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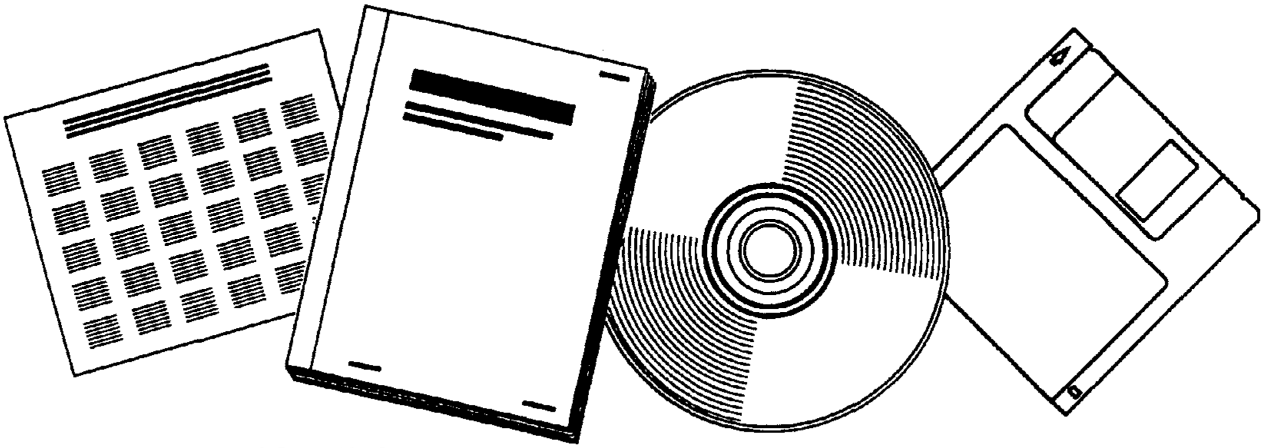
BATTERY SAFETY PROCEDURES FOR SURFACE-MINING EQUIPMENT -- A BUREAU OF MINES HANDBOOK

U.S. BUREAU OF MINES
MINNEAPOLIS, MN

1984



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Recent mine accident data compiled by the Mine Safety and Health Administration indicate a need for better understanding by operators and mechanics of the hazards of lead-acid storage batteries and proper safety precautions to be observed when working with such batteries. This publication will familiarize the miner with lead-acid battery terminology and procedures for safe and proper battery installation, storage, inspection, testing, servicing, and jump starting of engines. These procedures are presented as a guide for assuring battery safety associated with surface mining equipment.

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UNITED STATES
DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

A	ampere	min	minute
A·h	ampere hour	mm	millimeter
°C	degree Celsius	pct	percent
°F	degree Fahrenheit	s	second
h	hour	V	volt
in	inch	yr	year
lbf·in	pound (force) inch		

BATTERY SAFETY PROCEDURES FOR SURFACE-MINING EQUIPMENT

By James C. Mitchell[1]

CAUTION:

The procedures discussed in this handbook are presented with the miner's safety as the primary objective. No persons should work near a battery, either in a vehicle or on the bench, unless they know and observe the safety precautions described in this handbook. They should be familiar with the procedures to be used if they attempt to charge or test a battery or jump start an engine. The manufacturer's instructions must be followed when any equipment such as a battery charger or tester is used.

ABSTRACT

This Bureau of Mines handbook outlines proper procedures for safe lead-acid battery usage, storage, inspection, testing, servicing, and jump starting for surface-mining equipment.

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[1] Electronics technician, Twin Cities Research Center, Bureau of Mines, Minneapolis, MN.

INTRODUCTION

A large proportion of the people who work in surface mines have jobs that involve the operation, servicing, or maintenance of mobile equipment. This publication is directed at mine personnel involved in mobile equipment battery maintenance and repair. The use of such batteries has resulted in many severe injuries, such as burns and inhalation of hazardous fumes.

Recent mine accident data compiled by the Mine Safety and Health Administration (MSHA)[2] indicate a need for better understanding by operators and mechanics of the hazards of lead-acid storage batteries and proper safety precautions to be observed when working with such batteries.

