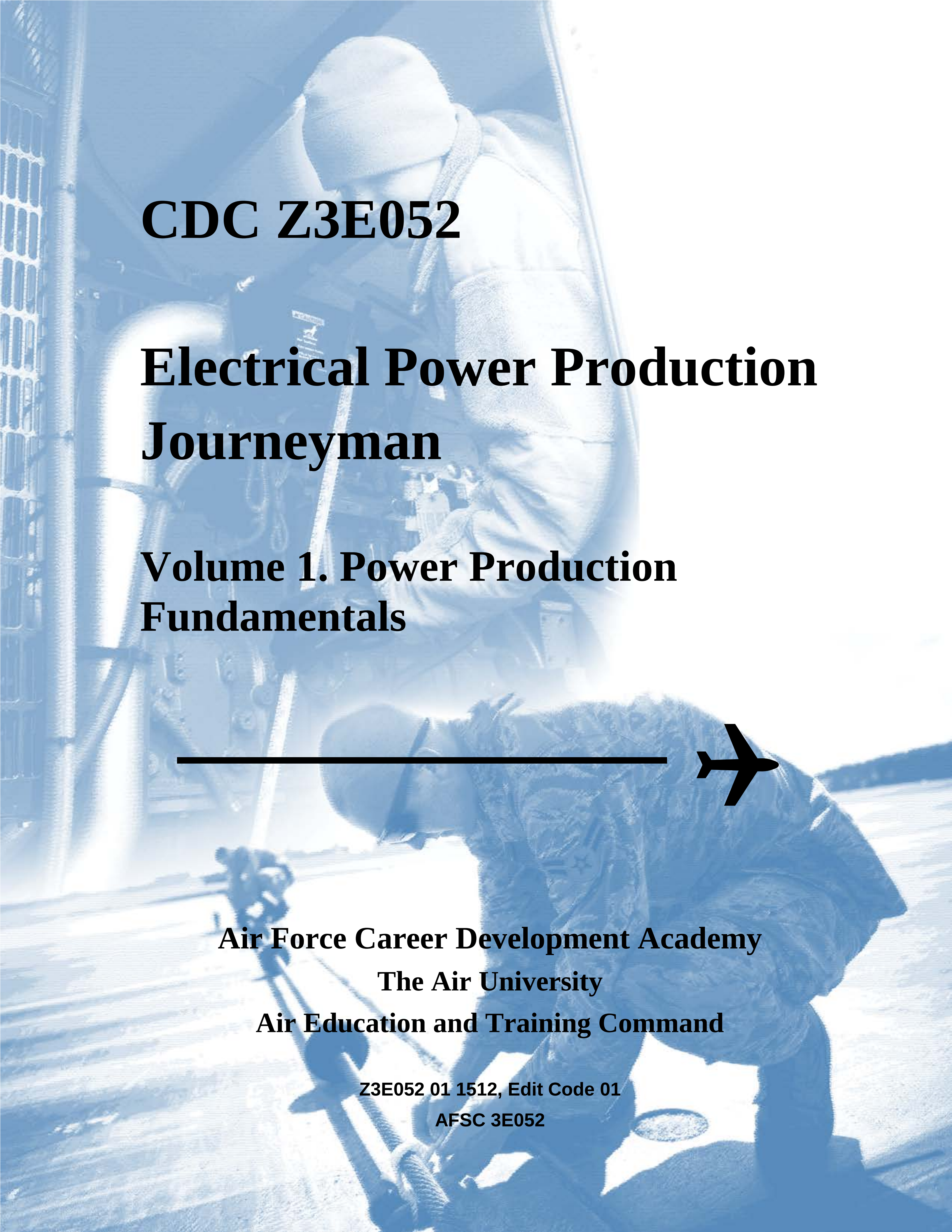

# CDC Z3E052

# Electrical Power Production Journeyman

## Volume 1. Power Production Fundamentals

**Air Force Career Development Academy**
**The Air University**
**Air Education and Training Command**

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Material in this volume is reviewed annually for technical accuracy, adequacy, and currency. For SKT purposes the examinee should check the *Weighted Airman Promotion System Catalog* to determine the correct references to study.

CONGRATULATIONS on achieving your 3-skill level graduating from the Electrical Power Production Apprentice Air Force Specialty basic course. You are now in the beginning stages of your upgrade training towards a 5-skill level within your Air Force specialty code. Achieving your 5-skill level is the next milestone on your journey of career progression as an electrical power production journeyman.

After completing this 3E052, Electrical Power Production Journeyman, career development course (CDC), along with on-the-job training, you will be awarded your 5-skill level. This is a five volume course which covers various areas important to your job as an electrical power production journeyman. Volume 1 covers career field fundamentals. Volume 2 introduces you to electrical systems. Volume 3 covers engine, fuel, lubricating, cooling, and intake and exhaust systems. Volume 4 introduces you to aircraft arresting systems. Lastly, volume 5 explores contingency operations and provides you with information you need to perform your duties in a contingency environment.

Volume 1 introduces you to the fundamentals of power production. Unit 1 covers safety in and around energized circuits and AFSC and technical publications. Unit 2 covers special tools (hand tools and soldering guns) and electronic diagnostic devices and specialty testing devices. Unit 3 covers support equipment, (such as battery chargers and load banks), and corrosion control and winter starting aids for generators. Unit 4 describes how to operate permanently installed generators and mobile generators. It also shows how to calculate kilowatts and amperages in single and three-phase circuits.

As an electrical power production journeyman, you have stepped into one of the most important career fields in the Air Force, and we depend on you to uphold the long standing excellence that has come before you.

A glossary is included for your use.

Code numbers on figures are for preparing agency identification only.

The use of a name of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force.

To get a response to your questions concerning subject matter in this course, or to point out technical errors in the text, unit review exercises, or course examination, call or write the author using the contact information on the inside front cover of this volume.

**NOTE:** Do not use the IDEA Program to submit corrections for printing or typographical errors.

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This volume is valued at 12 hours and 4 points.

# Acknowledgment

Preparation of this volume was aided through several industry partners. The Fluke Corporation, Greenlee/A Textron Company, Associated Equipment, and HOTSTART Inc. provided both graphical and literature support and their cooperation is greatly appreciated.

| Company | Figure(s) |
|---|---|
| Fluke Corporation | 2–13 through 2–21, 2–24 and 2–25 |
| Greenlee/A Textron Company | 2–22 |
| Associated Equipment | 2–23 |
| Kim HOTSTART | 3–04 |



**NOTE:**

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

# Unit 1. Safety and Technical Publications



POWER PRODUCTION IS a very diverse career field. During your time as an Electrical Power Production Journeyman, you will work on electrical and mechanical systems. This volume will cover many of the tasks and pieces of equipment that you will encounter on a regular basis.

This unit will cover safety and the Air Force Specialty Career (AFSC) field forms and technical publications (TO) you will use while working with generators.

## 1–1. Safety

You will be working around electrical equipment throughout your career in power production. You need to know how to prevent getting shocked or electrocuted. Getting yourself tied into an energized circuit will not be the highlight of your day. You also need to know what to do if one of your co-workers gets shocked. The next few paragraphs will provide you with information that can save your and your co-workers' lives.

### 001. Working around energized circuits

Voltages are different around the world. The most common voltage and frequency in the United States is 120 volts, alternating current (VAC), 60 Hertz (Hz). As little as one tenth of an amp (0.1 A), or one hundred *milliamperes* (100 mA), of current can kill you. Power production personnel routinely produce and work with voltages from 120 up to 4160 VAC and currents from 100 mA and up. Use the chart below to find out what kind of effect specific amperages can have on the human body.

| SPECIFIC AMPERAGES EFFECT ON THE HUMAN BODY | |
|---|---|
| **Current** | **Body Response** |
| .007 – 5 mA | Start to feel the energy, tingling. |
| 5 – 15 mA | Experience pain, muscle contraction. |
| 15 – 50 mA | Grip paralysis threshold (brain says let go, hand will not listen) |
| 50 – 100 mA | Respiratory system shuts down. |
| 100 – 300 mA | Heart fibrillation. |
| 300 – 700 mA | Heart clamps tight, full contraction with no rest. |
| 700 – 2,000 mA | Tissue and internal organs burn. |

Air Force instruction (AFI) 91–203, *Consolidated Air Force Safety Standard,* states that you will normally de-energize electrical circuits and equipment before performing maintenance *except* as necessary to support a critical mission, prevent injury to persons, or protect property. This instruction also requires that when you *must* work on an energized circuit, a *minimum* of two people who are fully qualified for energized, or "hot," work *must* be present. Regardless of what you must do if you work on energized circuits, the *safest* way to do your business is to de-energize all circuits regardless of the voltage. Always treat circuits with maximum respect, as energized, or "hot," until you double-check. Only the Base Civil Engineer can authorize work on energized circuits and or equipment.

### Power production electrical standards

There is a variety of electrical safety standards for power production. Some are AFIs while others are unified facility criteria (UFC) along with commercial standards such as the National Fire Protection Agency (NFPA) 70E, Standard for Electrical Safety in the Workplace. The table below gives a description of these standards:

| ELECTRICAL SAFETY STANDARDS | |
|---|---|
| **Standard** | **Description** |
| AFI 91–203 | This is the Air Force consolidated safety standard. It covers everything safety including working around energized circuit. |
| AFI 32–1064, Electrical Safe Practices | This is the instruction for electrical safe practices as it relates to civil engineering. |
| UFC 3–560–01, Electrical Safety, O&M | This document covers operations and maintenance (O&M) of electrical systems and applies to all branches of the Department of Defense (DOD). |
| NFPA 70E | This is the National Fire Protection Association's commercial standard for electrical safety in the workplace. |

### Arc flash safety

When working around energized circuits, one of the most important hazards to be aware of is the danger of an arc flash. An arc flash is the result of the passage of electric current through air, the air failing as an insulator but serving as a conducting medium. Blasts result when the metal at the arc site expands and vaporizes. High-energy arcs can be fatal even at distances of 10 feet (ft) or more.


**Figure 1–1. Arc flash warning label.**

Arc flash warning labels (fig. 1–1) must be on electrical equipment likely to require examination, servicing, or maintenance while energized. Some typical types of equipment include pad-mounted transformers, switchgear, switchboards, panel boards, disconnect switches, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling occupancies.

When working around energized circuits, you must be aware of the approach limits and boundaries involved. They are the arc flash boundary, limited approach boundary, restricted approach boundary, and prohibited approach boundary.

#### *Arc flash boundary*

The distance from an arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault on the surface of the skin is 1.2 calories per centimeter squared (cal/cm2) or 5 joules per centimeter squared (J/cm2). Within this boundary, workers are required to wear appropriate personal protective equipment (PPE) clothing. The minimum flash protection boundary must be 10 ft for voltages up to 750 volts, and 20 ft for voltages greater than 750 volts. Only qualified workers wearing appropriate PPE are permitted to be within this boundary.

#### *Limited approach boundary*

A *limited* approach boundary is a shock protection boundary to be crossed by only qualified personnel (at a distance from a live part). Unqualified personnel will not cross the shock protection boundary unless escorted by qualified personnel.

### *Restricted approach boundary*

A *restricted* approach boundary is a shock protection boundary that will only be crossed by qualified personnel (at a distance from a live part) that, due to its proximity to a shock hazard, requires the use of shock protection techniques and equipment when crossed.

### *Prohibited approach boundary*

A *prohibited* approach boundary is a shock protection boundary to be crossed by only qualified personnel (at a distance from a live part) that, when crossed by a body part or object, requires the same protection as if direct contact is made with a live part.

## Prohibited clothing items

Clothing made from synthetics, such as acetate, nylon, polyester, or rayon, either alone or in blends, is unsafe for work on or near energized electrical circuits or equipment over 50 volts. Synthetics can melt when exposed to electric arcs or open flames and increase the extent of injuries.

Consult applicable AFI, UFC, or commercial standard for Arc Thermal Performance Value (ATPV) ratings, PPE requirements, and more information regarding Arc Flash.

## Lifting heavy loads

Workers often hurt themselves while picking up heavy equipment and toolboxes. If your toolbox is too heavy to carry comfortably, divide the tools into two or more boxes that are easier to handle. Use common sense in moving objects. If an object is too heavy or cumbersome to lift, ask someone to help you. If you decide you can lift a heavy load, use the proper lifting technique to do it.

To prevent a serious back injury *use your legs—not your back* to lift a heavy or bulky object from the floor. An injured back heals very slowly and keeps you from participating in many work and athletic activities. If you take the following precautions in lifting (shown in fig. 1–2), you can greatly reduce your chances for an injury:

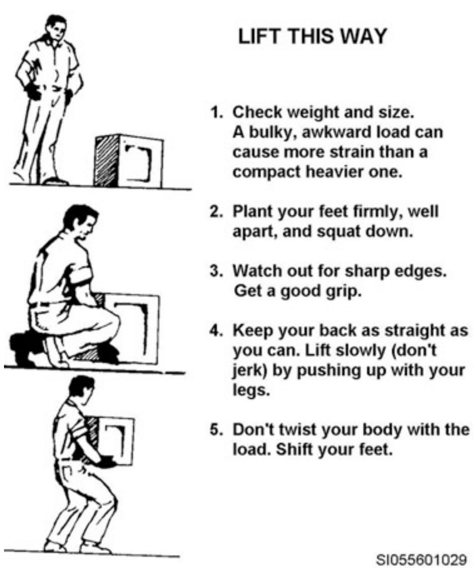


**Figure 1–2. Proper lifting technique.**

- Consider the size, weight, and shape of the object to be carried.
- Do *not* lift more than you can handle comfortably. If necessary, get help.
- Set your feet solidly, with one foot slightly ahead of the other for increased stability. Place your feet far enough apart to assure good balance.
- Get as close to the load as possible. Crouch and bend your legs about 90° at the knees.
- Remember; do *not* squat by sitting on your legs. It takes about twice as much effort to get up from a squat position as it does from a crouch position.
- Keep your back as straight as possible. You do not need to keep it vertical, but do not arch it. Bend at the hips, *not* the middle of the back.
- Grip the object firmly. Maintain your grip while lifting and carrying the object to the desired location.
- Straighten your legs to lift the object, and at the same time, bring your back to a vertical position.
- *Never* carry a load that you cannot see over or around. Make sure the path of travel is clear. To set an object down, reverse the procedures used to pick it up.

## 002. First aid for electrical shock

Electrical shock is the passing of electricity through your body. Sources of electricity can include power lines, lightning, defective electrical equipment, and unprotected electrical outlets. Electrocution is another cause of electricity passing through your body. The difference between the two is if you are electrocuted, you will die and if you are shocked, you will live to tell about it. Shock can cause burns, bleeding, and physical shock. Knowing how to remove someone from an energized, or live, circuit is one of those skills you hope you never have to use. Lack of proper training becomes painfully aware if you have ever been shocked. You have probably wished someone were there to help you get back up if you have been shocked. By knowing these procedures, you can prevent someone from receiving more serious injury from prolonged contact with the circuit and can administer first aid to the victim.

### Removing victim from energized circuit

The very *first* thing you must do when encountering a victim on an energized circuit is *use your brain!* You will not help anyone if you become part of this live circuit! Take every precaution *not* to place yourself in jeopardy when attempting to remove this victim. The second thing to do is try to *disconnect* the power source. Locate the main power disconnect around where you are working, open it quickly, and cut off the current flow to the victim.

If the main disconnect cannot be found, you *must* pull the victim away from the energized conductor or pull the energized conductor away from the victim. The longer it takes you to react, the greater damage the victim will sustain.

**WARNING:** Do *not* use your bare hands to pull a victim off an energized circuit. You will place your body in the path of current and be shocked as well! *Always* use an insulated object to move the victim or conductor away.

A good electrical safety program at your workplace will have suitable objects for this task located on the maintenance truck, but they should always be present in the room or facility where you are performing electrical work. Here are some of these suitable objects:

1. Dry lumber.
2. Dry rope.
3. Wooden or fiberglass canes.
4. Broom handles.
5. Tool handles (such as shovels, rakes).
6. Plastic pipe or conduit.

### Burns

Electrical burns can happen at home, work, or wherever a person may come in contact with electricity. Coming in contact with these sources can send electrical current throughout the body. The severity of electrical burns is based on several factors:

1. Length of contact with current.
2. Strength of current.
3. Type of current alternating current (AC) or direct current (DC).
4. Direction, or path, of current through the body.

Hopefully, most of the burns you encounter will be minor ones. Cool the burn with water to lessen the pain, apply an antibiotic ointment, and cover the burn with a dressing to prevent infection. Do *not* apply ice to a burn because it causes more damage to the tissue. If you encounter a severe burn, where the skin is charred and turns black (third degree burn), do *not* cool the burn with water. Just apply a dry dressing to the burn and seek medical help immediately.

### Bleeding

Bleeding occurs when a blood vessel is torn. With any open wound, bleeding can be severe enough to be life threatening. The most common bleeding you will encounter related to your job could be a direct result of electrical shock, or contact with another object as a result of getting shocked. If bleeding is the result of direct electrical shock, follow these steps to control the bleeding.

1. Have the victim lie down (this lessens the chance of physical shock).
2. Expose the wound. If parts of the victims clothing are charred and stuck to the wound, do *not* remove the clothing.
3. Apply a clean dressing to the wound and press directly against the wound with your hand.
4. Never remove the dressing from a wound. If the dressing becomes saturated, add a new one on top of the old one. The old dressing will pull the scabbing off if you remove it.
5. Elevate the limb if the wound is on the arm or leg.
6. Apply pressure to the pressure points on the inside of the upper arm or inside the thigh if you cannot control the bleeding by direct pressure alone.

If those steps still cannot help control the victim’s bleeding, a tourniquet is the last resort. Tourniquets are devices designed to stop or limit arterial or venial bleeding when all other measures have not worked. Only use a tourniquet if the victim is in danger of bleeding to death before help arrives.

### Physical shock

Any serious injury or illness will trigger a series of responses in the body that acts like a chain of falling dominoes. This condition is known as shock. Shock is the body’s natural attempt to keep oxygen-rich blood flowing to the most important organs, such as the brain, heart, and lungs. Without oxygen, these organs will fail to operate properly. When the oxygen-deprived tissues of the arms and legs begin to die, the body sends blood back to them and away from the vital organs. As the brain is affected, the person becomes drowsy, restless, and eventually falls unconscious. As the heart is affected, it beats irregularly resulting in an irregular pulse. The heart’s rhythm becomes chaotic and the heart fails to pump blood. This chain of falling dominoes will eventually result in death.

Caring for shock involves following these simple steps:

1. Have the victim lie down. This is often the most comfortable position. Helping the victim rest comfortably is very important because pain will intensify the body’s stress and accelerate the progression of shock.
2. Control any external bleeding.
3. Help the victim maintain normal body temperature. If the victim is cool, try to cover them to avoid chilling. Ensure the victim has something between their body and the ground to keep them off the ground.
4. Try to reassure the victim. Attempt to keep the victim from seeing their injuries.
5. Elevate the legs about 12 inches, unless you suspect head, neck, or back injuries. This will help the blood return to the main organs. If you are unsure of the extent of injuries, leave the victim lying flat. Do *not* give the victim anything to drink or eat, even though they are likely to be thirsty.
6. If the victim loses consciousness, place them on their side until help arrives.

You cannot manage shock effectively by first aid alone. A victim of shock requires advanced medical aid as soon as possible.

Knowing what to do in an emergency will save lives. You will not have the time to look up the first aid procedures when someone gets hurt. Your actions can be the difference between life and death. You will attend first aid courses on a regular basis. Be sure to pay close attention so you can say you had the ability to save your co-worker instead of making excuses.

## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

### 001. Working around energized circuits

1. At what amperage will you get grip paralysis threshold (brain says let go, hand will not listen)?

2. If you work on energized circuits, what is the *safest* way to do your business?

3. What Air Force instruction states that you will normally de-energize electrical circuits and equipment before performing maintenance unless approved by the Base Civil Engineer?

4. What commercial standard deals with electrical safety in the workplace?

5. What happens to metal during an arc flash?

6. What are some of the *typical* equipment items that arc flash warning labels would be on?

7. When is an *unqualified* person allowed to cross the limited approach boundary?

8. Which approach boundary requires use of shock protection techniques and equipment because of its proximity to a shock hazard?

9. What approach boundary will only be crossed by *qualified* personnel who have the same protection as if they were coming in contact with energized components?

10. How should you lift an object to prevent a serious back injury?

### 002. First aid for electrical shock

1. What factors contribute to the *severity* of electrical burns?

2. Why should you elevate the legs of a person in shock about 12 inches, unless you suspect head, neck, or back injuries?

## 1–2. AFSC forms and technical publications

Throughout your time as a power production technician, you will have to use forms to annotate generator operations and maintenance. Additionally, there are several different technical publications that you must be familiar with in order to perform maintenance on a piece of equipment. Being able to identify the proper use of these forms and publication are key to keeping your equipment in peak operating condition.

### 003. AFSC specific forms and other requirements

During your time operating and maintaining generators, you are required to use several forms. These forms show historical trends and allow for diagnosis of system faults. Additionally, they are used to size a generator to a facility. It is important to remember the job is *not* done until the paperwork is done.

#### Filling out Air Force Form 487, Generator Operating Log (Inspection Checklist)

The Air Force Form 487, Generator Operating Log (Inspection Checklist), is the most commonly used form you will use during your career. You use this form to annotate generator operations and show a history of generator, transfer switch, and load conditions at a generator site.

When filling out the 487, be sure to fill out *all* 19 blocks *legibly*. This lesson covers how to fill out this form. Follow along with figures 1–3 and 1–4 as we give a description of each block.

| GENERATOR OPERATING LOG (Inspection Checklist) | Front: annotate optimal readings (operating temp., peak kW and amps, etc.) Reverse: continuation of readings and annotate any discrepancies and/or corrective actions. |
|---|---|

**1. GENERAL INFORMATION**

| A. INSPECTOR/OPERATOR (Print) | B. DATE | C. SUPERVISOR (Print/Signature) | | D. DATE |
|---|---|---|---|---|
| | 20 Feb 2015 | | | 22 Feb 2015 |

| E. RECORD ID | F. SITE NAME/BUILDING NUMBER | G. ORGANIZATION | H. BASE |
|---|---|---|---|
| 187 | RAPCON/1515 | 555CES | PRIME BEEF AFB |

| I. START HRS | J. FINISH HRS | K. TIME | L. OUTSIDE TEMP. | M. SYSTEM TYPE | | N. EQUIPMENT TYPE | |
|---|---|---|---|---|---|---|---|
| 125 | 126.2 | 1230 | 65 | AUTO | MANUAL ✓ | RPIE ✓ | EAID |

**2. ALTERNATOR INFORMATION**

| A. MAKE | B. MODEL | C. SERIAL NUMBER | D. POWER FACTOR |
|---|---|---|---|
| Marathon | 123456B | 123456789 | .8 |
| **E. VOLTAGE** | **F. AMPERAGE RATING** | **G. KILOWATT RATING** | **H. OTHER** |
| 120/208 | 208 | 60 | |

**3. ENGINE INFORMATION**

| A. MAKE | B. MODEL | C. SERIAL NUMBER | D. RPM/HZ | E. EXHAUST GAS TEMP. |
|---|---|---|---|---|
| Cummins | B1250 | 02154623 | 1800/60 | |

**4. AUTOMATIC/MANUAL TRANSFER SWITCH DATA** ☐ N/A (This section is not required for generators without switchgear)

| A. MAKE | B. MODEL | C. SERIAL NUMBER | D. BYPASS CAPABILITY |
|---|---|---|---|
| Kohler | 1256987 | 2349851357 | YES ✓ NO |

| E. AMP RATING | F. PHASE | G. POLES | H. DISCONNECT METHOD FOR LOAD TEST | | I. ATS OPERATED (Attempt) | | | |
|---|---|---|---|---|---|---|---|---|
| 250 | 3 | 4 | KEY/TEST SWITCH | MAIN DISCONNECT ✓ | FIRST ✓ | SECOND | THIRD | MANUAL |

**5. GENERAL SITE AND GENERATOR SET CONDITIONS**

| | SAT | REMARKS/CORRECTIVE ACTION | | SAT | REMARKS/CORRECTIVE ACTION |
|---|---|---|---|---|---|
| A. CLEANLINESS | ✓ | | E. BELT CONDITION | ✓ | |
| B. LOOSE ITEMS | ✓ | | F. CONTROLS/GAUGES | ✓ | |
| C. AREA (Room) LIGHTING | ✓ | Light burned out, opened w/o #F13654 | G. ENGINE VIBRATION | ✓ | |
| D. GROUND CONNECTION | ✓ | | H. EXHAUST TEMP./CONDITION | ✓ | °F |

| 6. COOLING SYSTEM | | | 7. FUEL SYSTEM | | | | |
|---|---|---|---|---|---|---|---|
| A. LEAKS | ✓ | | A. LEAKS | ✓ | | | |
| B. COOLANT LEVEL | ✓ | | B. TRANSFER PUMP OPERATION | ✓ | | | |
| C. HOSES | ✓ | | C. TANK CAPACITY (Gal) | DAY | N/A | STORAGE | 450 |
| D. RADIATOR, LOUVERS | ✓ | | D. TANK LEVEL (Gal) | DAY | N/A | STORAGE | 385 |
| E. AMBIENT TEMP. | 65 | °F | E. WATER DRAINED (Gal) | YES | | NO ✓ | QUANTITY |
| F. OPERATING TEMP. | 202 | °F | **9. LUBRICATION SYSTEM** | | | | |

| 8. LOAD DEMAND | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A. KILOWATTS (PEAK) | | 30.8 | | | | | A. LEAKS | ✓ | |
| | | | | | | | B. OIL LEVEL | ✓ | |
| B. AMPERAGE | PH1 | 112 | PH2 | 102 | PH3 | 107 | C. OIL PRESSURE | 55 | PSI |
| C. VOLTAGE (L-L) | PH1 | 208 | PH2 | 208 | PH3 | 208 | D. OIL TEMP. (If applicable) | N/A | °F |

| 10. BATTERY AND CHARGING SYSTEM | | | | | | 11. AUTOMATIC/MANUAL TRANSFER SWITCH | |
|---|---|---|---|---|---|---|---|
| A. WIRING CONNECTIONS | ✓ | | | | | A. WIRING AND CONNECTIONS | ✓ |
| B. BATTERY VOLTS DC | | C. INSTALL DATE (mm/yy) | | 12/14 | | B. CONTACT CONDITION | ✓ |
| D. BATTERY TYPE | WET CELL | | SEALED | ✓ | | C. COMPONENTS AND CONTROLS | ✓ |
| E. BATTERY CHARGING | VOLTS DC | 14.2 | AMPS | 1 | | D. MECHANISM OPERABILITY | ✓ |
| F. BATTERY LOAD TEST | GOOD ✓ | WEAK | NOT TESTED | | | E. INDICATOR LIGHTS | ✓ |

| 12. MAINTENANCE ACTIONS ✓ (No maintenance due) | | | | | 13. INSPECTION TYPE | | |
|---|---|---|---|---|---|---|---|
| A. FILTER CHANGE | AIR | COOLANT | FUEL | OIL | A. SEMI-MONTHLY | B. MONTHLY ✓ | C. QUARTERLY |
| B. FLUIDS ADDED (Gal) | COOLANT | 1 quart | OIL | N/A | D. SEMI-ANNUAL | E. ANNUAL | F. OTHER |
| C. LAST OIL CHANGE DATE (mm/yy) | 12/14 | | | | G. TEST METHOD (EGT, 30% Load or Less Than 30% Load) | | |
| D. OIL ANALYSIS DATE (mm/yy) | 12/14 | RESULTS | Sat | | H. LOAD TYPE (Facility/Load Bank/Both) | | I. DENIED LOAD TEST |

| 14. SITE DOCUMENTATION (Current Documentation) | | | 15. UNIT STARTED | | | |
|---|---|---|---|---|---|---|
| A. OI's ✓ | B. TRAINING LETTER ✓ | C. ONE-LINE DIAGRAMS ✓ | A. FIRST ✓ | B. SECOND | C. THIRD | D. DID NOT START |

**Figure 1–3. AF Form 487, front.**

**16. SEMI-MONTHLY** (These checks are minimum inspection requirements, personnel must complete all manufacturer inspection items)

| DATE | TIME | FLUID LEVEL | | FUEL LEVEL | | DC ELECTRICAL SYSTEM | | PRINT NAME | SIGNATURE |
|---|---|---|---|---|---|---|---|---|---|
| | | OIL | COOLANT | DAY | STORAGE | BATTERY | CHARGER | | |
| 6 Feb 2015 | 1130 | Sat | Sat | N/A | 392 | Sat | Sat | | |
| | | | | | | | | | |

**17. READING CONTINUATION** (This form will be closed out by 0000 hrs daily; close-out engine hours will be recorded in block 1J)

| TIME | ENGINE HOURS | OIL PRESSURE | WATER TEMP | FUEL LEVEL | | AMPS | | | kW | PRINTED NAME |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DAY | STORAGE | PH1 | PH2 | PH3 | | |
| 1125 | 125 | 55 | 180 | N/A | 392 | 99 | 109 | 104 | 29.9 | |
| 1230 | 126.2 | 55 | 202 | N/A | 385 | 112 | 102 | 107 | 30.8 | |
| | | | | | | | | | | |
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**18. REMARKS**

| **19. FACILITY REPRESENTATIVE** (Required for Semiannual Insp. or Denied Test) | Print Name/Rank | Sign |
|---|---|---|
| A. TEST DENIED ☐<br>Approval MFR from MAJCOM/CV has been provided | B. TEST COMPLETED ✓<br>I have verified proper function of all building equipment and systems while connected to actual facility load and under generator operation | |

**Figure 1–4. AF Form 487, rear.**

1. General Information.
   - A. Printed name of the inspector/operator.
   - B. Date of inspection.
   - C. Shop supervisor printed name and signature.
   - D. Date the supervisor reviewed the form.
   - E. The Record ID will vary by shop and how the shops manage their records.

