceed the rated line current listed on the generator nameplate. The windings can be easily damaged if the rated line current is exceeded.

8. While monitoring the **line current** , slowly increase the rpm until the rated **line current** is obtained or until the full generator set speed is obtained.

NOTE: When measuring **line current** on multiple lead units, measure the current in each conductor per phase and add the currents together.

9. If the generator reaches full speed and more **line current** is still necessary, run the generator at idle speed, close switch (2), and slowly turn rheostat (4) until the rated phase current is obtained.

10. Continue running current at these settings for one hour, then stop the drying procedure. Test the insulation resistance with a 60 - second megohmeter test. Observe each insulation resistance reading for at least one minute.

If the resistance decays with time the winding needs to be cleaned and thoroughly dried to determine the drying trend. Record and compare these readings. (Keep these records for future reference).

11. Repeat steps 5 through 10 until the insulation resistance tests correct.

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