F. Assigned generator facility and building number.
G. Unit or organization maintaining the equipment.
H. Base or installation responsible for maintaining the equipment.
I. Engine start hours *before* the inspection begins.
J. Engine finish hours *after* the inspection is complete.
K. Indicate current time.
L. Current outside air (ambient) temperature.
M. Select either “Auto” or “Manual” system type.
N. Select either “Real Property Installed Equipment (RPIE)” or “Equipment Authorization Inventory Data (EAID)” equipment type.

2. Alternator Information.
   A. Make of the alternator assembly.
   B. Model number of the alternator assembly.
   C. Serial number of the alternator assembly.
   D. If known, the power factor of the alternator.
   E. Designed operating voltage of the alternator.
   F. Maximum amperage output of the alternator.
   G. Maximum kilowatt or kilovolt ampere rating of the alternator.
   H. User input for another value of the alternator.
3. Engine Information.
   A. Make of engine.
   B. Model of engine.
   C. Serial number of engine.
   D. The output frequency or hertz.
   E. Manufacturer’s recommended exhaust gas temperature.
4. Automatic or Manual Transfer Switch Information.
   A. Make of automatic transfer or manual transfer switch.
   B. Model of automatic transfer or manual transfer switch.
   C. Serial number of automatic transfer or manual transfer switch.
   D. Select appropriate box for system bypass capability.
   E. Maximum ampere output of the automatic transfer or manual transfer switch.
   F. Number of phases the system powers.
   G. Number of poles to include number of phases plus neutral.
   H. Select appropriate box according to how the system was tested.
   I. Select appropriate box according to which attempt the switch transferred.
5. General Site and Generator Set Conditions.
   A. Check satisfactory (SAT) after you clean the site during the inspection or make comments that need attention.
   B. Check SAT after you check for loose items and annotate what you did to correct or open job order to correct.
   C. Check SAT if area lighting is good or if you replaced any lights or open job order to correct. Annotate any corrective actions in the remarks section.

D. Check SAT if ground connection is correct according to National Electric Code (NEC)—if not, do not operate equipment.

E. Check SAT if belt condition is acceptable or annotate corrective action or open job order to correct.

F. Check SAT if all controls/gauges are operating properly. If not, replace or open job order to correct.

G. Check SAT after engine is at operating temperature and verify engine vibration is not excessive.

H. After engine reaches operating temperature, record exhaust gas temperature and check SAT to verify the exhaust condition. (Identify color of smoke if not normal).

6. Cooling System.

A. Check SAT if no leaks are found. Correct any leak you find during the inspection or open a job order to correct.

B. Check SAT if coolant level is acceptable. Correct any low coolant condition before you begin the inspection.

C. Check SAT if hoses are acceptable. Correct any discrepancy or open a job order to correct.

D. Check SAT if radiator and louvers are operating efficiently. Correct any discrepancy or open a job order to correct.

E. Annotate the ambient temperature. This will be the temperature inside the building, coolant heater setting, or outside air temperature.

F. Annotate the operating temperature after the generator has sustained the load for 15 minutes.

7. Fuel System.

A. Check SAT if no leaks are found. Correct any leak you find during the inspection or open a job order to correct the leak.

B. Check SAT after you verify the pump is operating correctly. Correct any discrepancy or open a job order to repair the pump.

C. Annotate the capacity for the day tank and/or storage tank in gallons.

D. Annotate the current level in the day tank and/or storage tank in gallons.

E. Check “Yes” or “No” and if water was drained, annotate how many gallons were drained.

8. Load Demand. Annotate the peak kilowatt (kW) observed during the inspection.

B. Annotate the peak amperage observed during the inspection.

C. Annotate the operating line-voltage of the generator.

9. Lubrication System.

A. Check SAT if no leaks are found. Correct any leak you find during the inspection or open a job order to correct.

B. Check SAT if the oil level is acceptable. Correct any low/high oil level condition before you begin the inspection.

C. Annotate the oil pressure of the generator while operating under a loaded condition.

D. If applicable, annotate the oil temperature after the generator has sustained load for 15 minutes

10. Battery and Charging System.

A. Check SAT if all wiring connections are acceptable. Correct any discrepancy or open a job order to correct the wiring connections.

B. Annotate the battery voltage prior to engine cranking.

C. Annotate the month and year the battery(s) were installed.

D. Select appropriate box according to the type of battery used to start the engine.

E. Annotate the battery charging volts and amperes.

F. After you load test the batteries, select appropriate box.

11. Automatic/Manual Transfer Switch.

A. Check SAT if all wiring connections are acceptable. Correct any discrepancy or open a job order to correct the wiring connections.

B. Check SAT if all contacts are acceptable. Correct any discrepancy or open a job order to correct the contacts.

C. Check SAT if all components and controls are acceptable. Correct any discrepancy or open a job order to correct the component(s) and controls.

D. Check SAT if the transfer mechanism operated satisfactory when initiated.

E. Check SAT if all indicator lights are acceptable. Correct any discrepancy or open a job order to correct the indicator lights.

12. Maintenance Actions.

A. Check box(s) of the corresponding filters changed during the inspection.

B. Annotate how many gallons of fluid were added during the inspection.

C. Annotate the date (month/year) of the previous oil change.

D. Annotate the date of the oil analysis and the results of this test.

13. Inspection Type.

A. Check this box if the inspection is a semi-monthly.

B. Check this box if the inspection is a monthly.

C. Check this box if the inspection is a quarterly.

D. Check this box if the inspection is a semi-annual (The facility manager needs to sign block 19).

E. Check this box if the inspection is an annual.

F. This box is a user input.

G. Write in the test method used during the inspection (Exhaust Gas Temp, 30% Load, or Less than 30% Load).

H. Write in the type of load used during the inspection (Facility, Load Bank, or Facility with Load Bank).

I. Check box if the user denied the load test (The facility manager needs to sign block 19).

14. Site Documentation Check the box if the operating instruction at the site and shop record is current.

B. Check the box if the training letter at the site and shop record is current.

C. Check the box if all one-line diagrams at the site and shop record are current.

15. Unit Started.

A. First attempt.

B. Second attempt.

C. Third attempt.

D. Did not start.

16. Semi-monthly.

A. RPIE – Only one line is required to be filled out prior to the semi-monthly inspection. Annotate engine hours in block 1I of this inspection log. If engine start is not performed during the semi-monthly, no readings or operating parameters will be annotated.

B. The readings on this form are the *minimum* requirements. All additional manufacturer inspection criteria must be accomplished.

C. Test batteries to determine status. (e.g., battery load tester, hydrometer, or similar device).

D. Check battery chargers for output voltage and amperage. (Engine driven chargers are not included in this inspection).

17. Continuation readings will be annotated depending on the length of time the generator will remain operational. This form is to be used as a daily form and will be closed out at the end of every day and a new form will be started.

18. Remarks: user inputs for additional information during the inspection or about the equipment or generator room.

19. Facility Representative: Print and sign.

A. The facility representative marks this block if he or she denied test.

B. The facility representative marks this block if the test was completed.

## Maintenance forms and power plant logs

Whether you are completing maintenance or operating a power plant, documentation is the key to keeping generators running efficiently. Two forms you will use are the AF Form 719, Historical Record – Diesel-Electric Generator and System, and the AF Form 1167, Daily Power Plant Operating Log (Diesel-Electric). Both forms are located on the Air Force E-Publication site; however, you must order AF Form 1167, so plan ahead if you need this form at your location.

### *AF Form 719*

When completing generator maintenance, other than monthly inspections, use the AF Form 719 to annotate actions. . This form documents maintenance and stays with the generator for the life of the unit. Figure 1–5 is an example of an AF Form 719. Remember, whenever any maintenance is completed, it must be annotated on the AF Form 719.

| HISTORICAL RECORD - DIESEL-ELECTRIC GENERATOR AND SYSTEM | | | | CARD NO. |
|---|---|---|---|---|
| COMMAND<br>Air Combat Command | BASE<br>Prime BEEF AFB | SITE<br>RAPCON | RECORD IDENTIFICATION NO.<br>187 | DATE INSTALLED *(YYYY MM DD)*<br>20101212 |
| ENGINE MAKE<br>Cummins | SERIAL NO.<br>02154623 / MODEL<br>B1250 | RATING KW<br>60 | PRIME | EMERGENCY<br>X / VOLTAGE<br>120/208 |

| DATE | ENGINE HRS | DESCRIPTION OF MAINTENANCE AND/OR INSPECTION | MAN HOURS | LABOR COST | PARTS COST | CUMULATIVE TOTAL COST |
|---|---|---|---|---|---|---|
| 20101212 | 1.0 | Installed at RAPCON | | | | |
| 20111210 | 25 | Performed Annual/changed oil, oil filter, fuel and air filters | | | | |
| 20120505 | 55 | Replaced injection pump | | | | |
| 20121211 | 70 | Performed Annual/changed oil, oil filter, fuel and air filters | | | | |
| 20131220 | 100.2 | Performed Annual/changed oil, oil filter, fuel and air filters | | | | |
| 20141215 | 122.5 | Performed Annual/changed oil, oil filter, fuel and air filters | | | | |
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AF IMT 719, 19670201, V3

**Figure 1–5. AF Form 719.**

### *AF Form 1167*

The AF Form 1167 allows for detailed logging of power plant information. Some of the areas that you fill out on this form include the engine information such as oil pressure and temperature. Additionally, this form allows you to log load information and generator output. This form can help identify load changes and forecast peak demand to allow for efficient use of prime power generators.

Some other forms that you will use are the Generator Authorization Design Request and the New Facility Generator Authorization Request. These forms request approval from the Air Force Civil Engineer Center (AFCEC) for generator installation.

### *Generator Authorization Design Request*

Use the Generator Authorization Design Request form when design information is available. Load data information is available from several different sources: generator-operating logs, monitoring systems, load surveys, design notes, and so forth.  Use this form to obtain advanced design approval before ordering the generator. This will help eliminate getting generators that are sized incorrectly for the load.

### *New Facility Generator Authorization Request*

Use the New Facility Generator Authorization Request form during the planning and programming portion of a new project. Fill this form out to obtain the authorization for the generator for the specific facility.

### Environmental Protection Agency requirements

Federal regulatory air quality requirements for generator engines must be met; however, they vary greatly from engine to engine and are frequently amended. Requirements include, but are not limited to, emissions limits, operating limits, management practices, maintenance requirements, performance testing, recordkeeping, and reporting. The specific requirements differ according to whether the engine is new or existing and whether the engine is located at an area source or major source of hazardous air pollutant (HAP) emissions. Each state has different requirements beyond the federal laws. You may be required to fill out a run log or take air samples. All of these requirements have their own documentation that must be completed.

### Generator training requirements

At every generator site, there should be a list of all personnel trained to operate the emergency power system. You will be required to perform training on the system and to ensure that the documentation is completed.

**Facility one-lines** Each facility that has a generator must have a one-line diagram on both the electrical and fuel systems.

### *Electrical one-lines*

When posting an electrical one-line diagram, ensure that it shows all the electrical components in the system. The on-line diagram should include switch positions in the various operating positions of the generator and transfer switches.

### *Fuel one-lines*

If an external fuel tank is installed, post a one-line diagram of the fuel system indicating tank size and valve locations.

## 004. Technical publications

There is a variety of technical publications that are used in the power production career field. Some of these are produced by the Department of Defense (DOD) and others by private industry.  Regardless of who produces them, knowing where to look for technical information will make your job much easier.

### Technical orders

Within the power production career field, there are various technical orders that you will use. As you already know, you must use technical orders when performing any maintenance or operations on military design equipment. For power production, that is MEP series generators, military design light carts, and all aircraft arresting systems.

#### *Generator TOs*

Generator TOs that are used in power production fall under the 35C2 series. They cover all of the MEP generators that power production uses in the career field. With legacy generator sets (MEP–5, MEP–6, MEP–7), all of the technical information is contained in the 35C2 series technical orders. However, in the tactical quiet generators (MEP–805 and MEP–806), once you move beyond the generator unit to the engine, you must consult the engine's technical order. These engine TOs are grouped in the 38G series TOs. All of these technical orders should be available to you in your work center and you must use them when operating and maintaining the generators.

#### *Aircraft arresting systems technical orders*

Aircraft arresting system technical orders are critical tools for maintaining and operating these lifesaving systems. It is crucial to follow the directions contained in the TOs. Arresting system TOs are in the 35E8 series . Just like the generator technical orders, several of the aircraft arresting systems have engine TOs that are in the 38G series as well.

### Work cards

Additionally, there are work cards that are abbreviated portions of the TO. Work cards are designed for ease of use while completing periodic maintenance. Just like any other technical order, work cards must be followed when completing tasks.

### Engineering technical letters

Engineering technical letters (ETL) are an important part of power production's technical publication collection. These are used to supplement current Air Force instructions, to rescind certain parts of instructions, or to clarify new procedures. You must follow these publications just as you follow an Air Force instruction or TO.

### Unified facility criteria

Unified facility criteria (UFC) are created at the DOD level and are agreed upon standards that all services follow. Many UFCs provide the foundation for our AFIs and ETLs. A UFC applies directly to power production. One of them that you should be familiar with is UFC 3–540–01, *Engine-Driven Generator Systems for Backup Power Applications.* As we continue to evolve into a joint force, UFCs will become more common for practical everyday use.

### Accessing UFCs and ETLs

You can access the UFCs through the Whole Building Design Guide website http://www.wbdg.org/ this site allows access to UFCs and ETLs. Go to the page, click the DOD link, then click UFC Technical publications. To access an ETL from the UFC page, select Air Force Criteria then click Engineering Technical Letters (AFETL).

### Commercial manuals

Commercial manuals are developed by manufacturers to provide technical information on their products. The manuals serve the same purpose as a technical order. They provide operations, maintenance, and repair information. There is not any one standard for how these are laid out or even how the electrical diagrams are arranged. Commercial manuals are essential for maintaining a reliable generator fleet.

### National Fire Protection Agency standards

NFPA 70, *National Electric Code (NEC)*, is the basis for all electrical installation for facilities. It provides safe practices for all aspects of electrical wiring. When installing generators and automatic transfer switches, you must know the correct method for your specific application. In addition, the NFPA 110, *Standard for Emergency and Standby Power Systems*, provides you with the information needed for compliance with commercial standards.

You must follow numerous technical publications while in the power production career field. It is important to remember that they may not always line up with each other. If there are any questions on what to follow, talk with your base electrical engineer and the Air Force Civil Engineer Center (AFCEC) for clarification.

## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

### 003. AFSC specific forms

1. When filling out AF Form 487, in which block do you annotate load demand?

2. When filling out AF Form 487, what do you check for when reviewing site documentation?

3. Which form do you use to document generator maintenance?

4. What are some methods you can used to gather load data on a generator?

5. What type of one-line diagrams must be at *every* generator facility?

### 004. Technical publications

1. Generators fall under which series of TOs?

2. Aircraft Arresting Systems fall under which series of TOs?

3. What are abbreviated portions of the TO that are designed for ease of use while completing periodic maintenance?

# Answers to Self-Test Questions

**001**

1. 15 – 50 mA.
2. De-energized all circuits regardless of the voltage.
3. AFI 91–203.
4. NFPA 70E.
5. Metal at the arc site expands and vaporizes.
6. Pad-mounted transformers, switchgear, switchboards, panel boards, disconnect switches, industrial control panels, meter socket enclosures, and motor control centers.
7. When escorted by a qualified person.
8. Restricted approach boundary.
9. Prohibited approach boundary.
10. With your legs.

**002**

1. (1) Length of contact with current.
   (2) Strength of current.
   (3) Type of current AC or DC.
   (4) Direction, or path, of current through the body.
2. This will help the blood return to the main organs.

**003**

1. Block 8.
2. (1) Are the operating instruction at the site and shop record current.
   (2) Are the training letter at the site and shop record current.
   (3) Are the one-line diagrams at the site and shop record current.
3. Air Force Form 719.
4. Generator-operating logs, monitoring systems, load surveys, and design notes.
5. Electrical and fuel systems.

**004**

1. 35C2 series.
2. 35E8 series.
3. Work cards.

**Do the unit review exercises before going to the next unit.**

## Unit Review Exercises

**Note to Student:** Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

**Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).**

1. (001) What is the *minimum* number of fully qualified people that the Air Force instructions require to be present when you must work on an energized circuit?
   a. 1.
   b. 2.
   c. 3.
   d. 4.

2. (001) Who is authorized to approve work on energized circuits and/or equipment?
   a. Base Civil Engineer.
   b. Flight Commander.
   c. Facilities Superintendent.
   d. Shop noncommissioned officer in charge (NCOIC).

3. (001) Which boundary is based upon the arc fault on the surface of the skin and requires anyone within the boundary to wear the proper personal protective equipment (PPE)?
   a. Arc flash.
   b. Limited approach.
   c. Prohibited approach.
   d. Restricted approach.

4. (001) What is the *minimum* distance for the flash protection boundary for all energized equipment under 750 volts alternating current (VAC)?
   a. 3 ft. 6 in.
   b. 7 ft.
   c. 20 ft.
   d. 10 ft.

5. (001) What type of materials is prohibited to be worn when working near energized equipment?
   a. Acetone, nylon, polyester, and rayon.
   b. Cotton, nylon, and polyester.
   c. Denim, rayon, and polyester.
   d. Acetone, denim, and polyester.

6. (002) If the power cannot be turned off, what should you use to move the victim connected to a live circuit away from the energized conductor or the conductor away from the victim?
   a. Wet rope.
   b. Bare hands.
   c. Insulated object.
   d. Galvanized conduit.

7. (002) You *never* apply what to a burn because it causes more damage to the tissue?
   a. Ice.
   b. Dry dressing.
   c. Clean bandage.
   d. Burn ointment.

8. (002) What is the body's natural attempt to keep oxygen-rich blood flowing to the most important organs, such as the brain, heart, and lungs?
   a. Sweating.
   b. Bleeding.
   c. Shock.
   d. Fever.

9. (003) When filling out an Air Force Form 487, Generator Operating Log (Inspection Checklist), what site documentation are you checking for currency?
   a. Generator training letter, one-line diagrams, and operating instructions.
   b. Generator training letter and operating instruction only.
   c. Generator training letter, one-lines, and AF Form 719.
   d. Generator training letter, one-lines, operating instructions, and AF Form 719.

10. (003) Which Air Force form is a detailed log of power plant operations?
    a. 487.
    b. 719.
    c. 1167.
    d. 1197 .

11. (003) Which generator authorization request form is used during the planning and programming portion of a new project?
    a. Generator authorization design request.
    b. New facility generator authorization request.
    c. Generator requirements request.
    d. Generator disposition request.

12. (003) When is a fuel one-line diagram required at a generator site?
    a. It is required at all generator sites.
    b. If an external fuel tank is installed.
    c. If the tank holds more than 200 gallons.
    d. If a day tank is present.

13. (004) Which technical order series covers generators?
    a. 35C2.
    b. 35E8.
    c. 38G.
    d. 88A.

14. (004) Which technical order series covers aircraft arresting systems?
    a. 35C2.
    b. 35E8.
    c. 38G.
    d. 88A.

**Please read the unit menu for unit 2 and continue ➔**

# Student Notes

# Unit 2. Special Tools and Test Equipment



YOU ALREADY KNOW how to use common hand tools. This unit discusses commonly used special tools in the power production field. You use them during higher-level maintenance. Because there are many types of tools that you can use, we do not cover them all. Understanding these tools and test equipment is essential to the maintenance that you do.

## 2–1. Special Tools

This section covers special engine tools with which you need to be familiar to do your job effectively. It also discusses the proper use and care of various types of micrometers and engine test devices. Additionally, it contains information on soldering which will allow you to repair electrical connection.

### 005. Hand tools

To do a job as big as overhaul an engine, you need your regular tool kit as well as some special tools. These tools are designed for a specific purpose and can be quite expensive. We discuss several of the common types throughout this lesson, but by no means do we cover all of the special tools that you may come across.

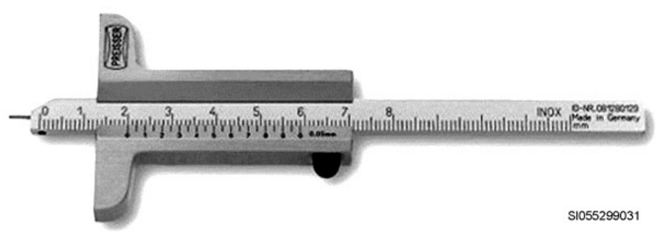


**Figure 2–1. Depth gauge.**

#### Depth gauge

Depth gauges measure the depth of an item. They are similar to depth micrometers except that they do not provide precision measurements. Simply put, they are rulers that slide through a frame (fig. 2–1). Together, they create a “T” shape. The frame rests on the top of the device you are measuring. The ruled portion slides through the frame until it rests on the bottom depression. The frame has a mark on it to determine the measurement. You may also see them with a dial or digital scale on them.

#### Calipers

We use calipers for determining the thickness of objects, the distance between surfaces, and the depth of openings in mechanical parts. We can use the slide caliper for making both inside and outside measurements.

The slide caliper has a fixed jaw on the end of a bar or rule and a movable jaw fastened to a frame that slides over the rule to take either inside or outside measurements. As shown in figure 2–2, the frame has two index marks, IN and OUT. We use the index mark identified as IN for taking inside measurements and the index mark identified as OUT for taking outside measurements.

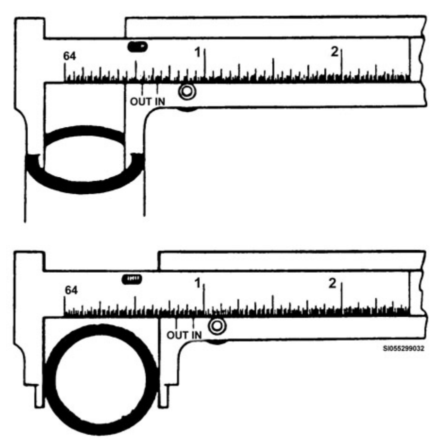


**Figure 2–2. Slide calipers.**

Place the insides of the jaws over an object to take its outside measurement and the outsides of the jaws inside the opening to take its inside measurement. A locking screw is located on one side of the frame to lock the slide in position; this enables you to hold the exact point while you are taking the reading.

### Torque wrenches

Use the torque wrench when you must tighten a nut or bolt to a given amount of pressure. The handle, which you use with a socket, is designed so you can tighten a nut or bolt to a specified pressure. The types of torque wrench designs are the bending beam, dial indicator, and preset ratchet types as seen in figure 2–3. The bending beam has a stationary rod above the handle and a scale attached to the handle. As you pull the handle, it bends while the stationary rod remains in place. The rod and scale determine the amount of pressure applied to the nut or bolt. The dial indicator type has a round gauge built into the handle. The gauge registers the pressure applied to the nut or bolt. The preset ratchet type has an adjustable setting built into the handle. After adjusting the handle to the desired torque setting, tighten the nut or bolt until the handle ratchets, or pops. You generally hear it and feel it at the same time.

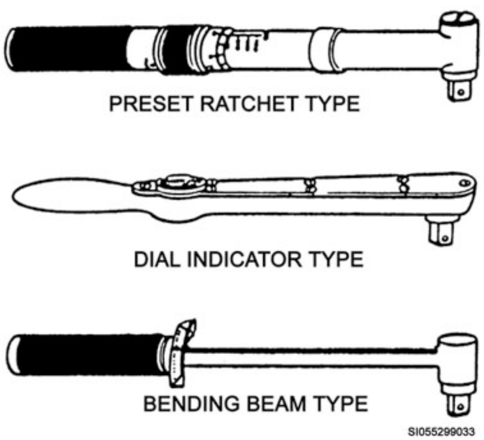


**Figure 2–3. Torque wrenches.**

Torque wrenches are precision measuring instruments that you must handle carefully. Steady pressure makes sure that you apply the appropriate pressure to the nut or bolt. Never jerk on the torque handle. This results in improper torque and may damage the handle. Torque wrenches also require calibration to make sure they are tightening to the appropriate pressure.

### Handheld tachometer

Tachometers are instruments that measure the speed at which an item is rotating. Handheld tachometers are portable and come in several different designs. They have analog or digital gauges. They also have different designs for getting the reading, contact, photo, and laser.

#### *Contact handheld tachometer*

The contact type of handheld tachometer is equipped with several different types of adapters to allow you to take the speed of a device in the safest way possible. Once you determine where to take the reading, choose and install the adapter that best suits the reading. Remember, you are working with rotating machinery and you must observe the proper safety precautions, such as, no jewelry, loose clothing, and so forth. Carefully place the tachometer adapter snugly against the rotating surface and observe the reading. The reading may be on an analog or digital readout.

#### *Photo handheld tachometer*

The photo type of handheld tachometer is equipped with reflective strips and the tachometer. The end of the tachometer has two small lenses. To get a reading on the photo handheld tachometer, make sure you shut the equipment you are about to test down and lock it out to prevent possible start up. Then, place one of the strips on the rotating surface. Start the equipment, point the lenses at the reflective strips, and press the button for the tachometer to begin taking a reading. Again, you are working with rotating machinery and must take the appropriate safety precautions. The reading may be on an analog or digital readout.

#### *Laser handheld tachometer*

The laser handheld tachometer uses a laser to determine the speed of the equipment. Once you turn it on, it projects a laser beam and displays a reading. You must be careful when you use the laser tachometer because if you direct the laser into someone's eyes, it could cause damage. Be sure to wear the proper safety gear for the rotating machinery.

There are times when your understanding how to use the special tools you have just read about could be the difference between the success and failure of the mission. These are the common types of special tools that you use.

## 006. Soldering

Soldering is the process of joining two or more metals together by the application of heat and a low-melting-point alloy. When we heat the metal, the alloy flows between and around the metals we are joining. Once it cools, it solidifies bonding the metals together. Before we get started, let's take a look at some safety precautions.

### Safety precautions

Soldering is a safe process if we recognize the hazards associated with soldering and observe normal safety precautions. To keep you safe when soldering, we include both the following list of safety precautions for you to observe while soldering and provide the reason each precaution is necessary.

| ***Safety Precaution*** | ***Reason Why Necessary*** |
|---|---|
| Always handle soldering irons cautiously. | The risk of receiving painful and dangerous burns during soldering operations is always present. You can receive such burns easily from touching a soldering iron or from handling soldered connections or parts that have not cooled sufficiently. |
| Support large work pieces securely while you are soldering. | Otherwise, you may receive severe injuries or burns as you attempt to grasp a falling work piece. |
| Protect your eyes and skin with proper clothing and protective devices. | Soldering fluxes splatter when heated. |
| Do *not* rest a hot soldering iron on a wooden bench or chair. | Use an appropriate soldering iron holder to avoid burning furniture or equipment or, worse still, causing a fire. |
| Do *not* flip excess solder from the tip of a soldering iron. | If you do this, bits of hot solder can hit you and cause serious skin and eye burns. Instead, use a clean, damp sponge or cloth for cleaning hot soldering iron tips. |
| Do *not* wear rings or wrist watches while you are soldering. | Even a small solder splatter caught under a ring or a watch can cause a severe burn. |
| Disconnect electronic equipment from the supply circuit before you begin to solder. | You can be seriously burned or killed as a result of contacting energized circuits |
| Provide adequate room ventilation. | Vapors from degreasing solvents and fluxes may contain toxic gases. |
| Do *not* allow degreasing solvents or fluxes to touch or remain on your skin unnecessarily. | Many materials used in these products can cause skin irritations. The remedy is to wash contacted areas with cool water. |
| Wash your hands thoroughly before you eat or smoke. | Most fluxes contain materials that are hazardous to your health if you ingest them. |

### Materials

Proper soldering and de-soldering of connections in electronic equipment requires the proper materials and certain basic tools and equipment. Other requirements for soldering are cleanliness, proper temperature, and stability.

To solder a connection, you need solder and flux. Once you have the item to join the solder and the flux, you need the proper tools and equipment to perform the soldering operation.

### *Solder*

The solder we use is usually classified into two general categories—hard and soft. Hard solders consist of alloys of tin and lead. One of the most commonly used solders is the 60/40 tin-lead ratio (60 percent tin/40 percent lead), which has a relatively low-melting temperature.

A solder commonly used in electronics work comes in wire form. The wire is hollow with the core filled with rosin flux. You use rosin-core solder for electronics repair since it does not have the corrosive effects of an acid-core solder. You must select the right type of solder for the soldering job at hand.

### *Flux*

Cleanliness is the key to reliable soldering.  You must remove all dirt, grease, oxide, and scale from the surface you will solder. Since necessary processing by the manufacturer often leaves an oxide formation on component leads, always clean the leads to brightness regardless of their appearance.

The primary function of a soldering flux is to clean oxidation and other contamination from the metal surfaces just before applying the solder. However, do not expect the flux to remove heavy surface oxides from metals. Instead, remove heavy surface oxides with a mechanical or chemical cleaning process.

It is good workmanship practice to apply the flux at a point near the highest portion of the connection you will solder. You do this so the flux can precede the solder in its flow downward and clean the surface properly. The flux attains its maximum activity and deoxidizing power at the soldering temperature. However, heat accelerates the formation of oxides. At unnecessarily high temperatures, the surfaces oxidize rapidly, and the flux, no longer a reducing agent at these temperatures, boils away.

Flux is available in solid, liquid, and paste form. Wire solder often contains an acid- or rosin-flux core for convenience in soldering. Soldering pastes are a mixture of flux plus wax, tallow, or grease. The flux and its residue can be either corrosive or noncorrosive. Thus, you select flux to fit the soldering application.

For cleaning areas you have soldered, use a medium-stiff natural or synthetic bristle or a lint-free industrial cleaning tissue. After the solder has solidified, dip the cleaning instrument into approved cleaning solvent for removing excess flux. You can use a pencil-type, white typewriter eraser for cleaning copper-clad unplated boards and for removing gold plating from printed circuits and some component leads.

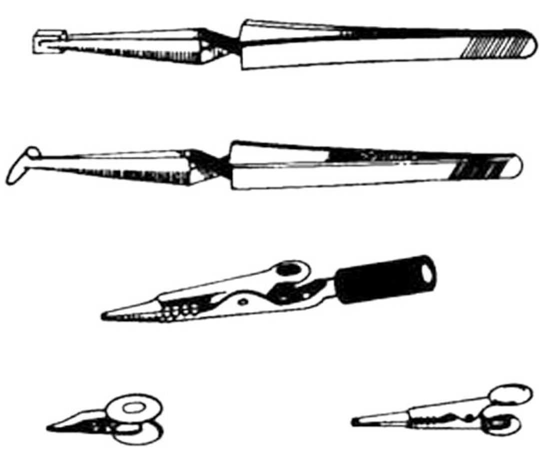

**Figure 2–4. Typical thermal shunts.**

### *Thermal shunts (heat sinks)*

When you perform a soldering operation, use thermal shunts or heat sinks, shown in figure 2–4, to protect heat-sensitive components such as semiconductors, crystal devices, meter movements, and insulating materials. You must consider a thermal shunt’s material, size, shape, and design to permit rapid heat removal from the area you are soldering. This prevents damage to heat-sensitive components.

Use thermal shunts of the clip-on type. An example is the alligator clip. This is the approved method and usually results in a minimum of damage to metal surface, insulation on the wires, and the component you are soldering.

### *Soldering and de-soldering aids*

Figure 2–5 shows three types of solder aids that are useful in the de-soldering of soldered connections. Use the slotted ends of the soldering aids to lift the ends of wires and part leads from the terminals. Use the pointed ends to remove solder from terminal holes and slots. The synthetic bristle brush aids in the removal of molten solder. Do *not* use wire brushes for this purpose.

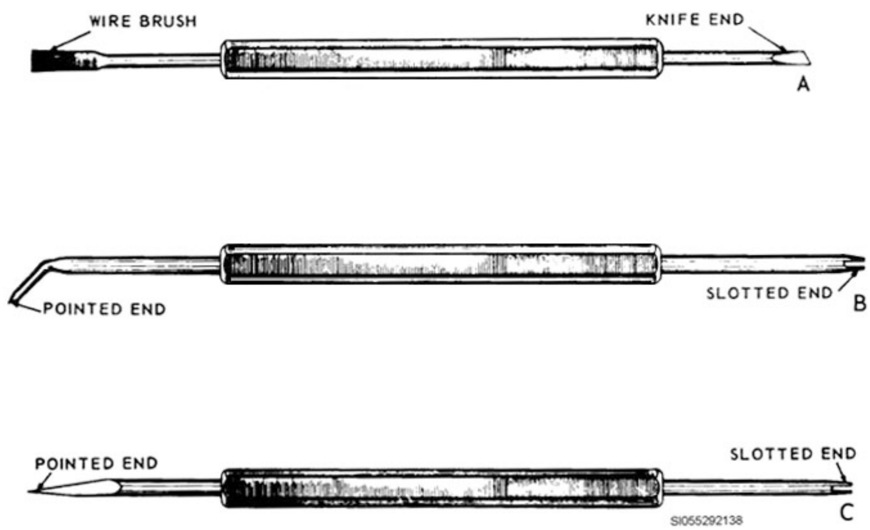


**Figure 2–5. Typical soldering aids.**

Do *not* use soldering aids to exert force on wires or components for security testing. Instead determine the quality of a properly bonded solder connection by a visual inspection.

### *Soldering irons*

A typical soldering iron, shown in figure 2–6, consists of a heating element, a tip, handle, and cord. You determine the sizes of soldering irons according to wattage rating and diameter of tip. The common tip sizes are $^{3}/_{8}$, $^{5}/_{8}$, and $^{7}/_{8}$ inch.

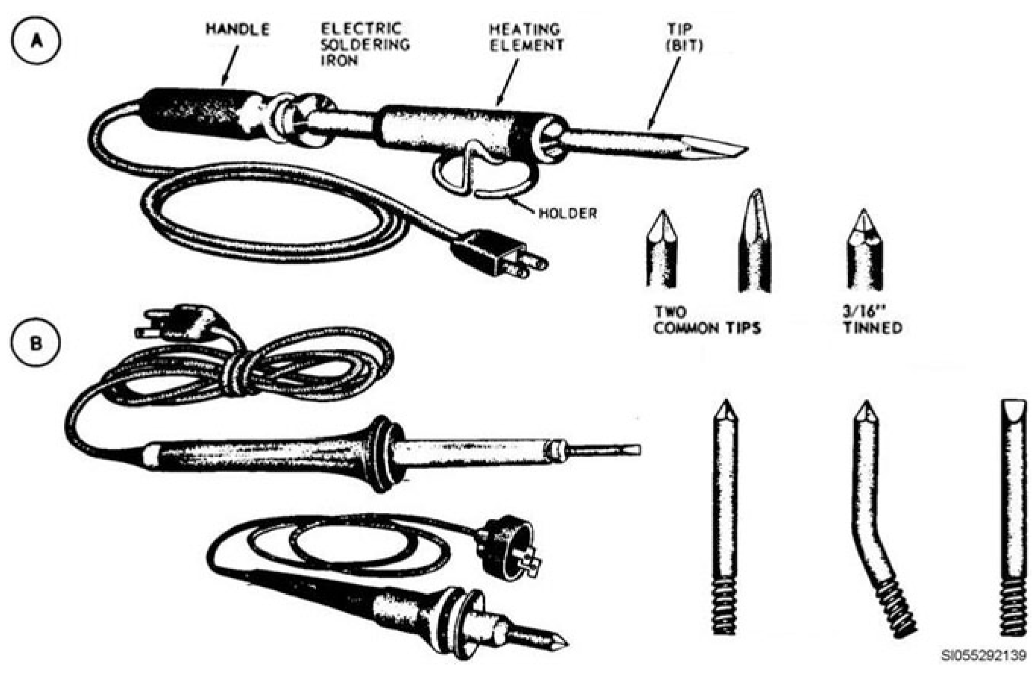


**Figure 2–6. Soldering irons and tips.**

We usually use soldering irons that have a 44- to 52-watt rating, as shown in section A of figure 2–6, for soldering on main distributing frames. Also, we use soldering irons that have a rating of 100 watts or more when working on heavy grounding wire. We should point out here that the higher the watt rating of the iron, the slower the iron initially heats up.

Soldering irons that have ratings in the 20- to 40-watt range, such as the one shown in section B of figure 2-6 have distinct advantages over irons rated at larger wattage. For example, we can use them more effectively where space is limited. Also, this type of iron is excellent for repairing miniaturized parts such as transistors or printed circuit cards.

## Soldering

The area you are going to use to solder components or connections should be clean and free from dirt and debris. Another important aspect of good soldering is the preparation of the soldering equipment, wires, and terminals.

### *Solder tips*

Always check that you have inserted the soldering tip completely into the heat element and that the attachment to the soldering iron or gun is tight. Periodically check that no oxidation scale has accumulated between the heating element and the soldering tip. Clean and dress unplated copper tips (while cold) with a flat, clean, single-cut, shear-tooth-type file to produce a flat, clean, unpitted working surface. After cleaning and dressing the soldering tip, heat and tin it with solder. Maintain a bright, continuous, tinned working surface on the soldering tip to ensure maximum heat transfer and to avoid transfer of impurities to the solder connection. To do this, heat the iron, remove the old solder with a damp cloth, and clean and smooth the tip with an old file. Continue heating the tip until it turns a light mahogany hue; then apply a small amount of rosin-core solder to the tip. Remove the surplus solder with a damp cloth. The solder that you cannot remove has fused with the copper. A properly tinned iron is essential if you want neat, professional solder joints.

Clean-plated soldering tips with an oxidation-resistive coating (while cold) with emery cloth or aluminum oxide cloth of approximately number 320-grit size. Use only sufficient pressure for proper cleaning and take care not to scratch or remove the plating. Do not use files for cleaning-plated tips. After cleaning-plated tips, heat and tin them to produce a bright, smooth, tinned working surface. Wipe hot soldering tips frequently with a wet, fine-textured sponge or cloth to maintain a bright, clean working surface.

### *Wires*

Remove insulation from wires by use of an approved stripper. Determine the amount of wire to strip by the type of terminal, whether you use maximum or minimum warp, and the required amount of insulation clearance. Insulation clearance is the length of exposed bare wire between the insulation and the terminal after the connection is complete.

When you remove insulation with a precision, cutting-type stripper, check the cutter to ensure that you use the correct stripping hole for the corresponding wire size. During the stripping operation, twist stranded wire in the direction of the lay to maintain the original form and prevent separation of the individual strands. The desired insulation clearance is the outside diameter of the insulation.

After stripping, examine the wire for insulation damage. Do not use wires with cut, split, or burnt insulation. However, slight discoloration from thermal stripping is acceptable. Examine wires to ensure that you have not stretched, nicked, cut, scraped, or otherwise damaged outside strands. Damaged wires degrade connection reliability—DO *NOT* USE THEM.

### *Terminals*

Clean terminals with a pencil-style typewriter eraser until the tinned surfaces are bright and shiny. Wash cleaned terminals with an approved solvent immediately prior to attaching any wire or part lead and soldering.

### *Procedures*

Whenever practical, make connections mechanically secure prior to soldering in such a manner as to aid the mechanical strength, increase the electrical conductivity, and provide an airtight covering to prevent corrosion from developing between the wire and the terminal.

### *Operation*

To perform proper soldering techniques, attach component leads to terminals and support them so that there is no movement during the soldering operation and cooling. Connect thermal shunts between heat-sensitive parts and the connections that you will solder. Clean the connections with an approved solvent. If you are using solid wire solder, apply rosin-core flux to the connection. Maintain a clean, well-tinned soldering iron tip during soldering operation.

Apply the working surface of a heated soldering tip to the connection in such a manner as to transfer optimum heat to the surfaces you are soldering. When the surfaces of the connection reach a temperature sufficient to melt solder, apply a proper amount of solder directly to the connection, as shown in figure 2–7. Do *not* melt the solder on the soldering tip and then allow the solder to flow onto the connection.

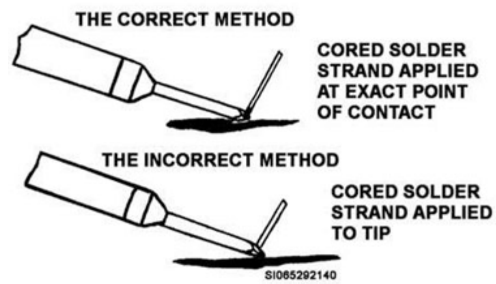


**Figure 2–7. The correct and incorrect methods of solder applications.**

Maintain contact of the soldering tip with the connection until all flux boils out and the solder has completely wetted (fused in a smooth continuous blend) with the wire and terminal surfaces. Do *not* overheat the connection. Do *not* use any more solder than necessary. The core size and wire size of the solder should be the minimum required to complete a satisfactory connection or joint.

Do *not* subject the connection to stress at any time during the cooling and solidification of the solder. Disturbing the finished work results in a joint that is mechanically weak and that has high electrical resistance. Do *not* use liquid to cool a soldered connection. Instead allow solder joints to cool naturally at room temperature.

The soldering operation for hollow cylindrical terminals (solder cups) and connector pins differs from the soldering operation described for other types of terminals. Figure 2–8 illustrates wire placement and insulation clearance in a solder cup terminal. Heat the solder cup terminal or connector pin prior to inserting tinned wire and melt a small amount of solder inside the terminal. Solder cup terminals should contain a sufficient amount of solder to completely fill the cup when the solder melts and you fully insert a tinned wire in the cup. Maintain contact of the soldering tip with the terminal until all flux boils out and the solder fuses smoothly into the conductor and terminal surfaces. Use a medium-stiff bristle brush dipped in solvent to remove all flux and impurities from the soldered connection following solder solidification.

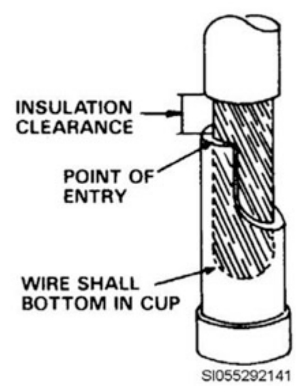


**Figure 2–8. Wire placement in solder cup terminal.**

### *Solder connection inspection*

Inspect each soldered connection after cleaning. Acceptable solder connections have a shiny, bright appearance with no pits or holes, a good concave fillet between the wire and the terminal, and no excess solder. In all applications, except solder cups and connector pins, the contour of the wire should be visible and the end of the wire should not extend beyond terminal dimensions. In solder cup applications, the contour of the wire should be visible from the insulation termination to the point of entry into the cup.

### *Protection of completed connections*

Solder connections requiring mechanical and electrical protection must have flexible insulation tubing of appropriate type and size installed over wires and part leads prior to attachment to terminals. Push flexible insulation tubing back on the wire or part lead to leave a sufficient distance from the terminal so that it does not interfere with the connection or soldering operation. After the solder cools and you clean the connection, push the flexible insulation tubing over the wire and terminal to protect the connection. Extend flexible insulation tubing beyond the insulation termination point for a distance equal to or greater than the diameter of the tubing.

### *Basic de-soldering procedures*

Since most of the soldering jobs you will encounter will be the removal, replacement, and repair of components, you must know de-soldering techniques as well as soldering techniques. Although there are other techniques for de-soldering, we discuss only the wicking and sniffing techniques. Each of these techniques is very effective in removing the old solder from a previously soldered joint.

#### *Wicking*

Figure 2–9 shows some typical materials that you can use to make a wick. You can make an effective wick by stripping the braided shield from a piece of coaxial cable or by removing the insulation from a piece of multi-strand wire.

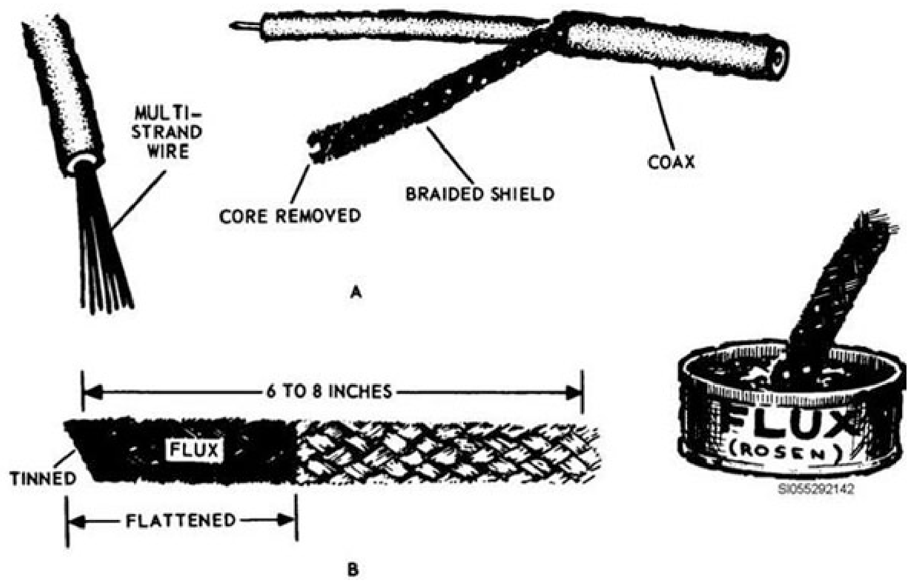


**Figure 2–9. Wicking tools.**

If you apply heat to a well-saturated rosin wick, the solder flows readily into the rosin area leaving the terminal to which it was previously affixed. Almost as if by osmosis, the solder travels into the saturated wick.

In preparing your wick, use a wire size no larger in diameter than the pad size from which you are wicking solder. This is important because if you let the wick touch the board, it “frogeyes” the material on the board.

Refer to figure 2–10 and the list below for the procedures to use in making an effective wick:

1. Remove 6 to 8 inches of shield from coaxial cable and flatten it with a bending tool.
2. Dip about 2 inches of the wick into liquid solder flux. Be sure the liquid flux rosin is the same as the rosin you intend to use in your repair work.
3. If you use multi-strand wire, strip about 4 inches of insulation from the wire.

4. Flatten the wire slightly, keeping the strands in place.
5. Dip the wire in liquid rosin and tin the end.

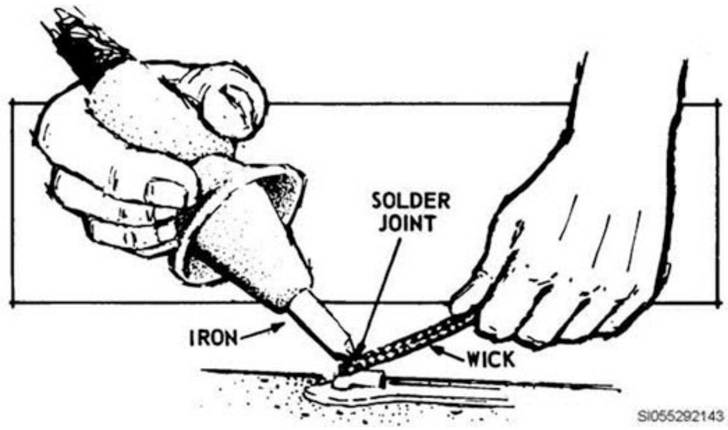


**Figure 2–10. Wicking application.**

Now that you have an effective wick, you need to apply it. Refer to figure 2–10 for an illustration of wicking and follow the steps below:

1. Place the wick on top of the solder joint to remove the solder.
2. Place the iron tip on top of the wick. When the iron melts the solder, the solder flows into the wick.
3. As the wick becomes saturated with solder, clip off the end of the wick and repeat the operation until you have removed all the solder from the joint.

*Sniffing*

In this method, you use a tool like a syringe as shown in figure 2–11. This tool is a material that does not bond to solder. Although this method is not as highly recommended as wicking, it is effective.

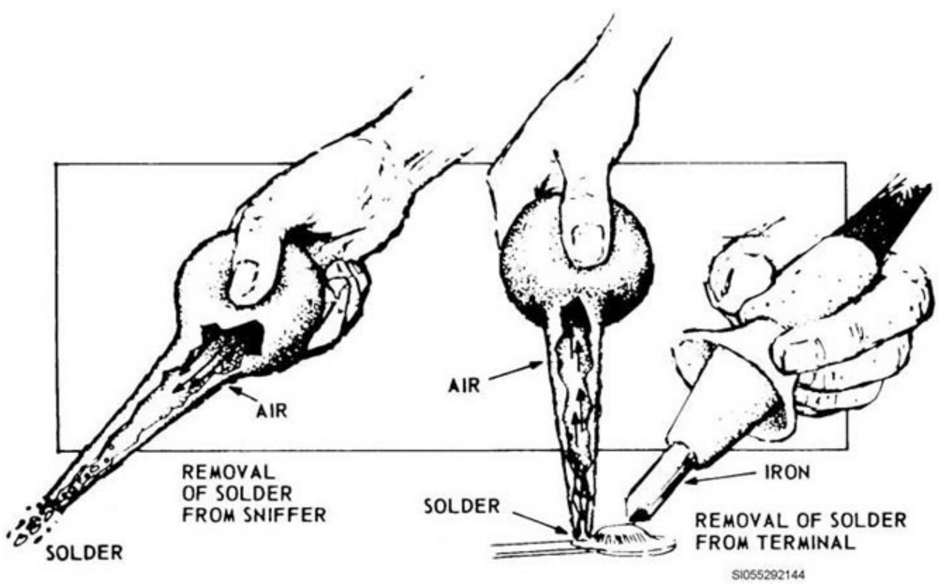


**Figure 2–11. Sniffing application.**

The *sniffer*, sometimes called a *solder sucker*, uses the force of air pressure to remove the molten solder. Use the sniffer as follows:

1. Squeeze the air out of the rubber ball at one end of the sniffer.
2. Keeping the ball depressed, place the pointed end of the sniffer next to the solder to remove.
3. Heat the solder with a solder iron; keep the tip of the iron in the solder and not on the sniffer.
4. Slowly release the pressure on the sniffer ball. As the air enters the tube, it pulls the molten solder in with it.
5. After you have drawn the solder from the joint, remove the sniffer. Depress the tube again to remove the solder from the sniffer.

Some solder suckers are part of the heating tool that we refer to as de-soldering tools, as shown in figure 2–12. This is often the case with soldering stations. Each of these methods removes solder from a joint. In each method, you must exercise caution because of the heat, component reaction to heat, and possible damage to base materials and adjacent components.

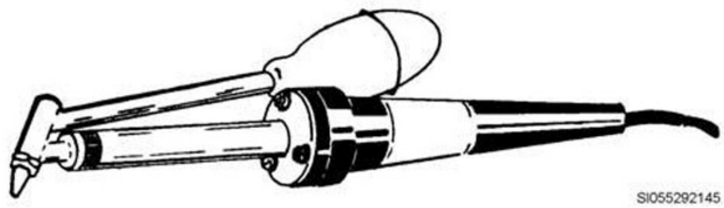


**Figure 2–12. De-soldering tool.**

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## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

### 005. Hand tools

1. What kinds of measurements of objects can you make using the slide caliper?

2. What are three types of torque wrenches?

3. How do you take a reading using a *contact* handheld tachometer?

### 006. Soldering

1. What is the key to reliable soldering?

2. When soldering, what should you do when the surfaces of the connection reach a temperature sufficient to melt solder?

3. How can you make an effective wick to remove solder?

# 2–2. Diagnostic Tools

As a power production technician, there will be times that equipment will not function properly. To find the problem, you will use some sort of diagnostic equipment to pinpoint the location of the malfunction. In this section, we will cover a variety of diagnostic tools, the digital multimeter, clamp-on ammeter, and megohmmeter, you will encounter throughout your career.

## 007. Electrical diagnostic devices

In the day-to-day operations of a power production technician, there are some common items that you will need to be familiar with to troubleshoot equipment. We will cover two of them, the digital multimeter and clamp-on ammeter, in this lesson.

### Digital multimeter

In the past, there has been a variety of multimeters used by power production technicians. We will cover one of the common meters used in the field, the Fluke© 80 series V multimeter. A multimeter provides the means for testing several different electrical values such as voltage, amperage, continuity (ohms), capacitor checks, diode testing, and resistance checks.

#### *Voltage*

To measure the voltage of a power source, you must first know what type of voltage (AC/DC) you are measuring. Double-check the type of voltage you are measuring. Set the meter to the correct position on the meter and connect the probes in parallel with the powered source. Figure 2–13 shows an example for both AC and DC measurements.

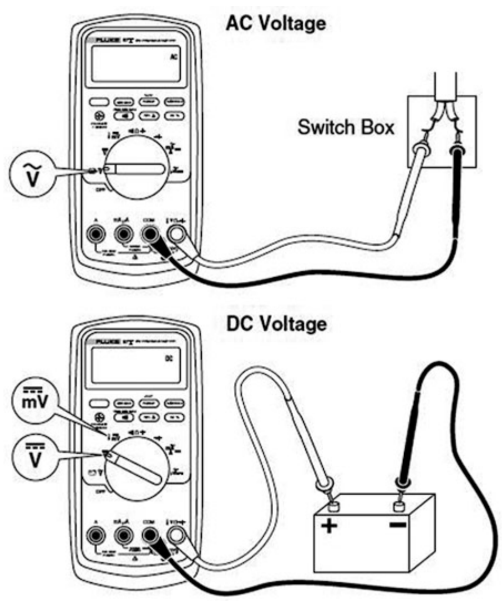


**Figure 2–13. Measuring AC and DC Voltage.**
**(Printed with permission, Fluke Corporation)**

#### *Amperage*

When checking amperage on circuits, there are several safety precautions that you must take before testing the circuit.

| |
|---|
| **WARNING:** To avoid possible electric shock or personal injury, never attempt an in-circuit current measurement where the open-circuit potential to earth is greater than 1000 V. You may damage the meter or be injured if the fuse blows during such a measurement. |

To avoid possible damage to the meter or to the equipment under test, make sure you do the following:

- Check the meter's fuses before measuring current.
- Use the proper terminals, function, and range for all measurements.
- *Never* place the probes across (in parallel with) any circuit or component when the leads are plugged into the current terminals.

To measure current in an AC or DC circuit, you must turn off the circuit to be tested, and then connect probes in series with the circuit. Next, turn the power on, take the reading, power off, and then disconnect probes.

Before measuring, you must also reconfigure the multimeter. To do this, follow these steps:

- Turn off power to the circuit. Discharge all high voltage capacitors.
- Insert the black lead into the communication (COM) terminal. For currents *between* 6 milliamperes (mA) and 400 mA, insert the red lead into the *mA/microampere (µA) terminal*. For currents *above* 400 mA, insert the red lead into the *A terminal*. Refer to the figure 2–14 below.
- To avoid blowing the meter's 400 mA fuse, use the mA/µA terminal only if you are sure the current is less than 400 mA continuously or less than 600 mA for 18 hours or less.

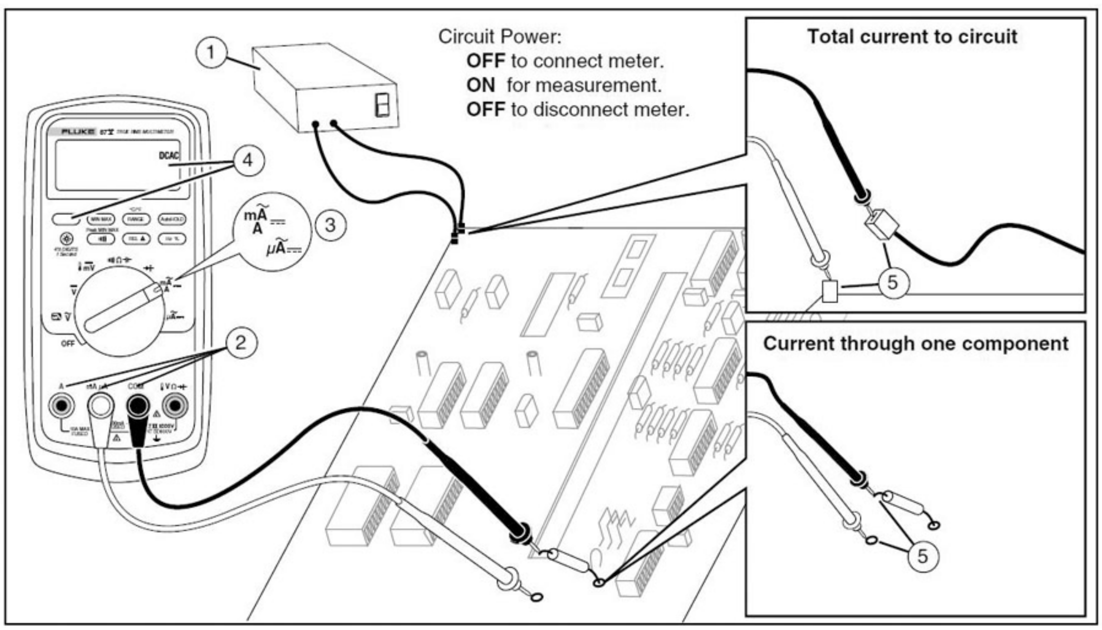


**Figure 2–14. Measuring amperage.**
**(Printed with permission, Fluke Corporation)**

### *Continuity check*

To test for continuity in a circuit, position the meter's function switch as shown in the figure 2–15. When testing for continuity, ensure the component being tested is isolated and that the power to the circuit is turned off. If continuity is present, you will hear a beep; if not, the meter will be silent.

**CAUTION:** To avoid possible damage to the meter or to the equipment under test, disconnect circuit power and discharge all high-voltage capacitors before measuring capacitance. Use the DC voltage function to confirm that the capacitor is discharged.

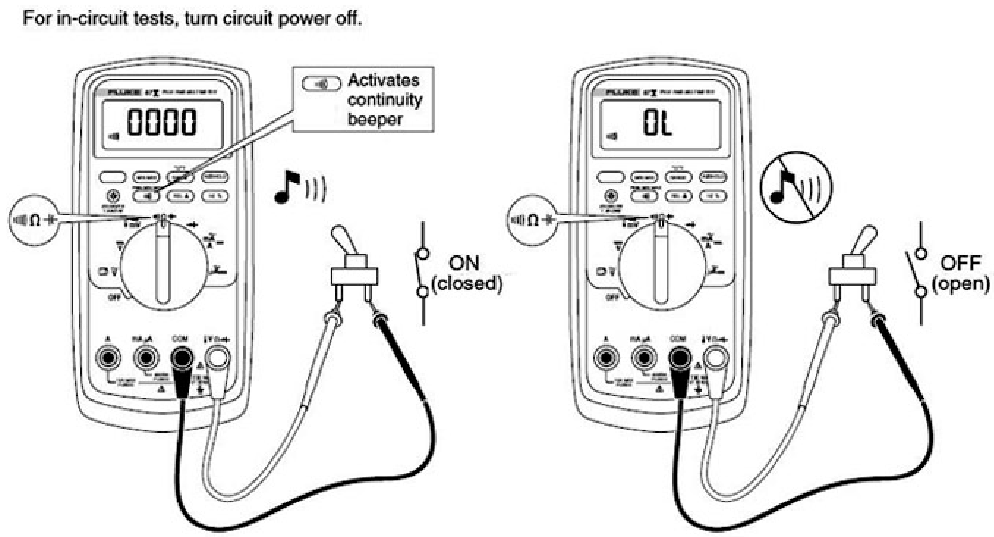


**Figure 2–15. Measuring continuity.**
**(Printed with permission, Fluke Corporation)**

### *Capacitor check*

The meter's capacitance ranges are 10.00 nanofarad (nF), 100.0 nF, 1.000 microfarad (µF), 10.00 µF, 100.0 µF, and 9999 µF. To measure capacitance, set up the meter as shown in figure 2–16. To improve the accuracy of measurements less than 1000 nF, use the relative (REL) mode to subtract the residual capacitance of the meter and leads. See figure 2–16 below for configuration.

**CAUTION:** To avoid possible damage to the meter or to the equipment under test, disconnect circuit power and discharge all high-voltage capacitors before measuring capacitance. Use the DC voltage function to confirm that the capacitor is discharged.

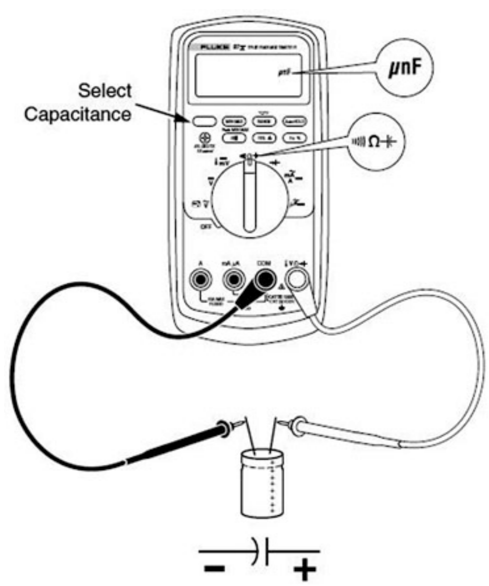


**Figure 2–16. Measuring capacitance.**
**(Printed with permission, Fluke Corporation)**

**NOTE**: If too much electrical charge is present on the capacitor or being tested, the display shows "diSC."

### *Testing diodes*

To test a diode out of a circuit, set up the meter as shown in figure 2–17. For forward-bias readings on any semiconductor component, place the *red* test lead on the component's *positive* terminal and place the *black* lead on the component's *negative* terminal.

**CAUTION:** To avoid possible damage to the meter or to the equipment under test, disconnect circuit power and discharge all high-voltage capacitors before measuring capacitance. Use the DC voltage function to confirm that the capacitor is discharged.

In a circuit, a good diode should still produce a forward bias reading of 0.5 volts (V) to 0.8 V; however, the reverse-bias reading can vary depending on the resistance of other pathways between the probe tips.

A short beep sounds if the diode is good (< 0.85 V). A continuous beep sounds if the reading is ≤ 0.100 V. This reading would indicate a short circuit. The display shows "OL" if the diode is open.

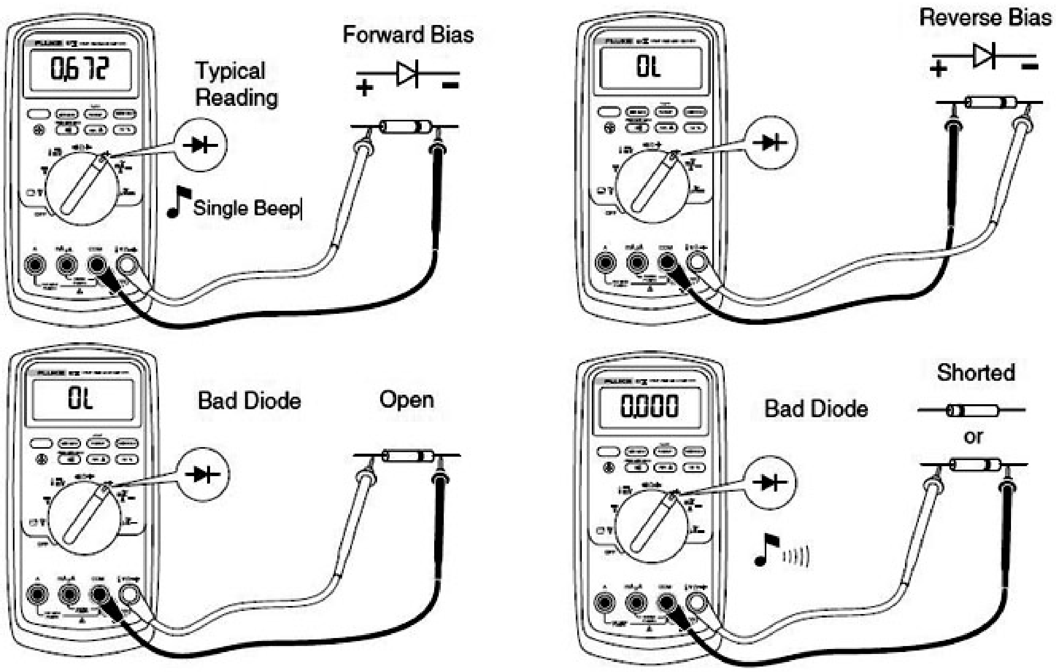


**Figure 2–17. Testing a diode.**
**(Printed with permission, Fluke Corporation)**

### *Resistance check*

A resistance check is very similar to testing for continuity. The difference is you are reading the actual resistance and not just checking for a path for current. See figure 2–18.

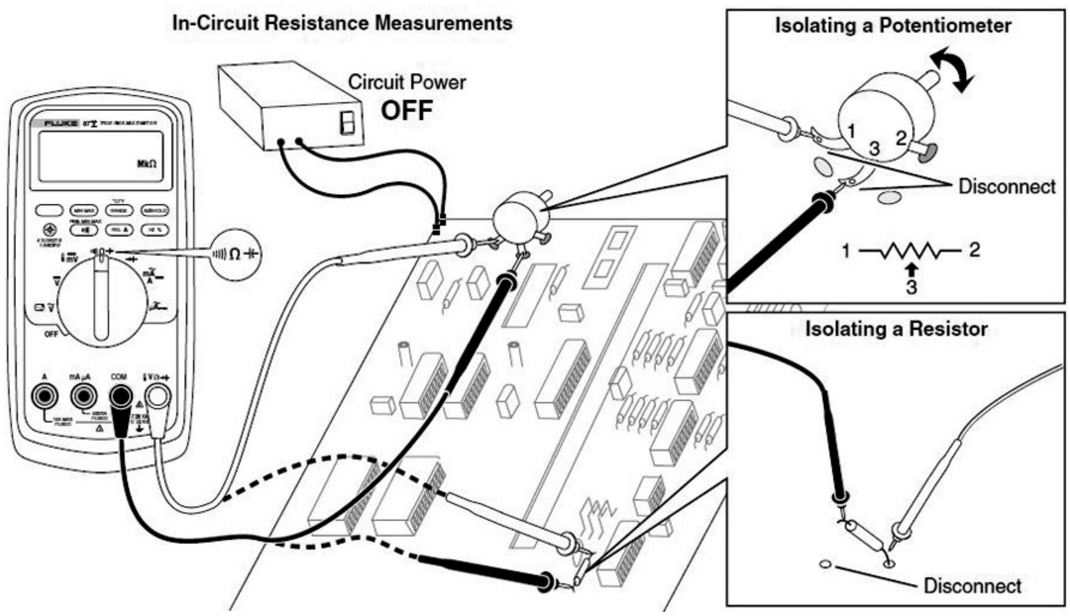


**Figure 2–18. Measuring resistance.**
**(Printed with permission, Fluke Corporation)**

## Clamp on ammeter

A clamp-on ammeter provides information on current flow without interrupting the circuit. This instrument can be very helpful when figuring generator load and facility power requirements. There are many types of clamp-on ammeters; we will use the Fluke 32x clamp meters as an example.

Before checking amperes in a circuit with a clamp on ammeter, make sure that you follow these safety steps:

- Use only correct measurement category (CAT), voltage, and amperage rated probes, test leads, and adapters for the measurement.
- Hold the product behind the tactile barrier. See figure 2–19, item 1.
- Do *not* exceed the CAT rating of the *lowest* rated individual component of a product, probe, or accessory.
- Do *not* measure current while the test leads are connected to the input jacks.
- Do *not* use the product around explosive gas, vapor, or in damp or wet environments.
- Limit operation to the specified measurement category, voltage, or amperage ratings.
- Before each use, examine the product. Look for cracks or missing pieces of the clamp housing. Also, look for loose or weakened components. Carefully examine the insulation around the jaws. See figure 2–20, item 2.
- *Never* work alone.

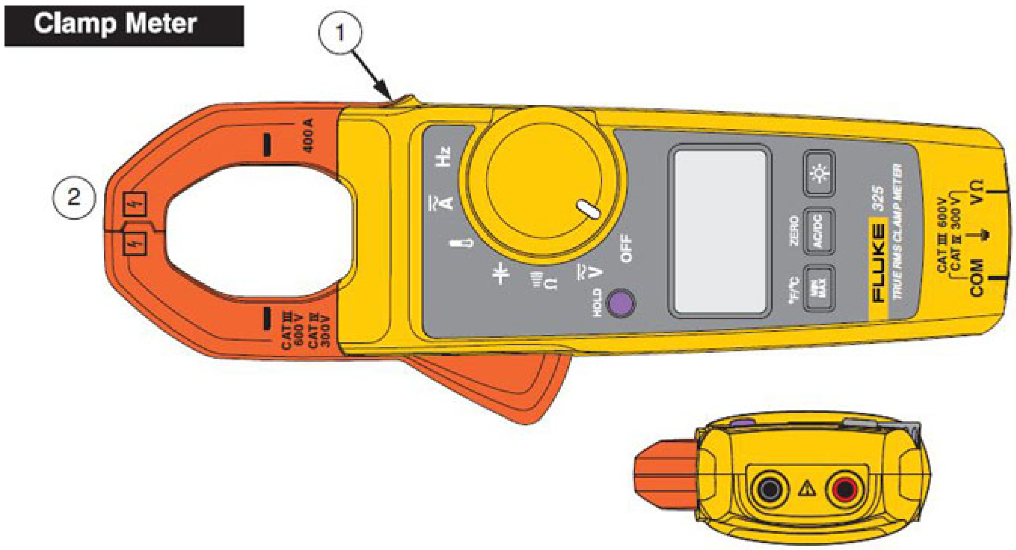


Figure 2–19. Clamp on Ammeter.
(Printed with permission, Fluke Corporation)

To take measurements, place selector switch to the correct position, open the jaws using the pushbutton on the side. Then place jaws around conductor. Take note of the reading, and then remove using the same steps in reverse.

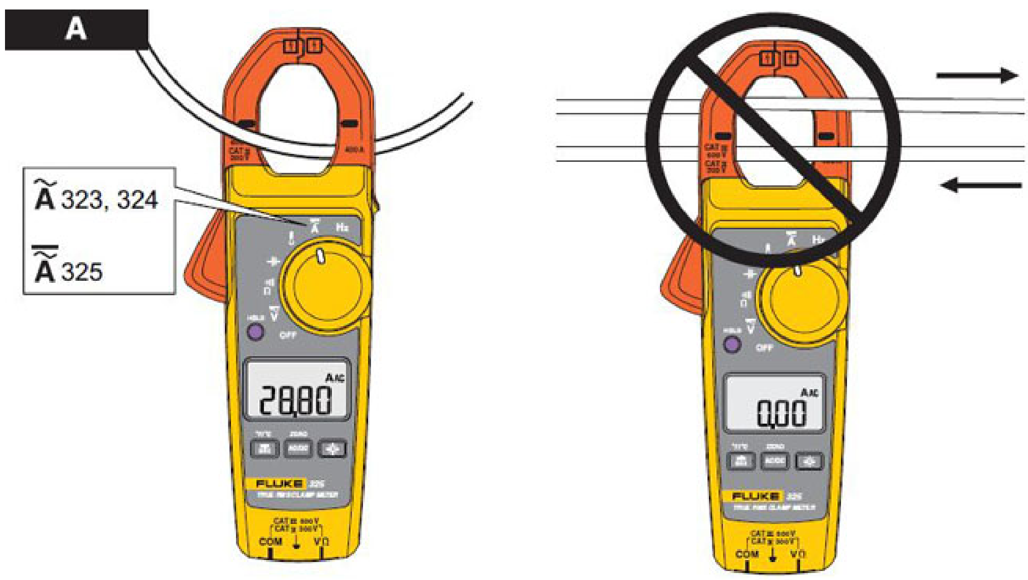


Figure 2–20. Using Clamp on Ammeter.
(Printed with permission, Fluke Corporation)

## 008. Specialty testing devices

Over time you will encounter different diagnostic tools that you may only use once or twice a year, or are you only use for a very specific purpose. This lesson will cover some of these items. We will start with a megohmmeter and then cover the phase rotation meter, a battery load tester, an earth ground tester, and finish up with a load analyzer. Knowing what purposes these tool are used for will help you become a more proficient power production technician.

## Megohmmeter

A megohmmeter can be used to test alternator windings. This requires the megohmmeter to produce a very high voltage so it can properly measure the resistance. For this reason, you must use extreme caution when performing these checks. When operating the megohmmeter, obey the following safety guidelines:

- Do *not* expose megohmmeter to wet conditions.
- Use the correct accessories and inspect them before use.
- Only use the megohmmeter for its intended use.
- Do *not* apply more than the rated voltage.
- Do *not* come in contact with uninsulated portions of the megohmmeter or equipment.
- Shut off and lock out power, unless measuring voltage. Make sure that all capacitors are discharged. Voltage must *not* be present.
- Do *not* use this unit near equipment that generates electromagnetic interference as it can result in unstable or inaccurate readings.
- Do *not* expose the unit to extremes in temperature or high humidity.
- Do *not* try to repair a megohmmeter.

**WARNING:** FAILURE TO FOLLOW THESE PRECAUTIONS MAY RESULT IN INJURY OR DEATH!

Follow these steps to use the megohmmeter:

1. Set the selector to the proper setting and connect the test leads to the meter.
2. Test the unit on a known functioning circuit or component.
   a) If the unit does not function as expected on a known functioning circuit, replace the batteries.
   b) If after replacing the batteries the unit still does not function as expected, send the unit to the manufacturer for repair.
3. Before connecting the unit to the alternator, make sure it is off and the generator is disabled from being able to start.

   **NOTE**: See figure 2–21 for configuring the megohmmeter.

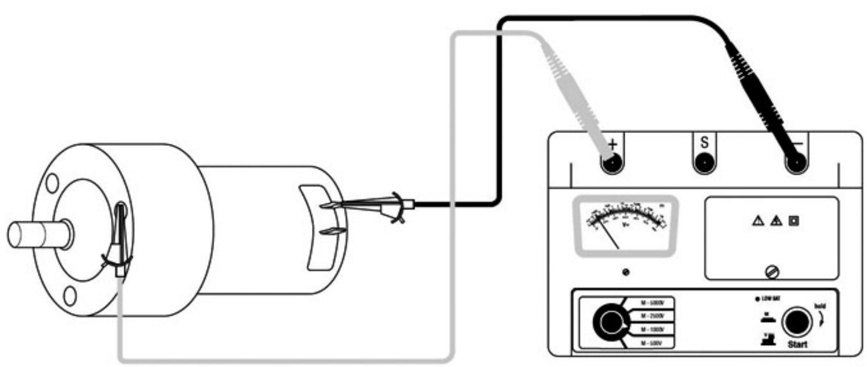


**Figure 2–21. Using megohmmeter**

**(Printed with permission, Fluke Corporation)**

4. Follow the steps under “General Operation.” Note meter reading, if voltage is present, do not attempt Insulation Resistance Test.

5. Press the START button to perform the test. To lock (hold) the START button for longer tests, press the button and turn it clockwise.

**NOTE**: Check the reading every 5 minutes to make sure that the insulation has not broken down.

6. To discontinue the test, release the START button. If the button is in the locked position, press and turn it counterclockwise.

### Phase rotation meter

Phase rotation meters are used on three phase power sources and are used to display the rotation of the three AC phases. You will use these when connecting a three-phase generator to any load. It is important to check phase rotation to make sure that any three-phase load, in particular motor, is turning in the correct direction and will not cause damage to you or the equipment you are driving.

As with all testing devices, there are several different models and companies. We reference the Greenlee © 5702 Phase Sequence Indicator (fig. 2–22) for this lesson. Be sure to familiarize yourself with the ones being used at your location.

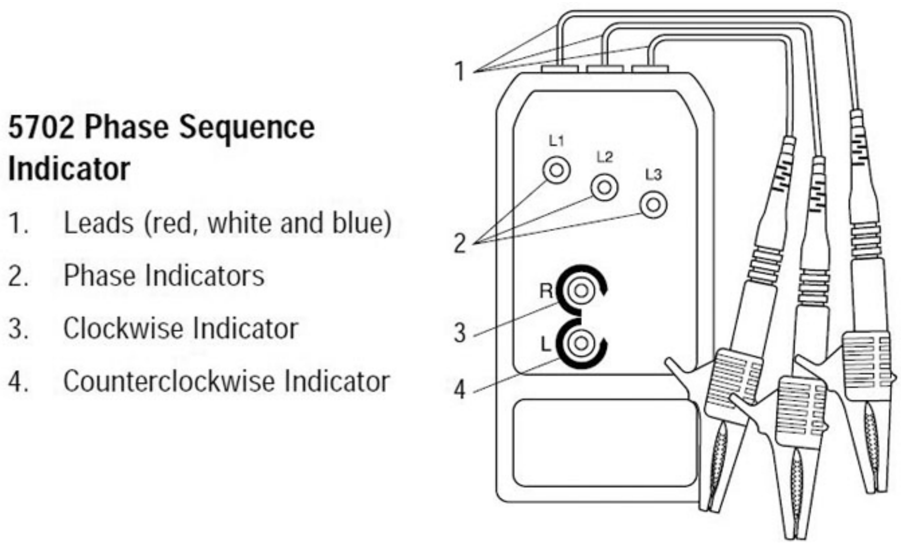


**Figure 2–22. Phase sequence indicator.**
**(Printed with permission by Greenlee/A Textron Company)**

To check phase rotation, follow these steps:

- Shut off and lock out power source.
- Attach the leads to the three phases of the circuit.
- Energize the circuit.
- Read the tester:
  a) All of the phase indicators lights should illuminate; if not, investigate why one of the phases is not present.
  b) If the meter indicates clockwise, ensure that your generator's rotation is the same.
- De-energize the circuit and lock out the power sources.
- Disconnect the 0-phase rotation meter leads.
- Restore power.

### Battery load tester

The battery load tester is used to check the overall condition of a battery. It puts an artificial load on the battery to test the cranking amps capacity. You can use it to determine if a battery has a shorted or bad cell. The following steps are for an Associated Equipment © Model 6029 handheld battery tester (fig. 2–23). Always familiarize yourself with the specific equipment being used in your work center before use.

To test a battery using a battery load tester, follow these directions:

- Disable the generator from starting.
- Connect the battery load tester (black to negative and red to positive). The tester will indicate the state of charge on the battery. If a 12-volt battery is reading less than 12.4 volts, recharge the battery before testing.
- Depress and hold the load switch for 10 seconds.
- Read the volt meter after the 10 seconds; refer to table below for actions to take based on the results.

| TESTING BATTERIES | |
|---|---|
| ***Volt Meter Results*** | ***Action*** |
| Needle in temperature corrected green scale. | Battery is good. |
| Little if any movement. Needle in temperature corrected yellow scale. | Battery is questionable.<br>Recharge and retest. |
| Noticeable meter movement and/or needle in temperature corrected red scale. | Battery is defective. Replace. |

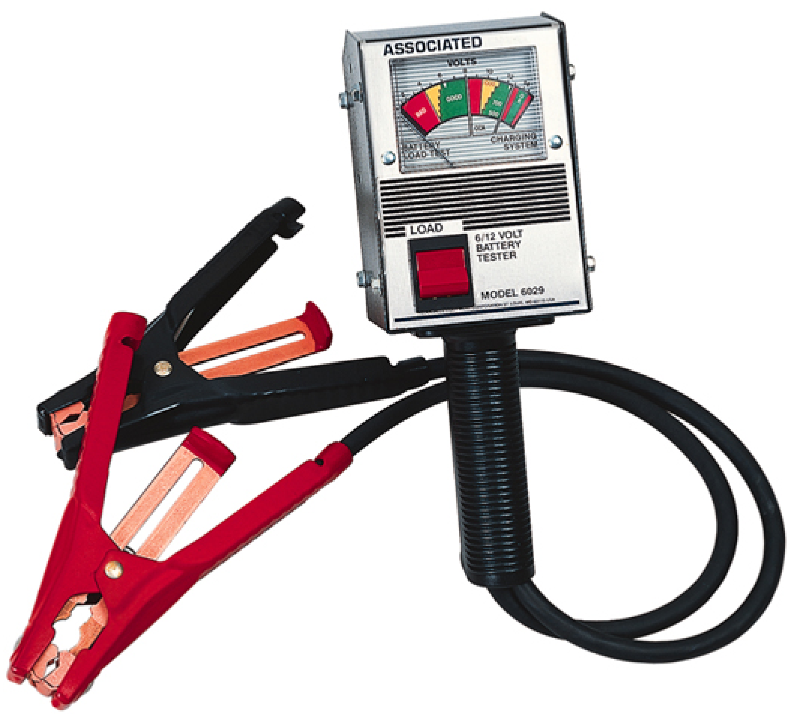


**Figure 2–23. Battery load tester.**

### Earth resistance tester

An earth resistance tester is used to measure the resistance of a ground rod or ground grid. This is a vital piece of equipment that can help you ensure that your grounds are providing the correct protection per equipment and personnel.

There are a variety of methods to test grounds. The 3-pole fall of potential measurement is done using the Fluke © 1621, earth ground tester. This is just an example; be sure to familiarize yourself with the earth resistance tester in your work center. To test grounds using the 3-pole fall of potential method, follow these steps:

1. Insert the probe and auxiliary electrode stakes into the soil as shown in figure 2–24.
2. Ensure the probe stake is a minimum distance of 64 ft. from the earth ground electrode. Ensure the auxiliary electrode stake is a minimum distance of 64 ft. from the probe stake.
3. Position the auxiliary electrode stake so it forms a straight line with the earth ground electrode and probe stake.
4. Turn off the switch.
5. Install the test leads shown in figure 2–24.
6. Set the switch to the 3-pole position and press start.
7. When the measurement is done, the earth ground electrode resistance (RE) automatically displays. To display the auxiliary electrode resistance (RH) press display. To display the probe resistance (RS), press display again.

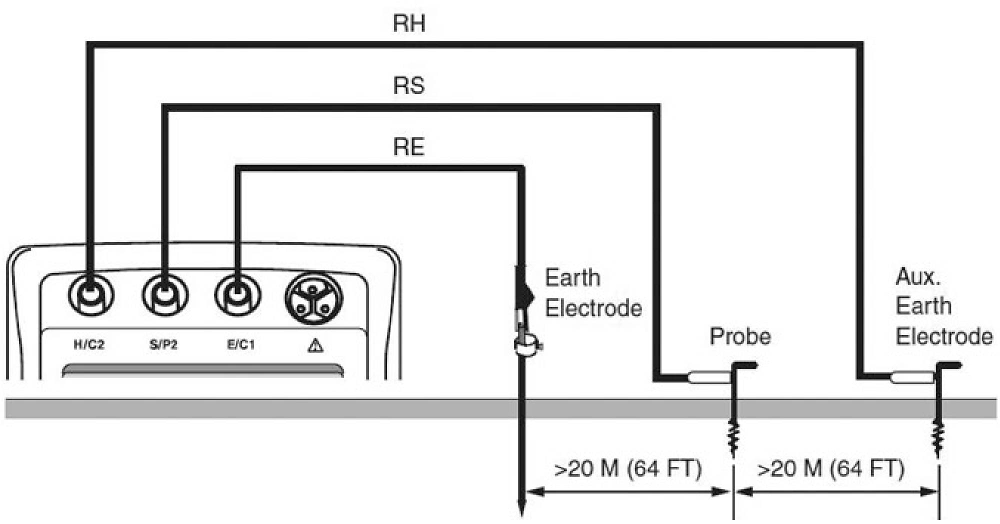


**Figure 2–24. Earth ground tester.**
**(Printed with permission, Fluke Corporation)**

### Power analyzer

Power analyzers are called many things—power quality loggers, power analyzers, and load analyzers. No matter what they are called, they perform one main function. They record power at a facility or load. The information from these can be used to help size generators and check the incoming power quality. In this lesson, we will be using the Fluke 17 series power quality logger. As with all test equipment, familiarize yourself with its operation.

When using a power analyzer ensure that you follow all safety precautions to include arc flash safety and user manual precautions. To connect a power analyzer, you must know which leads are connected to what wires. Thoroughly read the user’s manual to ensure that you are connecting the correct leads to the correct phases.

*Connecting current probes*

Connect current clamps and Flexi Set probes so that current will flow in the direction marked by arrows on the probes. Current must flow from the energy generator to the energy consumer (the load) to maintain a positive active power. (The polarization of the test lead for neutral conductor current is not significant, because the phase angle of the neutral conductor current is not evaluated.)

*Connecting voltage probes*

Connect the four voltage probes to the appropriate terminals for each phase and neutral. Figure 2–25 shows an example of a power analyzer connected to a wye system.

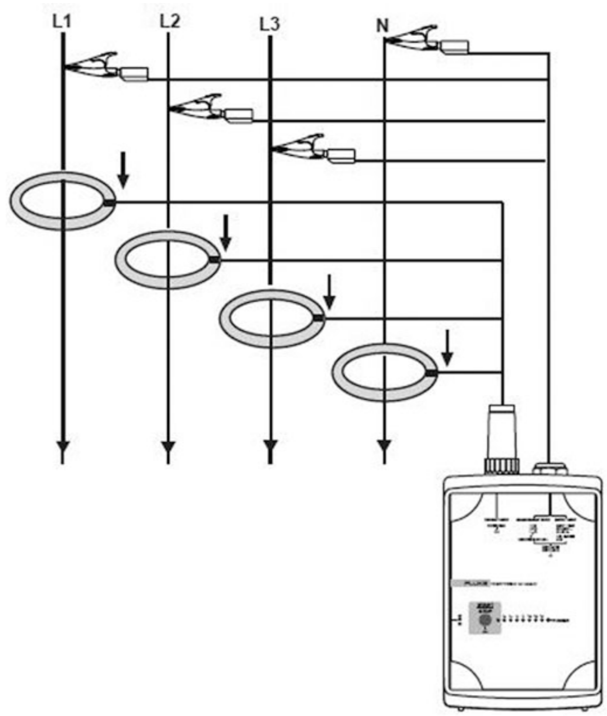


**Figure 2–25. Power analyzer.**
**(Printed with permission, Fluke Corporation)**

## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

### 007. Electrical diagnostic devices

1. When measuring voltage, how do you set the probes on a powered circuit?

2. When measuring amperage, how do you set the probes on a powered circuit?

3. What is the sequence for testing current in an AC or DC circuit?

4. When testing for continuity, what do you have to ensure before testing the component?

5. What meter can be used to check the current value of a circuit without any circuit interruption?

**008. Specialty testing devices**

1. What must you do *before* connecting a megohmmeter?

2. What is the *first* thing you must do when identifying phase rotation?

3. What tool is often used to test the *overall* condition of a battery?

4. Where are the leads of an earth resistance tester installed to test a ground?

## Answers to Self-Test Questions

**005**

1. Inside and outside measurements.
2. Bending beam, dial indicator, and preset ratchet types.
3. Carefully place the tachometer adapter snugly against the rotating surface and observe the reading.

**006**

1. Cleanliness.
2. Apply a proper amount of solder directly to the connection.
3. By stripping the braided shield from a piece of coaxial cable or by removing the insulation from a piece of multi-strand wire.

**007**

1. In parallel with the source.
2. In series with the circuit.
3. Turn off the circuit to be tested, place the meter in series, turn power on, take reading, power off, and then disconnect probes.
4. The component is isolated and the power to the circuit is turned off.
5. Clamp-on ammeter.

**008**

1. Set the selector to the proper setting and connect the test leads to the meter.
2. Shut off and lock out power source.
3. Battery load tester.
4. A minimum distance of 64 ft. from the probe stake.

**Do the unit review exercises before going to the next unit.**

## Unit Review Exercises

**Note to Student:** Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

15. (005) Which tool measures the *depth* of an item?
    a. Caliper.
    b. Depth gage.
    c. Torque handle.
    d. Outside micrometer.

16. (005) Which tool do you use for determining the thickness of objects, the distance between surfaces, and the depth of openings in mechanical parts?
    a. Calipers.
    b. Depth gage.
    c. Torque handle.
    d. Inside micrometer.

17. (005) Which tool do you use to tighten a nut or bolt to a given amount of pressure?
    a. Torque wrench.
    b. Ratchet handle.
    c. Boxed end wrench.
    d. Open ended wrench.

18. (005) What type of handheld tachometer is equipped with reflective strips and the tachometer?
    a. Laser.
    b. Photo.
    c. Contact.
    d. Pneumatic.

19. (006) What is the key to reliable soldering?
    a. Clarity.
    b. Low heat.
    c. High heat.
    d. Cleanliness.

20. (006) When preparing equipment for soldering, after you clean and dress the soldering tip, you heat and tin it with what?
    a. Flux.
    b. Solder.
    c. Leather.
    d. Steel wool.

21. (006) When preparing equipment for soldering, clean terminals with a pencil-style typewriter eraser until the tinned surfaces are
    a. dull and gray.
    b. bright and shiny.
    c. dark and reflective.
    d. brilliant and dreary.

22. (007) When measuring voltage using a multimeter, you connect the probes in
    a. series with the power source.
    b. parallel with the power source.
    c. series with the electrical unit to be tested.
    d. parallel with the electrical unit to be tested.

23. (007) What are the correct steps (in the correct order) to measure current in an alternating current or direct current circuit?
    a. Power off, connect probe, power on, power off, disconnect probe, and take reading.
    b. Power off, connect probe, power on, take reading, power off, and disconnect probe.
    c. Connect probe, power off, take reading, power off, disconnect probe, and power on.
    d. Connect probe, power on, take reading, power off, power off, and disconnect probe.

24. (007) When checking amperes in a circuit with a clamp-on ammeter, a safety precaution is to make sure the test probes are
    a. disconnected from the input jacks.
    b. connected in parallel to the circuit.
    c. connected in series to the circuit.
    d. connected to the input jacks.

25. (008) Which device is a quick and convenient tool for determining the overall condition of a battery?
    a. Vibroground.
    b. Frequency meter.
    c. Recording meters.
    d. Battery load tester.

26. (008) When load testing batteries, how many seconds do you hold the load switch on the tester?
    a. 5.
    b. 15.
    c. 10.
    d. 20.

27. (008) Which test instrument is used for testing grounds?
    a. Ammeter.
    b. Multimeter.
    c. Megohmmeter.
    d. Earth resistance tester.

28. (008) When doing the 3-pole fall of potential ground test using the earth resistance tester, at a *minimum*, how far apart must your probe stake be from the earth ground electrode?
    a. 64 feet.
    b. 46 feet.
    c. 128 feet.
    d. 64 meters.

29. (008) When installing current transformers clamps, which way does the arrow need to point?
    a. Against current flow.
    b. With current flow.
    c. Either with or against current flow.
    d. 120 electrical degrees from current flow.

**Please read the unit menu for unit 3 and continue ➔**

# Unit 3. General Tasks and Equipment



YOU WILL HAVE to maintain many different types of equipment during your time in power production. This unit covers a couple of them—battery chargers and load banks. It also covers corrosion control. Equipment maintenance and corrosion control will take a lot of your time and are important tasks needing to keep the generator fleet ready for mission requirements.

## 3–1. Support equipment

This section covers battery chargers and load banks. Battery charges are used to ensure that the generators starting system is ready in a moment's notice. Load banks are used to test a generator's ability to carry its rated load capacity.

### 009. Battery chargers

An important part of the power production career field is being able to maintain the working integrity of the generator set and its related equipment. To keep the unit running in peak condition, a few minutes spent inspecting the batteries and battery chargers before each generator run could mean the difference between 100 percent power reliability and answering why it didn't start. The battery charger is an essential part of the generator because it keeps your battery at a full charge—ready to start the generator on a moment's notice.

The battery charger consists of electronic components that transforms the voltage level to the level of the battery and converts AC into DC. It then applies the voltage to the battery to replenish its charge. Battery chargers can operate with multiple AC input voltages. The table below describes the electronic components of a battery charger:

| Components of a battery charger | |
|---|---|
| ***Component*** | ***Description*** |
| Power contactor | Controls the current flow from AC input to the primary side of power transformer. |
| Power transformer | Decreases the input voltage to required output voltage to provide the battery with a charge. |
| Control transformer | Provides the proper value of voltage to operate the power contactor. |
| Power diode | Rectifies the AC output of the power transformer to DC. |
| Timer switch | Allows you to charge the battery for a prescribed period of time. Turning it to the on position sets the timer for the charge. It automatically turns OFF after the period is over. Not all battery chargers are equipped with timer switches. |
| Meters | Allow you to determine the rate of charge that the battery is drawing. The battery charger typically contains two meters: a voltmeter and an ammeter. |

#### Theory of operation

Voltage is supplied to the control transformer, energizing the power contactor to close its contacts in the AC input lines to the power transformer. The magnetic field produced by the voltage in the core of the primary windings of the power transformer induces a voltage in the secondary windings. Since the secondary windings have fewer turns than the primary, the output voltage is lower than the input. The position of the high voltage and fine adjustment taps on the terminal board controls the output of the power transformer secondary windings. The power diode rectifies the AC voltage from the power transformer's secondary winding. This provides DC output to the battery. The DC ammeter shows the amperage draw on the battery charger and the voltmeter shows the voltage level at which it is charging. The rate of charge decreases as the battery nears a full charge.

### Battery charger maintenance

Performing battery charger maintenance is essential to the operation of generator sets. The battery charger keeps your batteries at a full charge at all times. This ensures that the generator is ready for starting at a moment's notice. This is essential to the completion of the mission.

#### *Inspect battery chargers*

Inspect the battery charger regularly to ensure that it works properly. Inspect its case for obvious damage, dirt, grease and foreign matter. Ensure the proper installation and security of the front panel cover. Check the input and output cables for cuts, abrasions, wear or other damage. Check the input and output connectors for damage and corrosion. Open the front panel cover and inspect the interior of the battery charger. Ensure the proper installation of the terminal board safety cover. Check the interior wiring for cuts, wear, signs of overheating, or other damage. Check the terminal connections to interior components for security and corrosion. Check the inside of the case for cleanliness and foreign matter.

#### *Replacing battery charger components*

The biggest thing to remember when you replace battery charger components is that you are working with electricity and must take the appropriate safety precautions. Be sure to de-energize the load bank and tag the control panel before you try and replace any component. Remember that the battery charger has two different connections: the input AC voltage and the output DC voltage. Disconnect both input and output and use a meter to verify that you have turned the power off before you start any maintenance. Be sure that any component you install has the same electrical rating as the one you are to replace. Tag and disconnect the wires from the component. Remove the hardware that secures the component to the mounting bracket and remove the component. Install the new component and secure it. Connect the wires and replace any access panels that you may have removed. Test the load bank to ensure that it operates correctly.

#### *Adjust battery chargers*

Battery chargers have adjustments that give you the ability to set the charging rate for a battery. This allows you to adapt the charger to numerous situations. The primary concern when adjusting a battery charger is the output voltage. Batteries only produce a certain amount of voltage based on their design. Set the battery charger with the output voltage slightly above this voltage. The charger will continue to charge at a high rate until the battery reaches this voltage. It then decreases the rate of charge to keep the battery at the voltage level. If you set it too high, the rate of charge will never decrease, which could possibly damage the battery. If you set the voltage level too low, the battery will never reach a full charge because the rate of charge will decrease before the battery reaches a full charge. Battery chargers have different adjustments depending on the manufacturer. Common adjustments are the output voltage adjustment and current adjustment.

Some battery chargers have other adjustments for an equalized charge. This adjustment is for a high charging rate for batteries that have a very low charge. Regardless of what adjustment that you make, keep in mind that the goal is to have a fully charged battery without causing damage to it.

The biggest adjustment that you make is to the output voltage. If you get this set right, the amount of current, or charging rate, takes care of itself. If you are working with a 12-volt battery, the output of the battery will be between 12.5 to 13.2 volts. Set the battery charger output voltage for no more than 13.2 volts. This provides you with enough current to reach a full charge but not damage the battery. If your battery charger has a current adjustment, set it with the battery at a full charge. This allows you to set a very small charging rate to maintain the battery at a full charge. When the battery is discharged, the charging rate automatically increases. If you set the charging rate while the battery is low, an incorrect rate of charge can cause it not to completely charge the battery.

Any time that you make adjustments to the battery charger, be sure to check the adjustments the following day. This allows you to take a second look at the charging rate to make sure it is set correctly. If you set it wrong initially and do not check it the next day, you could damage the battery from overcharging it or have a generator failure from undercharging it.

### Troubleshooting battery-charging system

The first step in troubleshooting the battery-charging system is to check the condition of the battery. If the battery voltage is near the lower limit of its recommended voltage, the battery-charging rate should be near its maximum rate. If the charger is not producing satisfactorily, the charger has to be adjusted by following the procedures given in the TO for the specific battery charger model in your unit.

Figure 3–1 is an example of a battery-charging circuit. Internal adjustments are provided for balancing the secondary load from the step-down transformer. You accomplish this by taking three readings with a clamp-on ammeter at three test points (A1, A2, and A3). Adjust rheostats R1, R2, and R3 while making sure the ammeter readings are as equal as possible. Next, adjust R7 to set the voltage. Then adjust the ampere rate with R11. Failure of any component to adjust to the specifications given in the TO can require removal of the charger to isolate the malfunction to a specific item for repair or replacement.

Control systems for the battery-charging circuits are highly specialized and specifically developed for each manufacturer’s unit. When you encounter special problems, use the manufacturer’s manual and the applicable wiring diagrams. Some of the general troubleshooting procedures are the same for all units. The manual describes situations common to charging-system troubles. These conditions have not stressed checking the battery; however, make sure you first check the condition of the battery or batteries if charging-system troubles are experienced. A bad cell or other internal conditions in the battery often cause symptoms of external component failure. Some situations you may experience are discussed in the following paragraphs.

#### *Situation No. 1*

This situation includes a fully charged battery or batteries and a low charging rate. It is the normal operating procedure for a battery-charging system and indicates that the source of power is adequate and the regulating device or devices are operating properly.

#### *Situation No. 2*

In this situation, a low battery and a low or no charging rate occurs. This condition should be analyzed by first assuring that the source of power is available. You must check the generator and rectifying devices for proper output. You need to bypass the generator controlling devices shortly to make the determination. An open or shortened rectifier, loose wires or high-resistance connections, or defects within the generator may be the source of trouble. If the generator is defective, you need to repair it. For small units using a special generator for battery charging, the generator may need replacement.

If the generator is okay, the voltage-regulating and current-regulating device should be checked. You must strictly follow the TO procedures for checking the regulator. An improper connection can burn up the unit. Operating the generator on an open circuit can also destroy the regulator or generator. If found to be defective, replace the generator or regulator.

#### *Situation No. 3*

A fully charged battery with a high charging rate is the final situation this lesson covers. This situation indicates that the voltage-regulating device is not doing its job. If this condition continues for very long, the battery or batteries may overcharge and possibly be destroyed. Again, check and repair or replace the regulator.

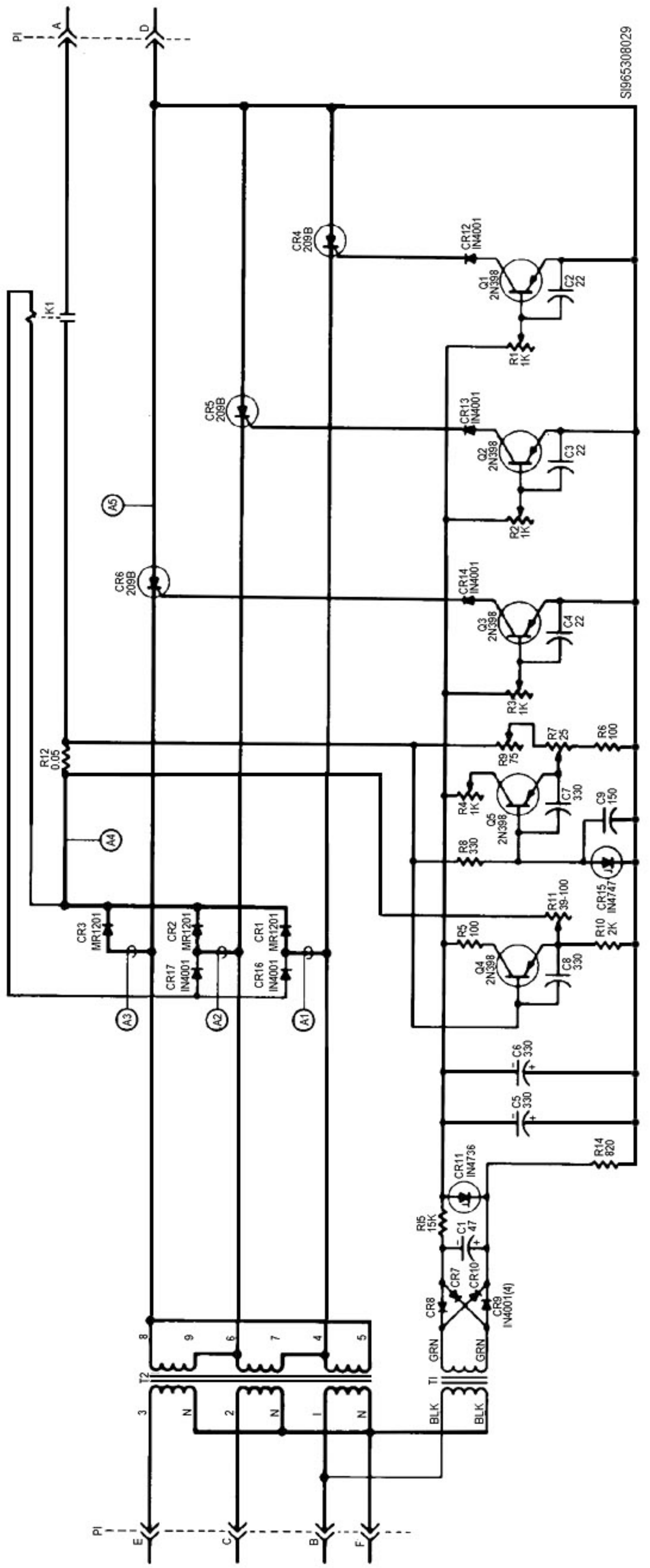


Figure 3–1. Generator-set battery-charging circuit.

### Troubleshooting a battery charger

Although a battery charger should require very little maintenance, it is subject to malfunction or fail the same as any other manmade machine. The best troubleshooting procedure is first to get accurate trouble symptoms using the battery-charger instruments and controls. The next step is to de-energize the unit and make a thorough visual inspection of the entire system.  Many times you detect and repair loose connections, broken wires, blown fuses, or burned-out components at this troubleshooting stage. If a visual inspection does not reveal the cause of the trouble, the next step is to use a good multimeter and check out the battery-charger circuit. The three common trouble symptoms are as follows:

1. Charging voltage “0,” amperage normal.
2. Charging voltage “0,” amperage “0.”
3. Charging voltage normal, amperage low.

#### *Charging voltage “0,” amperage normal*

If the DC ammeter shows a normal charging rate, simple logic indicates that the DC charging voltage must be correct. The DC voltmeter or its leads must be at fault. Use a multimeter to check the voltmeter and its leads. If a voltmeter lead is bad, repair it. If the DC voltmeter is defective, replace it.

#### *Charging voltage “0,” amperage “0”*

The cause of this trouble symptom could be anywhere in the battery charger from the input power terminals to the place where the DC voltmeter taps into the circuit. If a visual inspection does not reveal a blown fuse in the AC input circuit or the DC output circuit, check these fuses with a multimeter. If the fuses are good, use the multimeter to check the transformer AC voltage input and output; then check the DC output of the rectifier assembly. Replace all defected components.

#### *Charging voltage normal, amperage low*

The cause of this trouble symptom is probably a poor DC output cable connection. Clean, check, and tighten all DC output cable connections. If the trouble persists, de-energize the battery charger and then check the sensing and saturable reactor circuits and components for proper resistance values and continuity. You need to isolate the components such as the potentiometer and resistor and check their resistance values against those given by the manufacturer of the battery charger. Remove and replace any defective components.

Batteries are a crucial piece of equipment for reliable emergency generators.  Without them many generators would not start due to batteries that have discharged.  Knowing how batteries work and how to fix them will greatly enhance your generator fleet.

## 010. Load banks

The purpose of load banks is to simulate actual operating conditions without having to disturb the using activity. Years ago, emergency power generators were tested to make sure they would start and that their frequency and voltage reached rated values. It was not a common practice to connect them to their actual load. This might disrupt the services for which they are supposed to provide—power in an emergency. As a result of field analysis of emergency units failing under this condition, a new philosophy developed that required testing emergency generators under full load operating conditions. Because of this new philosophy, manufacturers developed load banks using modern engineering and heat transfer techniques. The two types of load banks developed are portable and stationary.  Portable load banks are most generally skid mounted or equipped with wheel mounting kits to increase mobility. Stationary load banks are permanently installed and are normally very large in kW rating, ranging from 250 kW to 8 MW. Both types provide a load by using resistive type heating elements which have motor driven cooling fans to cool the elements.

## Load bank components and theory of operation

The control panel contains all the switches required to operate the load bank (fig. 3–2). Voltage and current measurements display on meters mounted in the control panel. Typically a load bank uses construction features of aluminized steel and fiberglass, forming a rigid structure. Load banks have resistive elements (heat strips), the blower motor, load step contactors, motor starter, over temperature sensor, fuses, and terminals mounted within the housing. The resistive elements and cooling fans simulate a load for generators. Cooling air draws in from one end and is forced across the resistor elements and exhausted out the other end.


**Figure 3–2. Load bank.**

### *Controls*

There are several controls incorporated in the load bank. Power for control circuits may be either external (through separate power cord) or internal (from generator input). The table below provides a brief function of the load bank controls:

| Load Bank Controls | |
|---|---|
| ***Control*** | ***Function*** |
| Control/blower voltage select switch | Allows the operator to select internal or external power sources. Can be set to internal to operate from the generator or from an external source. |
| Main power switch | This switch connects the generator power to load bank control circuits. |
| Fan start and alarm clear switch | This switch energizes the cooling fan. It also clears the alarm that sounds if the fan is not running with power applied to the load bank. |
| Load voltage select switch | This switch allows the load bank to be configured for different generator output voltages. This is not found on all load banks. |
| Voltage reconnection panel | This panel contains reconnection bars that can be removed and configured according to the voltage input from the generator. It serves the same purpose as the load voltage select switch. This switch is not found on all load banks. |
| Master load switch | This switch connects the generator power to the circuit breakers for the kW step switches. |
| kW load step switches | A series of switches used to select a specific resistive load value from the generator. The switches provide several different load ratings. |

| Load Bank Controls | |
|---|---|
| ***Control*** | ***Function*** |
| Volts select switch | Used to check voltage between phases of generator output during three-phase operation. |
| AC volt meter | Displays the current voltage value relative to the volts selector switch. |
| Amps select switch | Used to monitor the amount of current on a selected generator output phase. |
| Range select switch | Selects between high (0–400) and low (0–80) range of ammeter. Not found on all load banks. |
| AC ammeter | Indicates the amperage drawn by the load bank from the generator. |
| Main power on indicator | This is a light that indicates that the main power to the load bank is on. |
| Blower fail indicator | If blower fails, this indicator light illuminates. The load bank airflow safety switch activates, opening the load bank breaker to prevent damage to the heating coils. |

### *Theory of operation*

When you hook a load bank up to a single- or three-phase AC power source, it draws current from the generator consistent with the amount of load resistors turned on. Turning the master load switch on and placing the proper kW load step switches to the ON position accomplishes this. This activates internal control relays allowing the user to control the amount of current drawn from the generator. This current then transforms into heat by the resistor elements. The internal blower removes heat from the load bank resistor elements. If there is any restriction or stoppage of the cooling airflow, the load bank may overheat and may even start a fire. This is why manufacturers incorporate a safety airflow switch into the design of many load banks. If the blower fails, the safety airflow switch activates to open the master load switch. The cooling blower and control circuits receive power either from the generator AC input or from a separate power source.

## Operating a load bank

We operate load banks to test generators on a regular basis. This provides the generator with enough load to prevent carbon buildup known as *wet stacking*. It also lets us know that the generator is capable of operating at full load. Many engines run fine at an idle, but falter once load is applied.

### *Connecting cables from generator set to load bank*

When connecting cables from the generator set to the load bank, make sure the generator is shut down and the power is off. Be aware that resistive elements and exhaust screens may be hot. Use caution when moving the generator cable as it may be heavy and pose a tripping hazard. Wear leather gloves when handling electrical cables to prevent injury. Start by connecting the load bank cables to the generator set output terminals. Next, tighten the generator terminal lugs securely. Be sure not to overtighten them. If you must connect the load bank cables to the ends of the generator output cable, wrap the connection with insulating tape.

### *Configuring load banks for proper input voltage*

Before you can operate a generator using a load bank, you must make sure that the generator and load bank are set for the same voltage. Make sure all power is off and disconnected from the load bank. Read the manufacturer’s manual before you operate any piece of equipment that you are unfamiliar with. Remove all jewelry and make sure you have the necessary PPE, such as gloves, goggles, and electrical safety boots. Sometimes adhering to safety rules may seem time consuming and bothersome, but our safety and the safety of others in any circumstance are paramount. Start by checking the generator voltage reconnection terminal board for the voltage setting. Once you have determined the setting, you can set the voltage on the load bank by placing the LOAD VOLTAGE SELECT switch or changing the reconnection panel to match generator set output voltage. This is an important step, and if overlooked could cause severe damage to equipment and injury to people.

Voltages can range from single phase 120/240 VAC or three phase 240/480 VAC. A diagram of the voltage bar reconnection configuration is located on the load bank.

### *Operate load banks*

To operate a load bank, inspect it to make sure it is ready for operation. Configure load bank input voltage to match generator output voltage. Place all of the switches to the OFF position. Connect the load bank cables to the generator. Select desired source of cooling blower power, internal or external. If you choose external power, connect power cable. Start the generator and close the load contactor. Be sure to wear hearing protection. Place the load bank MAIN POWER switch to the ON position. Place the fan switch to the ON position. On some load banks you may need to push a fan start button to start the fan motor. Place the MASTER LOAD switch to the ON position. Place kW LOAD STEP switches (fig. 3–3) to the ON position as required to provide the desired load on the generator.


**Figure 3–3. Load step switches.**

To shut the load bank down, place all kW LOAD STEP switches to OFF position. Place the MAIN POWER switch to the OFF position. If you are operating the load bank from internal power, leave the generator running while the load bank cools down. If operating the load bank from external power, start the shutdown for the generator after removing the load. Open the generator contactor and shut down generator after allowing for a five minute cool down. Place the BLOWER POWER selector switch to the OFF position and place fan blower circuit breaker to the OFF position. Disconnect the load bank cables from the generator.

### *Test generator using a load bank*

You are going to become very familiar with the term “load test.” The idea behind load testing is to make sure the generator operates properly under a variety of load changes. On mobile generators, a load bank is used to make sure the generator operates at the rated load without problems. Load banks are also used after performing major maintenance to make sure the generator is functioning properly.

First, connect generator phase leads to the load bank. Once the generator is connected to the load, perform single unit operation. Start adding load to the generator after it has reached operating temperature. Add this load in steps, allowing the generator to completely recover before adding more. Check the load, voltage, and frequency after every load change. Load the generator to the desired level using the ammeter on the generator to establish this. Do *not* load the generator to more than 100 percent amperage. Notice the kW meter reads well above the rated kW value of the generator if the amperage is at 100 percent. The reason for this is that the kW of the generator is calculated using a .8 power factor. Since the load bank is resistive load, it creates a power factor of one. Keep the ammeter below 100 percent to prevent an overload condition.

With the generator load test complete, it is time to shut everything down. Start by lowering the load on the generator in steps, allowing the generator to recover fully between each step. After the generator has reached no load, allow it and the load bank to operate for five minutes for cool down. Once everything is cooled down, open the AC circuit breaker and shut the generator down.

#### *Inspecting load banks*

Before inspecting the load bank, make sure it is de-energized. Be careful because the heating elements may be hot and could cause severe burns. Inspect the cabinet and control panel for damage. Make sure all of the panels and safety grills are in place. Make sure that all of the switches can move to all positions. Search for any debris or foreign matter inside the load bank housing that could be blocking airflow. Check the load connections for tightness and damage. Inspect the grounding terminal and wire for their overall condition, if unsatisfactory (deteriorated), do *not* use the load bank until repaired.

#### *Replacing load bank components*

Load bank components, like all electrical devices, sometimes break, and we need to replace them from time to time. The biggest thing to remember is that we are working with electricity and need to take the appropriate safety precautions. Be sure to de-energize the load bank and tag the control panel before attempting to replace any component. Always use a meter to verify there is no power before you start the maintenance. If replacing the heater elements, be sure that they have had time to cool completely before beginning work. Be sure that the component that you are installing has the same electrical rating as the one you are replacing. Tag and disconnect the wires from the component. Remove the hardware that secures the component to the mounting bracket and remove the component. Install the new component and secure it. Connect the wires and replace any access panels that you may have removed. Test the load bank to make sure that it operates correctly.

### Troubleshooting load banks

Load banks, regardless of the manufacturer, are essentially big electric heaters. They consist of heating coils, control circuitry, and a cooling fan. You will connect the load bank to a generator to create a load to test the generator. Load banks offer multiple levels of load to apply to the engine. Blown fuses are the most common problem you find. Other problems that can occur include burned out heating coils, malfunctioning control circuitry, and fan problems. The wiring diagrams are necessary when you are troubleshooting and, typically, simple to use.

## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

### 009. Battery chargers

1. What is the function of the control transformer?

2. What is the purpose of the voltmeter and ammeter?

3. What causes the output voltage to be lower than the input voltage on a battery charger?

4. What is the *primary* concern when adjusting a battery charger?

5. If you are working with a 12-volt battery, what is the range of the output of the battery?

6. Why must you check the adjustments you made to a battery charger the following day?

### 010. Load banks

1. What are the two types of load banks that have been developed?

2. What is the function of the control/blower voltage selector switch on a load bank?

3. What is the function of the load voltage selector switch on a load bank?

4. What is the function of the master load switch on a load bank?

5. What is the function of the AC ammeter on a load bank?

6. What is the function of the *internal* blower on a load bank?

7. What does testing generators with a load bank prevent?

8. Why should you wear leather gloves when handling electrical cables?

9. What should you do before you operate any piece of equipment that you are unfamiliar with?

10. When inspecting the load bank, what should you look for inside the load bank housing?

11. What safety precaution should you observe if you are replacing the heater elements on a load bank?

## 3–2. Corrosion and starting aids

Over time, corrosion will take place in any environment. In some areas, such as coastal areas, corrosion happens at a much faster rate. You will be tasked to perform corrosion control measures to protect tools and equipment. You will also use engine starting aids to operate equipment in the winter. This section will cover corrosion control and engine starting aids which are vital to proper generator operations.

### 011. Corrosion control

One of the main reasons you have to replace engine components is corrosion. What is corrosion anyway? Corrosion is the process that occurs when something is gradually eaten away, especially by chemical reaction. Oxygen is the most common cause of corrosion. Water, having a high concentration of oxygen, remains in contact with the metals for a much longer period of time than air. This is why many people commonly believed water to be the biggest cause of corrosion.

Some of the other common causes of corrosion are exposure of metal to weather, air, water, or other metals. The formation of corrosion can be accelerated when equipment is exposed to a variety of environmental conditions such as salt, brutal summer heat, ultra violet rays, acid rain, snow, mud, smoke, exhaust fumes, and battery acid. Although there are numerous types of corrosion, we discuss galvanic, pitting, exfoliation, and stress corrosion.

#### Galvanic

Galvanic corrosion can be one of the most common forms of corrosion as well as one of the most destructive. It occurs when two dissimilar metal types are in contact with each other and moisture is introduced. Galvanic corrosion seriously degrades the softer of the two metals. When a galvanic couple forms, one of the metals in the couple becomes the anode and corrodes faster than it would all by itself, while the other becomes the cathode and corrodes slower than it would alone.

#### Pitting

Pitting is a type of corrosion we find most on aluminum. It first appears as a gray or white powdery substance that develops on the metal surface. Removing the residue or powder reveals small pits or pinholes. Pitting is a localized form of corrosion in which cavities or "holes" are produced in the material. We often consider pitting to be more dangerous than uniform corrosion damage because it is more difficult to detect, predict, and protect against. Corrosion products often cover the pits. A small, narrow pit with minimal overall metal loss can lead to the failure of an entire engineering system.

### Exfoliation

Exfoliation corrosion is a further form of inter-granular corrosion associated with high strength aluminum alloys. Alloys that have been extruded or otherwise worked heavily, with a microstructure of elongated, flattened grains, are particularly prone to this damage. Corrosion products building up along these grain boundaries exert pressure between the grains, and the end result is a lifting or leafing effect. The damage often initiates at end grains encountered in machined edges, holes, or grooves and can subsequently progress through an entire section.

### Stress

Stress corrosion occurs when structural stress and corrosion attack at the same time. Cold deformation and forming, welding, heat treatment, machining, and grinding can introduce residual stresses. Press-fit bushings and tapered bolts are examples of high residual tensile stresses, which can lead to stress cracking. The buildup of corrosion products in confined spaces can also generate significant stresses; do not overlook these. Stress corrosion usually occurs in alloy metals. Stress on metal parts may be residual within the part as a result of the production process or externally applied by recurring loading.

### Corrosion control

The purpose of performing corrosion control is to ensure proper operation, prolong life, and increase reliability and efficiency of tools and equipment. Preventive maintenance is the key to a good corrosion control program. Inspection assumes a crucial role in preventive maintenance strategies. Inspect components for corrosion and other damage at planned intervals to identify corrective action before failure or destruction actually occurs.

Preventive maintenance performed at regular intervals *usually* results in reduced failure rates. The key to good preventive maintenance is a preventive maintenance schedule. However, should preventive measures fail, you must remove all signs of corrosion in its earliest state. You generally remove corrosion with a wire brush or sandpaper. You must remove all corrosion to keep it from reappearing in the same place. Once you thoroughly brush or sand away the corroded area, apply primer and repaint the area to protect it from the elements. Lightly coat surfaces with oil or an approved preservative that is designed to remain bare. Observe safety precautions when handling solvents or paint. Be sure to wear the appropriate safety equipment when brushing, sanding, or grinding on corroded metal. You must use respiratory protection, eye protection, and rubber gloves. Consult the safety data sheet (SDS) for specific information on safety requirements of corrosion preventive materials.

**CAUTION**: If the equipment has been treated with a chemical agent resistant coating (CARC), consult the base environmental engineer for its safe removal. The finish coat must also match these specifications.

Corrosion is one of your biggest adversaries when working with generators and aircraft arresting systems. Developing a skill in prevention can save you many hours of corrosion removal. This also keeps your equipment in top operating condition and prevents unnecessary failures. Now it is time for you to complete the review exercises. After that, we discuss lubrication systems.

## 012. Winter starting aids

To prevent damage to the engine during cold weather, use a starting aid to warm the engine before using the equipment. Let's look at some engine starting aids in this lesson and explain how they work.

### Coolant heaters

There are two types of coolant heaters, circulating and immersion. Circulating coolant heaters, shown in figure 3–4, are usually mounted externally to the frame of the engine. Cold coolant leaves the bottom of the engine block and enters the heater tank, where a heating element warms it. Percolation moves the warm coolant back into the engine block. Circulating heaters are available with or without thermostatic control. The main advantage of circulating coolant heaters is that they warm the engine in a very short period of time. Most circulating coolant heaters are electric, but some are propane fired.

Inspect these heaters by looking at the engine temperature with the engine off. The engine should be warm enough to allow the engine to start. Also, look at the heater fittings for leaks and corrosion. Check the clamps and the mounting brackets for tightness. Make sure the hoses are pliable and in good condition. Look at the electrical connections for signs of corrosion and overheating.

To replace an external heater, de-energize the power to the heater, and tag the switch or breaker. Drain the coolant from the radiator into a clean container so you can reuse it. Remove the heater by disconnecting the electrical leads, loosening the hose clamps, and removing the mounting bolts. Inspect the heater hoses very carefully. The heater produces high heat that can cause these hoses to deteriorate very quickly. If there is any doubt as to whether a hose is good, replace it. Install the new heater by bolting it to the bracket, then connecting the hoses and electrical leads. Fill the radiator with coolant and turn the power back on. If your engine is not equipped with shut off valves for the heater, now would be a good time to install them. This prevents you from having to drain the radiator the next time you have to replace the heater.

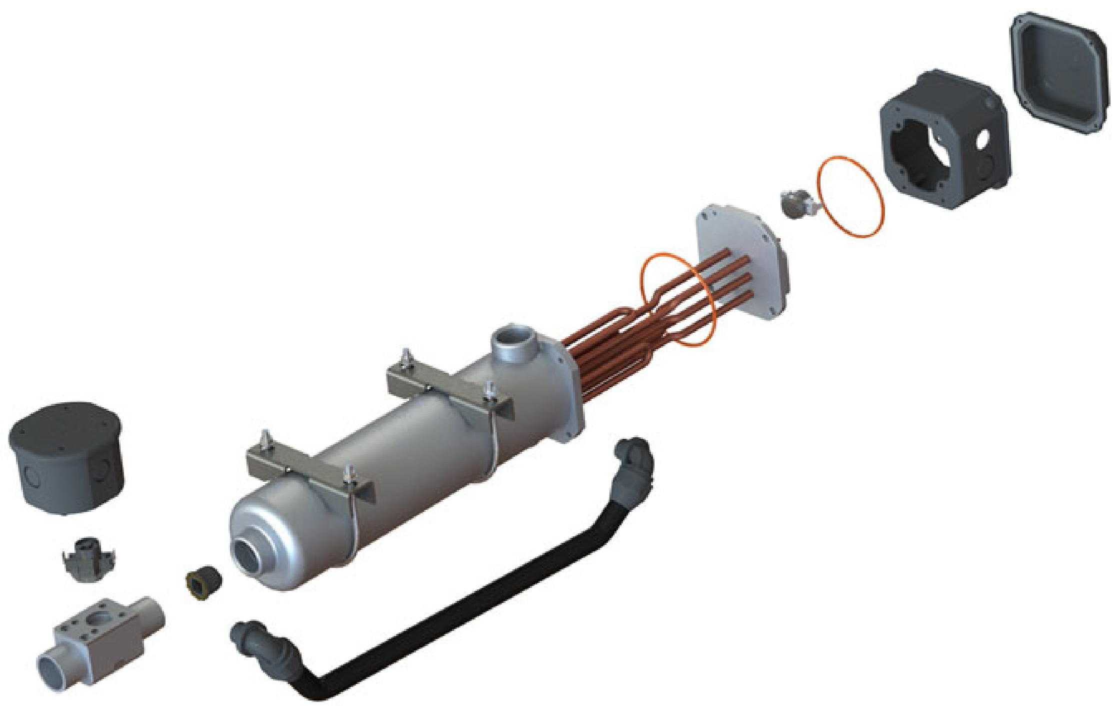

**Figure 3–4. Circulating coolant heater.**

Immersion coolant heaters, shown in figure 3–5, are installed internally in the engine block in place of a freeze plug. Large engines and V-type blocks usually require the use of two immersion heaters. Immersion coolant heaters do not circulate the coolant. Heat can move through the cylinder's wall only by convection; therefore, warm-up time is increased when compared to external coolant heaters.

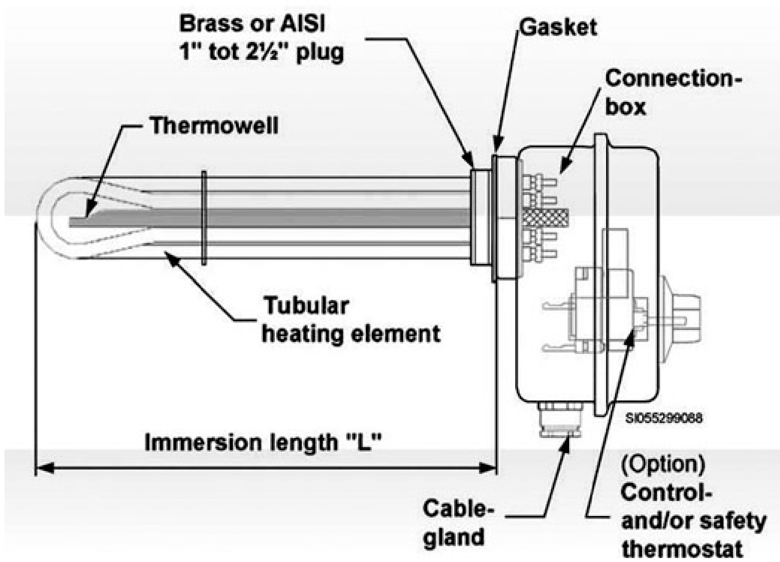


**Figure 3–5. Immersion heater.**

Inspect these heaters by looking at the engine temperature with the engine off. The engine should be warm enough to allow the engine to start. Also, look at where the heater mounts into the engine for leaks and corrosion. Look at the electrical connections for signs of corrosion and overheating.

Replacing internal heaters is similar to external heaters. First, de-energize the power source and tag the switch or breaker. Next, disconnect the electrical wiring and drain the coolant below the heater level. Loosen the heater mounting bolts and remove the heater from the engine. Install the new heater into the engine and tighten it into place. Do *not* turn the power on to the heater until the engine is full of coolant because doing so could burn the heater up causing it not to work. Connect the electrical connections and fill the engine with coolant. Once everything is back together, operate the engine until it reaches operating temperature to make sure that there are no leaks around the heater. Return the following day to check whether the heater is operating properly.

## Glow plugs

Glow plugs thread into the individual cylinders or intake manifolds and uses battery current to produce heat. Operating temperatures reach as high as 1,500 degrees Fahrenheit (°F) in seconds. Once the engine is running, the glow plugs turn off. Do not confuse glow plugs with spark plugs used in gasoline engines. They are not the same in either function or operation.

**CAUTION**: It is important that you do *not* use starting fluid on engines that are equipped with glow plugs. Using starting fluid on engines with glow plugs can cause an explosion that can damage the engine and cause injury to you. Glow plugs may be wired in parallel or series and have a fairly high current draw. They offer a method of warming the engine without the need for an AC hookup or alternate fuel fired heat source.

## Ether

The two most common ways ether is packaged are aerosol cans and pressurized cylinders. Use of spray cans of ether is discouraged as such devices can be dangerous. The only method of safely using ether is with a closed dispensing system. Starting aid systems of this type normally consist of a cylinder of pressurized ether, a metering valve, tubing, and an atomizer installed in the intake manifold. The valve trips only once during each starting attempt, to prevent a build-up of ether in the intake manifold that could lead to an explosion or hydraulic lock.

Diesel engines can also be fitted with another one-shot starting device consisting of a holder and needle. A capsule containing ether inserts into the device. The needle pierces the capsule, releasing the pre-measured dose of ether into the intake manifold. Regardless of the system used, introduce starting fluid into the intake manifold while the engine is cranking very sparingly.

## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

### 011. Corrosion control

1. Describe galvanic corrosion.

2. How does pitting *first* appear on a metal surface?

3. What is the key to a good corrosion control program?

### 012. Winter starting aids

1. What are the two types of coolant heaters?

2. How do immersion coolant heaters spread heat throughout the engine?

3. Why is it important that you do *not* use starting fluid on engines that are equipped with glow plugs?

4. What is the *only* safe method of using ether?

## Answers to Self-Test Questions

### 009

1. To provide the proper value of voltage to operate the power contactor.
2. These allow you to determine the rate of charge that the battery is drawing.
3. The secondary windings have fewer turns than the primary windings.
4. The output voltage.

5. Between 12.5 to 13.2 volts.
6. To take a second look at the charging rate to make sure it is set correctly.

**010**

1. Portable and stationary.
2. It allows the operator to select internal or external power sources.
3. It allows load bank to be configured for different generator output voltages.
4. It connects the generator power to the circuit breakers for the kW step switches.
5. It indicates the amperage being drawn by the load bank from the generator.
6. It removes heat from the load bank resistor elements.
7. This provides the generator with enough load to prevent carbon buildup known as wet stacking.
8. To prevent injury.
9. Read the manufacturer's manual.
10. Search for any debris or foreign matter inside load bank that could be blocking airflow.
11. Be sure that the heater elements have had time to cool completely before you begin your work.

**011**

1. It can be one of the most common forms of corrosion as well as one of the most destructive. It occurs when two dissimilar metal types are in contact with each other and moisture is introduced. Galvanic corrosion seriously degrades the softer of the two metals.
2. As a gray or white powdery substance.
3. Preventive maintenance.

**012**

1. Circulating and immersion.
2. By convection.
3. Using starting fluid can cause an explosion that can damage the engine and cause injury to you.
4. With a closed dispensing system.

**Do the unit review exercises before going to the next unit.**

## Unit Review Exercises

**Note to Student:** Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

30. (009) What battery charger component decreases the input voltage to the required output voltage to provide the battery with a charge?
    a. Voltmeter.
    b. Load switch.
    c. Power diode.
    d. Power transformer.

31. (009) Which battery charger component rectifies alternating current output of power transformer to direct current?
    a. Voltmeter.
    b. Load switch.
    c. Power diode.
    d. Power transformer.

32. (009) What is the *primary* concern when adjusting a battery charger?
    a. Input voltage.
    b. Output voltage.
    c. Input amperage.
    d. Output amperage.

33. (009) What battery charger fault situation is indicated by a *fully* charged battery and a *high* charging rate?
    a. Defective rectifier circuit.
    b. Defective voltage regulator.
    c. Open battery connections.
    d. Shorted battery.

34. (010) Which load bank control contains reconnection bars that can be removed and configured according to the voltage input from the generator?
    a. Volts select switch.
    b. Blower fail indicator.
    c. kW load step switches.
    d. Voltage reconnection panel.

35. (010) Which load bank control is a series of switches used to select a specific resistive load value from the generator?
    a. Volts select switch.
    b. Blower fail indicator.
    c. kW load step switches.
    d. Voltage reconnection panel.

36. (010) Which load bank control is used to check voltage between phases of generator output during three-phase operation?
    a. Volts select switch.
    b. Blower fail indicator.
    c. kW load step switches.
    d. Voltage reconnection panel.

37. (010) Which load bank control illuminates if the blower fails?
    a. Volts select switch.
    b. Blower fail indicator.
    c. kW load step switches.
    d. Voltage reconnection panel.

38. (010) What is the purpose, besides preventing carbon buildup, of operating a generator using a load bank?
    a. It makes the engine smoke more.
    b. It makes the engine operate at a higher speed.
    c. It lets you know that the generator will operate with clean fuel.
    d. It lets you know that the generator is capable of operating at full load.

39. (010) When you must connect the load bank cables to the ends of the generator output cable, you must
    a. plug the connections into the cables properly.
    b. wrap the connections with insulating tape.
    c. leave the connections bare to allow proper cooling.
    d. operate the load bank at 80 percent capability to prevent overheating the connections.

40. (010) How will you know where to place the reconnection bars to set them for the proper voltage?
    a. The position of the switch on the generator.
    b. The position of the switch on the load bank.
    c. A diagram of configuration on the generator.
    d. A diagram of configuration on the load bank.

41. (010) Before you install an electrical component on a load bank, be sure it
    a. is the same size as the one being replaced.
    b. is the same color as the one being replaced.
    c. has the same manufacturer as the one being replaced.
    d. has the same electrical rating as the one being replaced.

42. (011) Which type of corrosion do we find most on aluminum?
    a. Stress.
    b. Pitting.
    c. Galvanic.
    d. Exfoliation.

43. (011) Which type of corrosion is a further form of inter-granular corrosion associated with high strength aluminum alloys?
    a. Stress.
    b. Pitting.
    c. Galvanic.
    d. Exfoliation.

44. (011) What is the key to a good corrosion control program?
    a. Catching it early.
    b. Preventive maintenance.
    c. Cleaning it when you find it.
    d. Cleaning it when it gets severe.

45. (012) Which coolant heater has the *main* advantage of warming the engine in a very short period of time?
    a. Blanket.
    b. Immersion.
    c. Direct heat.
    d. Circulating.

46. (012) Which coolant heater is installed *internally* in the engine block in place of a freeze plug?
    a. Blanket.
    b. Circulating.
    c. Direct heat.
    d. Immersion.

47. (012) What is the *only* safe method of using ether in an engine?
    a. Spray can.
    b. Liquid mixture.
    c. Open dispensing system.
    d. Closed dispensing system.

**Please read the unit menu for unit 4 and continue ➔**

# Student Notes

# Unit 4. Generator Operations and Maintenance



YOU WILL SPEND a significant amount of time operating installed and mobile generators. Both types of generators have similar operations and maintenance requirement. Whether it is at your home base or deployed, understanding and applying the correct procedures are key factors to keeping your base's mission going.

## 4–1. Permanently Installed Generators

A large portion of a power production technician's time is spent operating and maintaining permanently installed generators. Many of these are commercial units and are used to provide back-up power to mission critical facilities. Knowing how to maintain and operate these generators will ensure that the mission will continue in the event of a commercial power failure.

### 013. Generator operations

Operating a generator involves several tasks: conducting the preoperational inspection, operating the unit, and conducting the post operational inspections. All of these tasks must be followed to ensure the unit operates correctly and that it will be ready to operate again when needed.

#### Preoperational inspection

The preoperational inspection is one of the most important inspections that take place. This inspection ensures the generator is ready to operate at a moment's notice and should be conducted every time the generator is going to be started.

##### *General site and generator conditions*

The first thing you must do during the preoperational inspection is to check the general site and generator conditions to ensure there is nothing that will impede safe generator operations. Then, check the following:

- Overall cleanliness. Inspect for corrosion both on the generators metal frame and on electrical connections.
- Site documents. Make sure that the one-lines, training documentation, and operating instructions are current. Also check to make sure that there is a generator operating log available to document the inspection if necessary.
- Generator set grounding. Check for security.
- All drive belts. Inspect for tension and wear to ensure proper operation of the cooling fan and other accessories.
- All controls and gauges. Check for damage and proper operation.

##### *Coolant system*

To prevent overheating and ensure operation, check the coolant system as follows:

- Inspect for any leaks in the cooling system.
- Check the coolant level.

- Check hoses for condition, if there is any question on the condition of a coolant hose replace it.
- Check the radiator; make sure that the fins are not clogged with dirt or any other debris.
- If equipped with louvers, make sure they are working properly and are not binding.

#### *Fuel system*

Fuel system checks are completed to avoid fires, prevent fuel spills, and ensure the generator will start. Inspect the fuel system as follows:

- Check for any leaks.
- Inspect the tank for corrosion.
- If equipped with a day tank, make sure it works properly.
- Check the fuel level.
- Check storage tank for water using water finding paste on the bottom of a dip stick.

#### *Lubrication system*

Inspect the lubrication system as follows:

- Check for any leaks.
- Check all oil lines for cracks and condition.
- Check the lubrication oil level. If it is too high, annotate the condition and drain off the excess oil.

#### *Battery and charging system*

Inspect the DC electrical system as follows:

- Check all wiring for wear.
- Check the test battery voltage.
- Lead test the battery.

#### *Corrective actions*

If any of these systems are not in proper working order, you must correct them immediately. If the repair cannot be made immediately, be sure to open a work order to document both the time and money spent on the repair.

### Unit operation

After all of the preoperational inspections have been completed, the generator is ready to be run. There are several different scenarios that may require the operation of a generator. Sometimes it is during an emergency outage and another time is during a planned outage.

#### *Emergency outage*

During an emergency outage generators equipped with an automatic transfer switch will start automatically and transfer the load to the unit. When this occurs there are several things you must inspect while it is operating.

The inspection must be done when you arrive at the generator site and every two hours afterwards. The *operational* inspection includes checking the following items:

- Check all indicators and gauges to ensure proper operating conditions. You do this to ensure that there are not any conditions that may cause damage to the generator or the load that it is supplying power to.
- Check the fuel system. Check the fuel level, and for any leaks in the system. This will keep the generator from running out of fuel or shutting down for fuel related issues. This will also ensure that air does not get into the fuel system, making the generator run erratically which can cause damage to electrical system at the facility.

- Check the coolant system for leaks. This will prevent engine shutdown for temperature.
- Check the engine for vibration. Look and listen for any noises that are not normal for the engine. Also check to see if there are any excessive vibrations. These can indicate a problem with the internals of the engine or other devices that may cause the unit to have catastrophic failure.

#### *Planned outage*

A planned outage may take place because work is being done on the electrical distribution that feeds the facility. There are several other reasons, but the main thing to remember is if the facility is going to lose power, the generator needs to be running to keep the mission going. During this outage, the same things are checked as in an emergency situation. The main difference is that you will be putting the generator on-line rather than it happening automatically.

### Post-operational inspection

Once a generator has run and is no longer needed there are several things that must be done to ensure it is ready for the next outage. Most of them are the same as the preoperational inspection with the exception of the coolant system inspection.

**WARNING**: DO *NOT* OPEN THE RADIATOR CAP TO CHECK THE LEVEL. The system is going to be very hot and under pressure. If you open the radiator cap, steam and hot coolant will come out and can cause severe burns.

### Emergency shutdown

When a generator experiences a major issue and the fault systems do not shut it down, it is up to the power production technician to shut it off. This is done to prevent damage to the generator and the facility that it is connected to. Here are several instances when an emergency shutdown would be done:

- Any major fluid leak that will cause engine damage and or a fire.
- Any electrical condition that will cause personal injury or damage to the facility.
- If the unit tried to shut down but is still running.

The preoperational inspection makes sure the unit is ready to perform its mission, the operational inspections keep the unit running, and the post operational inspection makes sure the unit is ready for the next time it is needed. Knowing when and why to perform these inspections is one of our most important tasks as power production technicians.

## 014. Periodic inspections

Periodic inspections are the basis for all things related to generator maintenance. These inspections and maintenance tasks ensure a reliable and long lasting fleet of generators. These preventative maintenance inspections are broken up into several intervals. They are the semi-monthly, monthly, quarterly, semi-annual, and annual inspections. The following inspections are the minimums; always consult with the generator manufacturer for recommended maintenance intervals.

### Semi-monthly inspection

A semi-monthly inspection on an installed generator involves checking the following items:

- Coolant and oil levels.
- Fuel levels.
- The DC electrical system, charger, and battery for their condition.
- Any other manufacturer’s requirements.

An engine start is optional during this inspection. Be sure to document the inspection on the AF Form 487 (section 16 only).

### Monthly inspection

A monthly inspection starts with a semi-monthly inspection followed by the additional tasks below:

- Exercise the generator for a minimum using one of the following methods:
  - a) Method 1 – Loading that maintains the minimum exhaust gas temperature (EGT) recommended by the manufacturer. The one-hour generator exercise time for Method 1 operational inspections includes warm-up, load test, and cool-down.
  - b) Method 2 – Under operating temperature conditions and at not less than 30 percent of the generator nameplate kW rating. The one-hour generator exercise time for Method 2 operational inspections includes warm-up, load test, and cool down.
- Document the inspection on the AF Form 487.

### Quarterly inspection

A quarterly inspection is only needed for certain types of petroleum, oil, and lubricants (POL) and fuel systems. The only real difference is that the fuel system must be put to its pumping capacity for one continuous hour. This will require some coordination with the personnel who run the fuels system.

#### *Semiannual inspection*

A semi-annual inspection starts with a semi-monthly inspection and ends with a load test. Follow the steps below to do the semiannual inspection:

- Test generators under facility load with loss of commercial power to the automatic transfer switch (ATS).
- Load the generator with the facility to 50 percent of the generator's rating for one continuous hour and to not less than 75 percent of its rating for one continuous hour. This will make this test 2 hours of run time. If the 50 and 75 percent rating cannot be obtained by the facility only, use a load bank to augment the load to achieve the ratings.

#### *Annual inspections*

An annual inspection starts with a semiannual inspection. Additionally, an annual inspection generally includes changing the oil, coolant, and oil and fuel filters. Always follow the manufacturer's recommendations for replacement intervals for fluids and filters. Additionally, you must follow any electrical inspections on the alternator as well.

## 015. Power calculations

Throughout your time as a power production technician, you will have to perform several calculations. These calculations will be used to figure out kilowatts, amperage, and facility power and fuel requirements. Knowing how to calculate these items allows you to properly size generators for facilities and contingency operations and plan operations for extended outages and prime power situations.

### Calculating kW and amperage

Being able to calculate generator loads is an important part of performing the power production mission. Calculating generator load gives us a variety of essential information, such as total power requirements. This calculation makes sure we do not exceed the generator's capacity and allows us to maintain accurate generator records. Calculating kW and amperage is often necessary because some generators do not have kW and amperage meters. Let's look at the different formulas you will use to obtain accurate generator loads and how to use them.

First, we must determine whether the power supplied is single-phase or three-phase power. Once we determine this, then we know the correct formula to use.

Below are the formulas for calculating kilowatts and amperage for single-phase generators:

$$\text{Kilowatts} = \frac{\text{volts} \times \text{amperes} \times \text{powerfactor}}{1000}$$

$$\text{Amperage} = \frac{1000 \times \text{kilowatts}}{\text{volts} \times \text{powerfactor}}$$

The formula value for volts is the value from phase voltage (phase to neutral value). The formula value for amperes is a value obtained either from a clamp-on ammeter reading of phase amperage or total amperage draw of all connected equipment. We base the formula value for power factor on the reading of the power factor meter. If our generator does not have a power factor meter, we should use .8 as the factor in the calculation. According to the manufacturer, this is the typical power factor of a facility. It is not as accurate as a power factor meter, but it is close.

Now, let's apply the formulas to a situation. We're operating a single-phase generator producing 120 VAC with an amperage draw of 25 amperes. We need to calculate the kW of the generator as follows:

$$\text{Kilowatt} = \frac{120 \times 25 \times .8}{1000}$$

$$\text{Kilowatt} = 2.4 \text{ kW}$$

If we have 2.4 kilowatts on the same generator but not the amperage, you need to calculate it as follows:

$$\text{Amperage} = \frac{1000 \times 2.4}{120 \times .8}$$

$$\text{Amperage} = 25 \text{ amps}$$

The following formulas are used for calculating kilowatts and amperage of three-phase generators:

$$\text{Kilowatts} = \frac{\text{volts} \times \text{amperes} \times \text{powerfactor} \times 1.73}{1000}$$

$$\text{Amperage} = \frac{1000 \times \text{kilowatts}}{\text{volts} \times \text{powerfactor} \times 1.73}$$

**NOTE**: The mathematical method of calculating three-phase amperage provides only an average amperage value per phase, not the actual amperage value.

The formula value for volts is the value from line voltage (phase-to-phase value). The formula value for amperes is a value obtained either from a clamp-on ammeter reading of phase amperage or total amperage draw of all connected equipment. We base the formula value for power factor on the reading of the power factor meter or .8 if our generator does not have a power factor meter. The 1.73, the three-phase factor, is the amount of increased power due to using three phases.

Now let's apply the formulas to a situation. We're operating a three-phase generator that produces 120/208 volts. The amperage readings are as follows: phase 1 reads 45 amperes, phase 2 reads 48 amperes, and phase 3 reads 42 amperes. We need to calculate the kW of the generator.

We start by finding the average amperage per phase using the formula below:

$$\mathrm{I} = \frac{\text{phase}\,1 + \text{phase}\,2 + \text{phase}\,3}{3}$$

$$\mathrm{I} = \frac{45 + 48 + 42}{3}$$

$$\mathrm{I} = 45\,\text{amps}$$

Now that we know the amperage portion of the formula, you can calculate the kW as follows:

$$\text{kW} = \frac{208 \times 45 \times .8 \times 1.73}{1000}$$

$$\text{kW} = 12.95$$

If we have 30 kilowatts on the same generator, but not the amperage, you need to calculate it as follows:

$$\text{Amperage} = \frac{1000 \times 30}{208 \times .8 \times 1.73}$$

Amperage = 104 amps

### Facility power requirements

At times you may be asked to size a generator to a facility. There are several resources that you need to consult to make sure that the generator can handle the load. A few things to check are any load analysis or recorder data, prior generator operating logs, and engineering data from original designs. There is no universal standard for figuring this out, but you should size the generator so that the load is no less than 50 percent of the generator's capacity.

### Fuel requirements

There are several different scenarios that you will need to consider to calculate fuel requirements. One is if you are setting up an expeditionary plant. In this case, you do not know the load, but you do know the generator being used. Research the technical data, then take the hourly burn rate for full load operations and multiply it by 24 to find out your daily consumption. Another situation would be for sizing a tank for 72 hours of run time. To do this, find the burn rate for the anticipated load by multiplying that number by 72. This will give you the amount of fuel needed for 72 hours. You will want to size a tank as close to that number as possible without going smaller. If the actual burn rate is unknown, you can estimate 1 gallon per hour for each 10 kW of load.  This will get you in the ballpark.

Knowing what calculations to use in which situation will help you better plan your operations.  Make sure that when performing these calculations you are using valid data and the correct formula.

## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

### 013. Generator operations

1. When is a *preoperational* inspection required?

2. When is it necessary to open a work order?

3. What are two instances when a generator may be required?

4. How often do you inspect the generator during emergency outages?

5. Why do you check all the indicators and gauges during the *operational* inspection during an emergency outage?

6. What would be a reason for a planned outage in which you would put a generator on-line?

7. Why would you perform an emergency shutdown?

### 014. Periodic inspections

1. What portion of the semi-monthly inspection is optional?

2. On what form do you annotate *periodic* inspections?

3. What can you do to augment load to achieve the minimum load requirements during a semiannual inspection?

### 015. Power calculations

1. Why is it often necessary to calculate the kW or amperage on a generator?

2. You are operating a single-phase generator that produces 240 VAC with an amperage draw of 74 amperes. You need to calculate the kW of the generator. Round it to the nearest kW.

3. You are operating a three-phase generator that produces 120/208 volts. The amperage readings are phase 1 reads 85 amperes, phase 2 reads 75 amperes, and phase 3 reads 92 amperes. You need to calculate the kW of the generator. Round it to the nearest kW.

4. You are operating a three-phase, 120/208 VAC generator with 63 kW on it, but it does not have an ammeter. What is the amperage? Round it to the nearest ampere.

5. You are operating a single phase, 120 VAC generator with 32 kW on it, but it does not have an ammeter. What is the amperage? Round it to the nearest amp.

6. When calculating facility power requirements to size a generator, the load should be what percent of the generator's rated capacity?

7. When generator fuel consumption is not known, what is the formula for calculating fuel requirements?

## 4–2. Mobile Generators

Mobile generators are rugged pieces of equipment meant to operate in just about any situation. These generators range from small kW sizes to mW in size. In this section, we will concentrate on the mobile electric power (MEP) series generators 200 kW and below. We work with these generators on a daily basis, both at our assigned duty station and during deployments.

### 016. Mobile generators 200 kilowatts and below

The military generator sets are portable skid-mounted self-contained units. The generator set consists of a diesel engine, brushless generator, excitation system, speed governing system, fuel system, 24-volts direct current (VDC) starting system, control system and fault system. Most of the engines use turbochargers to create more power in a small package. They also have controls, instruments and accessories necessary for operation as a single unit or in parallel. Sometimes the generator sets are mounted on trailers or wheel kits to make transportation easier.

These generators have housings to protect the systems from the weather. This means you can install them in just about any location to provide power to meet mission requirements. You are able to do this because all of the systems needed to operate the generator reside in the housing. You only need the generator, some cable, and a grounding rod to operate these generators. They are rugged systems meant to operate in extreme conditions and circumstances. These systems have proven time after time to be the workhorse of Air Force power systems. They have provided power for every military and diplomatic encounter the Air Force has embarked in for more than 20 years. This lesson looks at the basic operation and maintenance we perform on these systems. You need to remember to consult the appropriate TO before performing any operations or maintenance.  See figure 4–1 for an example of a mobile generator.


**Figure 4–1. Tactical quiet MEP series generator.**

## Positioning the generator

When deploying to either a real-world situation or an exercise, any planning of a bare-base camp must include finding possible locations for setting up electrical generators. The generators must be fairly close to the facilities which they power but not so close to constitute an unnecessary hazard to the people working around them.

Safety is always an important factor in any operation. To ensure the safety of people working near generators, consider the information below as you position the MEP:

- Make sure exhaust gases and hot air coming from the radiator blow away from any auxiliary fuel sources. This reduces the possibility of the fuel overheating and causing a fire.
- Exhaust gases produced by the generator build quickly in poorly ventilated or confined spaces. Make sure the generator does not blow exhaust into facilities where people work or reside.
- Lastly, when positioning the generator in a populated area, make sure that the generator does not obstruct troop movement or vehicle traffic in or around the area.

You must also take into account other factors that can hinder the operation of the generator. If you take the time to think about it, the majority of these issues are common sense. You want your generators to operate as efficiently as possible. You can make sure your generator is an asset to the operation, not a problem, by taking the list below into consideration as you select an appropriate site:

1. Make sure the area the generator is placed is as level as possible. The generator can operate on slopes up to a maximum of 15º.Make sure the ground is firmly packed and has good drainage. If the soil around the generator is soft, it may cause the generator to sink. In this situation, installing wood planks or other additional ground supports would be quite helpful.
2. Make use there are any natural barriers that can disperse the exhaust and noise of your generator. Allow a minimum of 36 inches of clearance on all sides of the generator for servicing and maintenance requirements.

3. Take into account the normal direction of the wind. Place the generator so the prevailing winds blow with the cooling fan, not against it. If this is not possible, install a wall of some sort to reduce the amount of air blowing into the fan.
4. Avoid placing the generator in direct sunlight. This compounds the generator's job of cooling itself by unnecessarily heating the air already inside its housing. If possible, construct some sort of shade or a roof to keep the sunlight off the generator. You can quickly do this in the field by the use of camouflage netting kits. This also reduces any contamination from nuclear, biological, and chemical (NBC) agents.

Now that you have looked at all of the areas and made decisions about where to locate the generator, you can bring it in to position it. Most of the mobile generators use mobilizers that make them easy to move; simply hook them up to the vehicle and tow to the connection point. These mobilizers have limits; therefore, we must never exceed 5 miles per hour on paved surfaces. When you tow a generator on unpaved surfaces, the speed should be even slower. You must also keep a close eye on the generator as you tow it; it has a tendency to wobble back and forth. If this happens, be sure to slow down, and the wobbling should stop.

## Grounding

The actual job of connecting the generator set to the ground is fairly easy. Wear the proper safety gear and take your time to do the job right. Always refer to the applicable TO for step-by-step procedures in connecting your generator to the ground. The general grounding procedures are as follows:

1. Insert the ground cable (fig. 4–2) into the slot on the ground stud attached to the generator and tighten the nut.

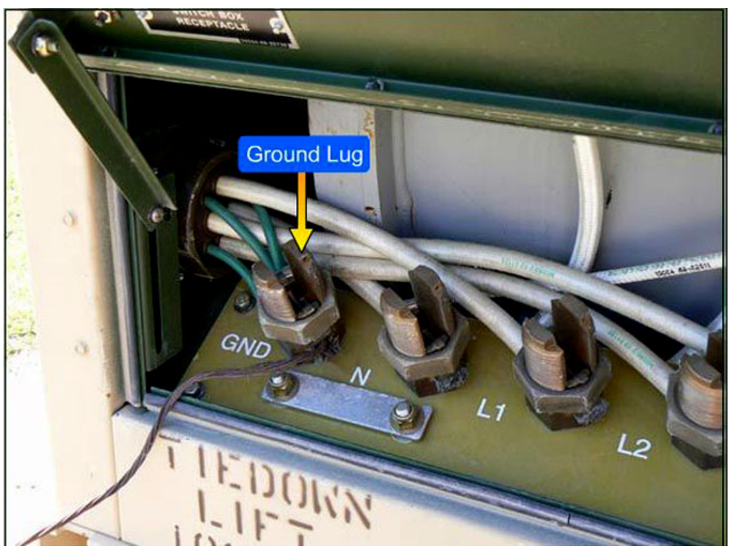


**Figure 4–2. Ground stud.**

2. Install the grounding rod.
3. Connect the clamp and the ground cable to the ground rod and securely tighten the screw.

Electrical current travels the path of least resistance. Your body has more resistance than pipe or wire; therefore, in finding its way to ground, it is easier for current to go through pipe or wire than to go through you. As a technician working on electrical equipment, you *must* install the ground rod properly.

## Selecting cables

When we talk about cables, we mean a complete wire assembly having a conductor that carries current. An insulated outer protective covering wraps around the conductor. Cables can contain one conductor or multiple conductors with separate insulation. We refer to the multiple conductor cables as bologna cable. We generally use cables for either connecting a generator to load or for paralleling operations. Without cable, there is no way to feed the current we produce to the customer.

The size and types of conductor used to connect the power source to the customer depends on the amount of current it must conduct, the distance the current must travel, and the type of installation. You cannot arbitrarily choose a conductor for use simply by its availability. You must consider many factors when selecting the correct conductor. Two methods are used in expressing conductor size: the American Wire Gauge (AWG) and circular mil. When using the AWG system, the smaller the number, the larger the wire. A No. 24 AWG wire is much smaller than a No. 14 AWG. The AWG system designates wires as large as No. 4/0 (four–aught).

There are three types of conductors used for wiring: copper, aluminum, and copper-clad aluminum. We limit our discussion to copper because it is the most common wiring we see. Copper has excellent electrical and physical properties, and this is probably why it has been in use for quite some time. Both solid and braided wire is used in the cables. Solid wire is a single strand of copper with insulation wrapped around it and is used in smaller cables. Braided cable uses multiple strands of copper wire twisted together to form the desired thickness to carry the amperage. This cable is much more flexible than solid cable of the same size.

We seldom use wire without insulation for conducting electricity. In almost every situation, we use insulated or covered wire. The most common covering or insulation is rubber and plastic. They are excellent nonconductors and, in many cases, are covered or protected by other substances such as braiding, paper, metal, or more plastic. The letter coding placed on a conductor, such as THW, THHN, or XHHW identifies the type of insulation and the appropriate use for that particular conductor. These codes can also identify the physical characteristics of the conductor and the type of overall outer layer. Take a look at the tables below for many of the common coding used on conductors.

| **INSULATION** | |
|---|---|
| **Insulation Composition** | **Letter Designator** |
| Asbestos | A |
| Mineral Insulated | MI |
| Rubber | R |
| Thermoplastic | T |
| Varnished Cambric | V |
| Cross-linked Synthetic Polymers | X |
| **CONDUCTOR APPLICATION** | |
| **Conductor Characteristic** | **Letter Designator** |
| Corrosion Resistant | C |
| Heat resistant to 167°F | H |
| Heat resistant to 194°F | HH |
| Appropriate for direct burial | UF |
| Appropriate for wet conditions | W |
| **OUTER COVERING** | |
| **Outer Layer** | **Letter Designator** |
| Armored Cable | AC |
| Lead Covered | L |
| Metal Clad | MC |
| Nylon | N |
| Nonmetallic Sheath | NM |

### *Cable or wire marking*

The cables we use also have other markings in the insulation. These marks vary slightly from manufacturer to manufacturer but have the same minimum standards. The NEC has established these standards manufacturers must follow for all cable sold in the United States. The minimum standards are as follows:

- AWG size.
- Insulation type.
- Voltage rating (maximum).
- Test agency approval.

Wire insulation also comes in different colors. We use the colors to assist in identifying which cables are which when we use more than one cable. This allows us to quickly make the proper connections based on the color of the insulation. We commonly use black, red, blue, and yellow cables for hot connections. This means these color cables connect to the phase windings of the generator. It is important to know that although we generally use the colors above for hot conductors, we may also use other colors as long as they are not the colors required for neutral or ground. Neutral colors are white or gray, and grounding conductors may be bare, green, or green with a yellow stripe.

### *Cable selection criteria*

There are many considerations you must look at as you choose the proper cable to support the load to which you are connecting the generator. The first thing to consider is whether the cable has the proper number of conductors for its application. Most of the cable you use in the Power Production field is bologna cable having more than one piece of wire in a casing with each wire individually insulated. At a minimum, you need cables for each hot leg and a cable for the neutral.

Many cables you use today also have a cable for the ground; this is nice to have, but not a necessity. You can run a separate ground cable if you need to. For example, if you were supplying single-phase power to a customer, you need to choose a cable with at least two wires, possibly three. One wire connects to the live or “hot” wire and one wire to the neutral. The third wire connects to the ground. If you are supplying three-phase power to a customer, you should choose a cable having at least four wires or possibly five. This allows enough wires to connect to the three phases of power, a neutral, and a ground.

Having cables with four to six wires in a single casing may cause the wire capacity to diminish. This is due to the heat created by the cable, as well as the magnetic fields cutting into the other conductors causing counter electromotive force (EMF). The rating of the four- to six-wire cable is 80 percent of the normal rating of the cable size.

The second thing to consider is the maximum amount of current the cable can carry. Each cable size has limits on the amount of current it can carry without failing. You must consider this current carrying capacity as you choose your cables. A general rule of thumb is that the greater the current, the bigger the cable required. The lesser the current, the smaller the cable required. Temperatures are also a factor in choosing the proper cable. The higher the temperature, the less current the cable is able to carry. As you choose the proper cable for the connection you need to make, you must consult a table to make these determinations. You can find tables in the NEC to determine the correct wire size to use.

## Configuring voltage

Our customers need the correct type of voltage. You must make certain to provide the correct voltage by using of the voltage reconnection panel. The reconnection panel allows you to connect the alternator windings in either series or parallel. Remember, voltage increases and current remains constant in a series circuit, and voltage remains constant and current increases in a parallel circuit.

By making an adjustment on the reconnection board, you can obtain two different values of voltage on a single generator. Before generator start-up, make sure the arrow on the reconnection board matches the arrow of the voltage the customer is using (fig. 4–3 and fig 4–4). It only takes a second to look at the reconnection panel to interpret the voltage set value.

**NOTE:** When reconfiguring voltages on the MEP–807A and MEP–809A you will have to program the controller for the applicable voltage.

**WARNING:** *Never* attempt to alter the position of the voltage reconnection panel while the generator set is operating. Failure to observe this warning may result in electrocution.


**Figure 4–3. MEP voltage reconnection panel 120/208.**


**Figure 4–4. MEP voltage reconnection panel 240/416.**

To change the output voltage of a mobile generator, disable it from starting and tag the control panel. Open the output box access door, locate the voltage reconnection board, and remove the protective cover. Remove the nuts and washers from the movable portion of the reconnection board. Adjust the movable portion of the reconnection panel so the arrow on the stationary board lines up with the arrow of the desired voltage output. Reinstall the movable portion of the reconnection board and secure it using washers and nuts. Reinstall the protective cover and close the output box access door. Start the generator and make sure the voltage is at the correct level. You can make any minor adjustments to the voltage using the voltage-adjusting rheostat located on the control panel.

### Connect cables

Once you have positioned the generator, grounded it, selected the cables, and configured the voltage, you need to connect the cables. You must observe all of the safety precautions to prevent shock or electrocution. Always wear work gloves and use the non-metallic boxed-end wrench provided with the generator. This adds an extra layer of protection as you connect the cables.

**WARNING:** Lethal voltages are present at the load connection board of the generator set during operation. Do *not* attempt to connect or disconnect load leads while the generator is operating. Do *not* attempt to connect or disconnect load leads with the generator shut down if the generator remains connected in parallel to another power source through the load cables.

Begin by shutting down the generator set. Open the output load terminal door. Using the terminal nut wrench, loosen the terminal nuts on the selected terminals. Insert the ends of the load cables through the load cable entrance box and insert the ends of the cables into the slots of the load terminal studs. The easiest way to do this is to completely remove the nut and slide the cable straight down through the opening. Reinstall the nut, being careful not to cross-thread it, and tighten the load terminal nuts using the terminal nut wrench. Be careful not to over tighten the nut to prevent stripping the nut and stud. Due to carelessness, the lugs may become damaged and need replacing. Once this is completed, check the phase rotation of all three-phase equipment and then mark the cable appropriately.

Correct configuration of generators and cables are essential to power the mission. If these steps are not completed correctly, you could cause serious damage to both the generator and load you are powering. Additionally, severe personnel injury or death may occur. Remember, if you have a question on a cable or voltage, *always* verify the information before running the generator.

## 017. Mobile generator set operations and maintenance

Operating a generator involves several tasks which include the preoperational inspection, operating the unit, and the post operational inspection. All of these tasks must be followed to make sure the unit operates correctly and that it does not shut down while powering the mission. In this lesson, we discuss the MEP 806B, which is one of the more common generators you will encounter in the field.

### Generator inspections

Just like an installed generator, mobile generators have several inspections that you must do to ensure proper operation. The following table shows these inspections which are called preventative maintenance checks and services (PMCS) in the TO.

**NOTE**: Column 1 is the items number; the intervals of the inspections have a B, D, and/or an A. The B stands for **B**efore operation, the D for **D**uring operation, and the A for **A**fter operation.

| GENERATOR INSPECTION | | | | | | |
|---|---|---|---|---|---|---|
| ***Item No.*** | ***Interval*** | | | ***Item to be inspected*** | ***Procedures check for and have repaired or adjusted as necessary.*** | ***Equipment is not ready/available if:*** |
| | ***B*** | ***D*** | ***A*** | | | |
| | | | | **GENERATOR SET** | | |
| 1 | X | X | X | Housing | Check door, panels, hinges for damage, loose or corroded items. Inspect air intake and exhaust grilles for debris | Cannot secure doors Cannot clear debris |
| 2 | X | | | Identification Plates | Check to ensure identification plates are secure. | |
| 3 | X | | X | Skid Base | Inspect skid base for cracks or corrosion | Skid base us cracked is shows signs of structural damage |
| 4 | X | | X | Insulation/Materials | Ensure that insulating materials are free of damage, not missing, and not touching moving or exhaust system parts.<br><br>**WARNING**<br>**Operating the generator set with any access door open exposes personnel to high noise level. Hearing protection must be worn when operating or working near the generator set with any access door open. Failure to comply can cause hearing damage to personnel.**<br><br>**WARNING**<br>**Fuels in the generator set are flammable. Do not smoke or use open flame when performing maintenance Failure to comply can result in flames and possible explosion and can cause injury or death to personnel and damage to the generator set.** | |
| | | | | **GENERATOR COMPARTMENT** | | |
| 5 | X | X | X | Engine Assembly | Check for loose, damages or missing hardware and wires | Any loose, damaged or missing hardware or wires |
| 6 | X | X | X | Fuel System | Inspect fuel system for leaks and damaged, loose, or missing parts.  Check fuel lines fuel injection pump and fuel injectors for cracks, leaks or evidence of damage | Any fuel leaks |
| 7 | X | | X | Fuel Filter/Water Separator | Drain water from fuel filter/water separator<br><br>**CAUTION**<br>**Catch in suitable container** | Fuel filter/separator not drained |

| GENERATOR INSPECTION | | | | | | |
|---|---|---|---|---|---|---|
| ***Item No.*** | ***Interval*** | | | ***Item to be inspected*** | ***Procedures check for and have repaired or adjusted as necessary.*** | ***Equipment is not ready/available if:*** |
| | ***B*** | ***D*** | ***A*** | | | |
| 8 | X | | | Ether Start System | Check for deteriorated, loose, or missing parts, loose tubing, and missing or damaged bottle gasket | Any deteriorated, loose, or missing parts, loose tubing, and missing or damaged bottle gasket |
| 9 | X | X | X | Lubrication System | Inspect lubrication system for leaks and damaged loose, or missing parts | Oil leaks at class III. Damaged, loose or missing parts |
| | X | X | X | | Check engine oil level | Oil level is low, and dipstick reads add. |
| | X | X | X | | Check engine oil for contamination (oil is milky, bubbles, foreign material in oil etc.) | Engine shows signs of contamination |
| | | | | | **WARNING**<br>**Cooling system operates at high temperature and pressure. Contact with high pressure steam and/or liquids can result in burns and scalding. Shut down generator set, and allow system to cool before performing checks, services, and maintenance. Failure to comply can cause injury to personnel.** | |
| | | | | **COOLING SYSTEM** | | |
| 10 | X | | X | Radiator | Check radiator for leaks, damage, or missing parts. | Class III leaks. Radiator cap is missing |
| 11 | X | | X | Hoses | Check hose for leaks or cracks. | Class III leaks. |
| 12 | X | | | Cooling fan | Check fan for damage or looseness. | Cooling fan is damaged or loose |
| | | X | | | Check for unusual noise being emitted from fan area | |
| 13 | X | | X | Fan Belts | Inspect belts for cracks, fraying. Or looseness | Broken belt(s) |
| 14 | X | X | X | Overflow Bottle | Check overflow bottle for leaks and missing parts. | Class III leaks. |
| | | | | **EXHAUST/INTAKE SYSTEM** | | |
| 15 | X | | | Exhaust System | Check muffler for leaks and exhaust system for corrosion and damaged or missing parts. | Muffler or exhaust missing parts, damaged or leaking excessively |

| GENERATOR INSPECTION | | | | | | |
|---|---|---|---|---|---|---|
| ***Item No.*** | ***Interval*** | | | ***Item to be inspected*** | ***Procedures check for and have repaired or adjusted as necessary.*** | ***Equipment is not ready/available if:*** |
| | ***B*** | ***D*** | ***A*** | | | |
| 16 | X | | | Air Cleaner Assembly | Inspect air cleaner assembly and piping for loose or damaged connections. | Piping connections are loose |
| | | | | | Check restriction indicator for indication of clogged air cleaner element | Clogged element is indicated |
| | | | | **ELECTRICAL SYSTEM** | | |
| | | | | | **WARNING**<br>**DC voltages are present at generator set electrical components even with generator set shut down. Avoid shorting any positive terminal with ground/negative. Failure to comply can cause injury to personnel and damage to equipment.** | |
| | | | | | **WARNING**<br>**Batteries give off a flammable gas. Do not smoke or use open flame when performing maintenance. Failure to comply can cause injury or death to personnel and equipment damage due to flames and explosion.** | |
| | | | | | **WARNING**<br>**Battery acid can cause burns to unprotected skin. Avoid contact with battery acid. Failure to comply can cause injury to personnel.** | |
| 17 | X | | | Batteries | Inspect electrolyte level (wet cell batteries only) | Electrolyte level is below battery plates |
| 18 | X | | | Battery Cables | Inspect cables and connectors for corrosion and loose, damaged, or missing parts | Battery cables are loose, damaged, or missing |
| | | | | | **WARNING**<br>**High voltage is produced when this generator set is in operation. Make sure unit is completely shut down and free of any power source before attempting any repair or maintenance on the unit. Failure to comply can cause injury or death to personnel.** | |
| 19 | X | | | Output box Assembly | Check for loose or damaged wiring or cables | Loose or damaged wiring or cables |
| 20 | X | | | Load Output Terminal Board | Check output terminal for damaged or missing hardware | Damaged or missing hardware |

| GENERATOR INSPECTION | | | | | | |
|---|---|---|---|---|---|---|
| ***Item No.*** | ***Interval*** | | | ***Item to be inspected*** | ***Procedures check for and have repaired or adjusted as necessary.*** | ***Equipment is not ready/available if:*** |
| | ***B*** | ***D*** | ***A*** | | | |
| | | | | **DCS CONTROL BOX ASSEMBLY** | | |
| 21 | X | | X | Controls and Indicators | Check all controls and indicators for damaged or missing parts. Ensure relays are securely plugged in | Controls or indicators with damaged or missing parts |
| | | X | | | Ensure all indicators are operating properly | Computer Interface Module (CIM) inoperative |
| 22 | X | | | Control Box Wiring Harness | Check for loose or damaged wiring. | Loose or damaged wires. |
| 23 | X | | | Parallel Operation Cable | If required for generator set operation, inspect parallel operation cable for damage.<br><br>**WARNING**<br>**High voltage is produced when the generator set is in operation. Never attempt to start the generator set unless it is properly grounded. Failure to comply can cause injury or death to personnel.** | |
| 24 | X | | | Ground Rod Cable and Connection | Inspect ground rod and cable for loose connections, breaks, damage, and corrosion | Cable is missing or damaged |
| | | X | | | Visual inspection only | |

## Single-unit operation

To run the MEP 806B in single-unit mode, you must first complete the preoperational checks. Once that is done, you need to make sure the computer interface module (CIM) display screen is in the MAIN mode (fig. 4–5). You can do this by using the Select button to click the FULL/MAIN button.

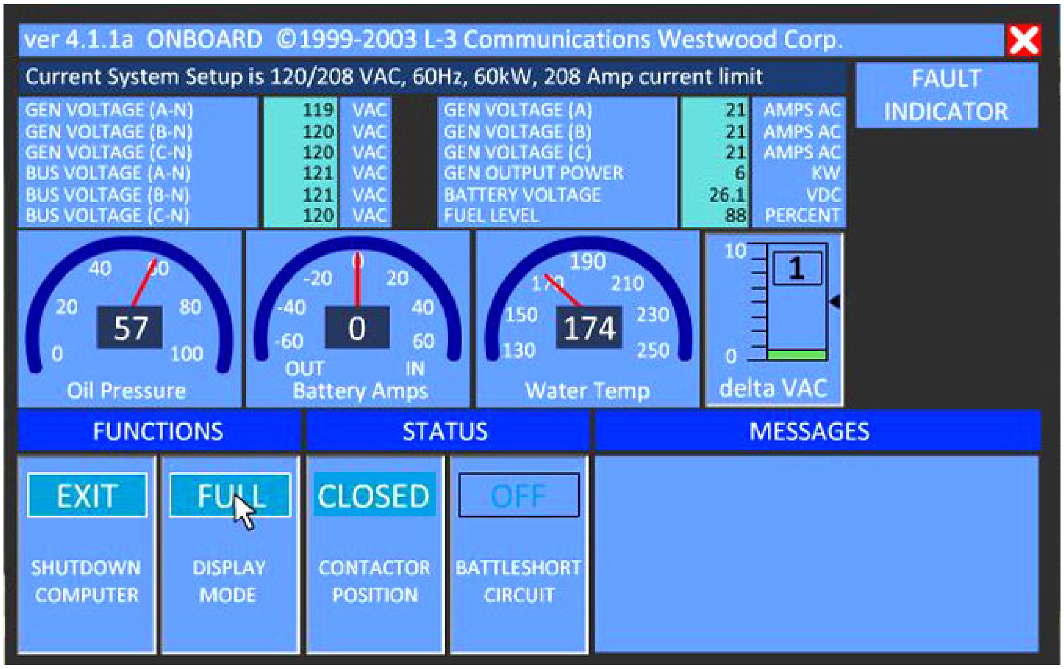


**Figure 4–5. MEP 806B CIM main display mode.**

Next, you will need to hold the FAUL RESET switch in the ON position for two seconds. Release the switch.

### *Starting the engine*

To start the engine, hold ENGINE CONTROL switch in the START position (for two seconds) and observe the CIM display screen until the oil pressure reaches at least 25 pounds per square inch (psi), voltage has increased to its approximate rated value, and engine has reached stable operating speed, then release the ENGINE CONTROL switch to the PRIME & RUN position. If operating with an auxiliary fuel source, rotate the ENGINE CONTROL switch to the PRIME & RUN AUX FUEL position. Check the WATER TEMP (170 - 200°F) and OIL PRESSURE (25 - 60 psi) meters on CIM display screen for normal readings. Use the keypad arrow buttons to move the cursor to the DISPLAY MODE on the CIM display screen. Use the SELECT button to click the FULL/MAIN button to toggle between the full and main mode screens. Access the FULL mode screen.

**NOTE:** Warm up the engine without load for five minutes. (If necessary, the load can be applied immediately.)

Use the VOLTAGE ADJUST and FREQUENCY ADJUST switches to adjust values for voltage and frequency until required values are displayed on VOLTAGE and FREQUENCY gauges on the CIM display screen. Press the TEST pushbutton on the GROUND FAULT CIRCUIT INTERRUPTER. Ensure RESET pushbutton is in the IN position.

### *Connecting to load*

Once the load is ready to be powered; hold the AC CIRCUIT INTERRUPT switch in the CLOSED position until the CONTACTOR POSITION on the CIM display screen reads CLOSED.

With the CIM display in the Main Display Mode, ensure the VOLTAGE and FREQUENCY gauges still indicate the rated values. Adjust if necessary. With the CIM display in the Full mode screen, if more than the rated load is indicated on the GEN CURRENT indicator for any phase, reduce load. With the CIM Display in Main Mode, observe the POWER gauge on the CIM display screen. If the indication is more than 60KW, reduce load. Perform all the DURING (D) PMCS requirements according to the TO.

### *Shutting down the generator*

Once the generator is no longer needed, follow the procedures below to disconnect the unit from load and shutdown:

- Hold the AC CIRCUIT INTERRUPT switch in the OPEN position until CONTACTOR POSITION on the CIM display screen reads OPEN.
- Allow the generator set to operate five minutes with no load applied.
- Place the ENGINE CONTROL switch in the OFF position.
- Perform all the AFTER (A) PMCS requirements according to the TO.
- Use the keypad arrow buttons to move the cursor to the SHUTDOWN COMPUTER on the CIM display screen. Use the SELECT button to click on the |EXIT| button to exit the digital control system (DCS) software.
- When the CIM display screen displays the message that it is safe to turn off the computer, place the MASTER CONTROL switch in the OFF position. Turn off the panel lights.
- Place the DEAD CRANK switch in the OFF position.

## Parallel unit operation

In the event that the load is more than one generator can handle, you can operate a MEP 806B in parallel (load sharing) mode.

**WARNING:** Prior to making any connections for parallel operation or moving a generator set which has been operating in parallel, ensure there is no input to the load output terminal board and the generator sets are shut down. Failure to comply can cause injury or death to personnel by electrocution.

### *Pre-operation*

Before operating MEP 806B in parallel, you must perform some setup. Follow these setup steps:

- Ensure the load requirement is equal to or below the combined rated capacity of the two generator sets.
- Determine the voltage requirements of the load and position voltage reconnection terminal boards of the two generator sets to the required voltage connection. Ensure the FREQUENCY SELECT switches on both generators are positioned for the same frequency requirements (50 Hz or 60 Hz).
- Identify one generator set as No.1 and the other as No. 2.
- Open the BATTERY ACCESS door and remove the paralleling cable.
- Connect paralleling cable between the two generators sets. Connect the generator sets to the load observing proper phase sequence. Check connections with phase rotation meter.
- Connect the load cables, see figure 4–6 for configuration.

**CAUTION:** Do *not* close the AC CIRCUIT INTERRUPT switch on either of the generator sets, *nor* close the load contactor at load, until specifically directed to do so. Closing any of these devices at any other time may severely damage one or both of the generator sets.

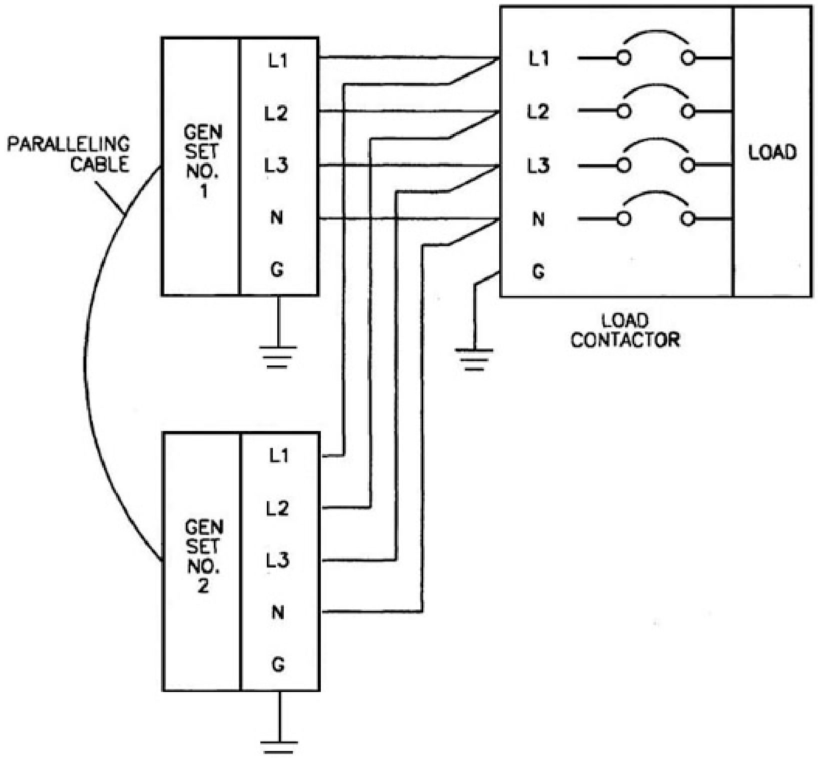


**Figure 4–6. MEP 806B parallel load cables.**

### *Operating*

Now that the setup is complete, it is time to put the two generators on line. You do this following the steps below:

- Start each generator set.

**WARNING:** High voltage is produced when the generator set is in operation. *Never* attempt to start the generator set unless it is properly grounded. Failure to comply can cause injury or death to personnel.

- Use the keypad arrow buttons to move the cursor to the DISPLAY MODE on the CIM display screen. If necessary, use the SELECT button to access the FULL mode screen.
- Use the VOLTAGE ADJUST switch to obtain the same voltage indication on each set.
- Use the FREQUENCY ADJUST switch to obtain approximately the same frequency indication on both sets. Observe the CONTACTOR POSITION on the CIM display screen to ensure the load contactor at load is open.
- Momentarily hold the AC CIRCUIT INTERRUPT switch on generator set No. 1 in the CLOSED position until the CONTACTOR POSITION reads CLOSED.

**CAUTION:** Check the CONTACTOR POSITION indication on the CIM display screen to ensure the load contactor at load is OPEN before attempting to place the generators on the line. Failure to comply can cause damage to the generator sets.

- Momentarily hold the AC CIRCUIT INTERRUPT switch on generator set No. 2 in the CLOSED position until the CONTACTOR POSITION on the CIM display screen reads CLOSED.

**NOTE**: The generator sets are now operating in parallel with no load.

- Check that the POWER gauge on the CIM display screen indicates approximately zero.
- Close the load contactor at the load.
- Check that the GEN CURRENT indicators on the CIM display screens of both generator sets display approximately the same amperage. If not, adjust the VOLTAGE ADJUST switch up or down to achieve the proper reading.
- Compare the POWER Meter readings from the CIM display screens on both generator sets. If readings are not within 10 percent balance loads until they are within 10 percent of each other.

### *Shutting down*

Once the generators are no longer needed, you need to remove them from load and shut them down.

**WARNING:** If necessary to move a generator set which has been operating in parallel with another generator set, shut down the remaining generator set connected to the load prior to removing load cables or ground. Failure to comply can cause injury or death to personnel by electrocution.

**CAUTION:** Prior to removal of one generator set from parallel operation, make sure the load does *not* exceed the full load rating of the generator set remaining on the line. Failure to comply can cause damage to the generator set still on line.

Follow these steps to shut down the generator set:

- Momentarily hold the AC CIRCUIT INTERRUPT switch in the OPEN position until CONTACTOR POSITION on the CIM display screen reads OPEN.
- Shut down generator set.

## Periodic maintenance

Just like installed generators, mobile generators require periodic maintenance. There are several intervals that require preventative maintenance. During contingency operations, it is vitally important to keep these generators in peak operating condition because they will encounter harsh conditions and prolonged periods of operation.

### *Semiannual inspection*

The oil must be changed during a semiannual inspection, or at 300 operating hours, whichever comes first.

**NOTE:** Oil changes have been approved to be deferred for up to two years if the correct oil analysis is done and hours have not exceeded 300 operating hours. See the applicable ETL for more specifics.

### *Annual inspection*

During an annual inspection, you must first complete the semiannual inspection, and then complete the following:

- Change the fuel filter/fuel water separator.
- Inspect the radiator cap for corrosion, torn or deteriorated seal, and obvious damage. This must be done every 1500 hours regardless of time interval.
- Remove batteries, clean batteries cable, terminals, and battery posts. Test batteries for state of charge.
- Inspect the air cleaner assembly and assembly mounting bracket for cracks, dents, and other damage. Inspect the element for clogs and damage. Clean or replace as necessary. Clean housing with clean cloth. This must be completed every 1500 hours regardless of time interval.

- Remove, clean, and inspect tubing and tubing and breather hose. This must be completed every 750 hours regardless of time interval.
- Inspect for loose, damaged, or missing hardware. Repair or replace hardware damaged or missing hardware or insulation.
- Clean the radiator exterior surfaces.
- Remove, inspect, and clean magnetic pickup. Check wiring harness for breaks and loose connections. Repair and tighten wiring harnesses as necessary.
- Check muffler for leaks, restriction, and accumulation of carbon. Replace or clean as required.

#### *Biannual inspection*

Biannual means every two years. As with every other inspection, all of the other inspections, semiannual and annual, must be completed during this inspection. Also, you drain and flush the coolant system. This must be done biannually or every 300 hours regardless of time interval.

#### *Operating hours inspections*

Some inspection items only have operating time intervals. The first oil change must be done at the first 100 hours of generator operation. The crankcase breather filter and assembly must be inspected and serviced every 300 hours of generator operations.

## Self-Test Questions

**After you complete these questions, you may check your answers at the end of the unit.**

### 016. Mobile generators 200kW and less

1. What is the *maximum* slope a MEP series generator can operate on?

2. What does the code THHN on a piece of cable mean?

3. What is the rating of cable with four to six wires in it?

4. How does the reconnection panel allow you to connect the alternator windings?

### 017. Mobile generator set operations and maintenance

1. When performing a *before* operations inspection, what do you do to the fuel filter/fuel water separator?

2. During what inspections do you check the oil level?

3. Why do you let the cooling system cool before performing checks, services, and maintenance?

4. When do you check the output box assembly for loose or damaged wiring or cables?

5. When starting the engine on a single-unit generator, in what position is the ENGINE CONTROL switch placed if you are using an auxiliary fuel source?

6. When connecting the generator to the load, what step must be done *after* closing the load contactor and ensuring the load is not too much for the generator?

7. What is the *last* step when shutting down the generator?

8. Are the MEP 806B generators able to parallel with no load?

9. How often is oil changed in mobile generators?

10. How often is coolant changed in mobile generators?

## Answers to Self-Test Questions

**013**

1. Before starting a generator**.**
2. When the problem found with any parts of the generator system cannot be immediately repaired.
3. During an emergency outage and a planned outage.
4. When you arrive at the generator site and every two hours afterwards.
5. To ensure that there are not any conditions that may cause damage to the generator or the load that it is supplying power to.
6. When work is being done on the electrical distribution that feeds the facility.
7. To prevent damage to the generator and the facility that it is connected to.

**014**

1. Engine start.
2. AF Form 487.
3. Use a load bank.

**015**

1. Because some generators do not have kW and amperage meters.
2. 14 kW.
3. 24 kW.
4. 219 amps.
5. 333 amps.

6. No less than 50 percent.
7. One gallon per hour for each 10 kW of load.

**016**

1. 15º.
2. Insulation: thermoplastic (T); conductor application: heat resistant to 194°F (HH), and outer covering: nylon (N).
3. 80 percent of the normal rating.
4. Either in series or parallel.

**017**

1. Drain water.
2. Before, during, and after operation inspections.
3. Cooling system operates at high temperature and pressure. Contact with high pressure steam and/or liquids can result in burns and scalding.
4. Before operation.
5. PRIME & RUN AUX FUEL position.
6. Perform all DURING (D) PMCS requirements in accordance with technical order.
7. Place the DEAD CRANK switch in the OFF position.
8. Yes.
9. Semiannually or every 300 operating hours.
10. Biannually or every 300 operating hours.

**Do the unit review exercises before going to the next unit.**

## Unit Review Exercises

**Note to Student:** Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

**Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).**

48. (013) When performing a preoperational inspection on a permanently installed generator, you check the coolant level to make sure the
    a. unit will *not* overheat during operation.
    b. coolant conditioners are working correctly.
    c. water pump is working properly.
    d. unit will *not* shut down for low coolant pressure.

49. (013) You are conducting a preoperational inspection on a permanently installed generator and find the oil level is too high. What should you do?
    a. Ignore it and start the engine.
    b. Annotate the condition and run the generator.
    c. Annotate the condition and drain off the excess oil.
    d. Run the engine for 15 minutes, shut it down, and check the level again.

50. (013) After a preoperational inspection, when is it necessary to open a work order for a permanently installed generator system that is not in proper working order?
    a. When the problem found doing the inspection *cannot* be immediately repaired.
    b. Anytime you do a preoperational inspection.
    c. When any discrepancy is found doing the inspection.
    d. Anytime you make a repair.

51. (014) Which portion of the semi-monthly inspection is *optional*?
    a. Engine start.
    b. Check coolant level.
    c. Check direct current (DC) electrical system.
    d. Annotation on inspection checklist for the Generator Operating Log.

52. (014) How is a permanently installed generator tested during a semiannual inspection?
    a. Using the automatic transfer switch (ATS) test switch.
    b. Starting the generator manually.
    c. Turning the power off to the ATS.
    d. Using the generator test switch.

53. (015) Select the appropriate formula to answer the question below.

$$\text{Kilowatts} = \frac{\text{volts} \times \text{amperes} \times \text{powerfactor}}{1000}$$

$$\text{Amperage} = \frac{1000 \times \text{kilowatts}}{\text{volts} \times \text{powerfactor}}$$

$$\text{Kilowatts} = \frac{\text{volts} \times \text{amperes} \times \text{powerfactor} \times 1.73}{1000}$$

$$\text{Amperage} = \frac{1000 \times \text{kilowatts}}{\text{volts} \times \text{powerfactor} \times 1.73}$$

You are operating a *three-phase* generator that produces 120/208 volts with 100 kW on its power meter but does *not* have an ammeter. What is the amperage? Round it to the nearest ampere.
a. 347.
b. 601.
c. 602.
d. 1041.

54. (015) Select the appropriate formula to answer the question below.

$$\text{Kilowatts} = \frac{\text{volts} \times \text{amperes} \times \text{powerfactor}}{1000}$$

$$\text{Amperage} = \frac{1000 \times \text{kilowatts}}{\text{volts} \times \text{powerfactor}}$$

$$\text{Kilowatts} = \frac{\text{volts} \times \text{amperes} \times \text{powerfactor} \times 1.73}{1000}$$

$$\text{Amperage} = \frac{1000 \times \text{kilowatts}}{\text{volts} \times \text{powerfactor} \times 1.73}$$

You are operating a *single-phase* generator that produces 240 VAC with 15 kW on its power meter but does *not* have an ammeter. What is the amperage? Round it to the nearest ampere.
a. 23.
b. 45.
c. 78.
d. 124.

55. (015) When calculating facility power requirements, to what percent of the permanently installed generator's load capacity should you size a generator?
a. No more than 50 percent.
b. No less than 75 percent.
c. No less than 50 percent.
d. No more than 60 percent.

56. (016) What is the *most* common material used in cables?
a. Brass.
b. Copper.
c. Aluminum.
d. Copper-clad aluminum.

57. (016) What type of coding is placed on a conductor to identify the type of insulation?
a. Letters.
b. Numbers.
c. Special symbols.
d. Combination of letters, numbers, and symbols.

58. (016) The voltage reconnection panel allows the alternator windings to be connected in
    a. either series or parallel.
    b. both series and parallel simultaneously.
    c. either sequence or series.
    d. both sequence and parallel simultaneously.

59. (016) What happens if you attempt to change the position of the voltage reconnection panel while the mobile electric power (MEP) series generator 200 kilowatts and below generator set is operating?
    a. Nothing.
    b. Electrocution.
    c. The voltage changes.
    d. The generator shuts down.

60. (016) On a 200 kilowatts and below mobile electric power (MEP) series generator, how is the movable portion of the reconnection panel adjusted to produce the desired voltage output?
    a. Turn it over and reconnect it.
    b. Rotate it 90 degrees and reconnect it.
    c. Align its arrow with the desired control panel arrow.
    d. Align its arrow with the desired stationary board arrow.

61. (017) Why do you wait to perform checks, service, or maintenance on coolant systems on a mobile electric power (MEP) 806B until it cools down?
    a. The level will be different.
    b. The pressure steam can cause injury.
    c. The coolant will not appear in the radiator.
    d. The safety systems will not allow you to open the radiator cap.

62. (017) When starting a mobile electric power (MEP) 806B, how long do you hold the engine control switch in the start position?
    a. 1 second.
    b. 2 seconds
    c. 3 to 5 seconds.
    d. 4 to 6 seconds.

63. (017) How long should you let the mobile electric power (MEP) 806B warm up before connecting to load?
    a. 2 minutes.
    b. 1 minute
    c. 5 minutes.
    d. 10 minutes.

64. (017) When is the magnetic pickup removed, inspected, and cleaned on a mobile electric power (MEP) 806B?
    a. Quarterly.
    b. Semiannually.
    c. Annually.
    d. Biannually.

65. (017) How often is the coolant drained and flushed on a mobile electric power (MEP) 806B?
    a. Semiannually or at 300 operating hours, whichever comes first.
    b. Annually or at 300 operating hours, whichever comes first.
    c. Every two years or at 300 operating hours, whichever comes first.
    d. Annually regardless of operating hours.

66. (017) When is the first oil change done on a mobile electric power (MEP) 806B?
    a. Semiannually or at 300 operating hours, whichever comes first.
    b. Every two years or at 300 operating hours, whichever comes first.
    c. Annually regardless of operating hours.
    d. At 100 operating hours.

# Student Notes

# Glossary of Abbreviations and Acronyms

| | |
|---|---|
| **AC** | alternating current |
| **AFCEC** | Air Force Civil Engineer Center |
| **AFI** | Air Force instruction |
| **AFSC** | Air Force specialty code |
| **ATPV** | Arc Thermal Performance Value |
| **ATS** | automatic transfer switch |
| **AWG** | American Wire Guage |
| **cal/cm2** | calories per centimeter squared |
| **CARC** | chemical agent resistant coating |
| **CIM** | computer interface module |
| **COM** | communications |
| **DC** | direct current |
| **DCS** | digital control system |
| **DOD** | Department of Defense |
| **EAID** | Equipment Authorization Inventory Data |
| **EGT** | exhaust gas temperature |
| **EMF** | electromotive force |
| **ETL** | engineering technical letter |
| **ft** | feet |
| **HAP** | hazardous air pollutant |
| **Hz** | Hertz |
| **J/cm2** | joules per centimeter squared |
| **kW** | kilowatt |
| **mA** | milliampere |
| **MEP** | mobile electric power |
| **mW** | megawatt |
| **NBC** | nuclear, biological, and chemical |
| **NEC** | National Electric Code |

| | |
|---|---|
| **nF** | nanofarad |
| **NFPA** | National Fire Protection Agency |
| **O&M** | operations and maintenance |
| **PMCS** | preventative maintenance checks and services |
| **POL** | petroleum, oil, and lubricants |
| **PPE** | personal protection equipment |
| **psi** | pounds per square inch |
| **RE** | ground electrode resistance |
| **REL** | relative |
| **RH** | auziliary electrode resistance |
| **RPIE** | Real Propety Installed Equipment |
| **RS** | probe resistance |
| **SAT** | satisfactory |
| **SDS** | safety data sheet |
| **TO** | technical order |
| **UFC** | unified facility criteria |
| **V** | volts |
| **VAC** | volts, alternating current |
| **VDC** | Volts, direct current |
| **W** | Watt |
| **µA** | microampere |
| **µf** | microfarad |

# Student Notes

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