This publication will familiarize the miner with lead-acid battery terminology and procedures for safe and proper battery installation, storage, inspection, testing, servicing, and jump starting of engines. These procedures are presented as a guide for assuring battery safety associated with surface mining equipment.

BATTERY BASICS

CONSTRUCTION

A cutaway view of the component parts and assembly of a lead-acid storage battery is shown in figure 1. A battery consists of a number of cells connected together as desired to produce a given voltage or current output. A cell is the minimum combination of parts required to generate electricity by chemical reaction that results in voltage. There are many ways to make cells and batteries, but only one kind of battery will be considered

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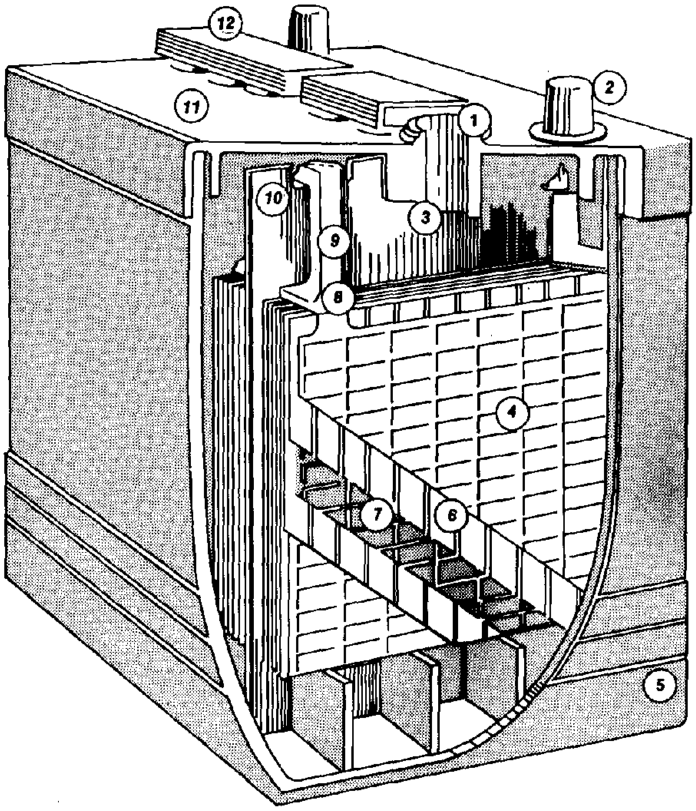
[2] Health and Safety Analysis Center, Denver, CO.



KEY

1 Vent
2 Terminal post
3 Electrolyte level mark
4 Negative plate
5 Container
6 Separator
7 Positive plate
8 Plate strap
9 Intercell connector
10 Cell partition
11 1-piece cover
12 Gang vent plug

FIGURE 1.—Cutaway view of a lead-acid storage battery. **(Courtesy ESB Inc.)**

here—the commonly used lead-acid battery. It consists of three or six cells connected in series. Since the nominal voltage of each cell is approximately 2 V, the batteries are rated at 6 or 12 V.

Each cell consists of a set of positive and negative plates. The positive and negative plates are separated by porous sheets of nonmetallic material called separators. The cell is filled with a liquid mixture of sulfuric acid and water. This liquid is called the electrolyte.

PRINCIPLES OF OPERATION

The chemical reaction of the acid with the plates generates electricity. As the electricity is used, the acid is consumed and water is produced. Since the acid is heavier than water, the electrolyte becomes lighter as it loses acid. Thus, the weight of the electrolyte is a measure of the electricity used (*1*).[3]

Lead-acid storage batteries are rechargeable with electricity from some other source. The recharging current reverses the chemical reaction that occurs during battery discharge. During recharge, the plates are restored and sulfuric acid is produced. The source of the new charge can be another battery, a generator, or any other source of direct current. Special devices that convert alternating current into direct current are designed for charging batteries. They have special circuitry to regulate the amount of the charge to prevent damage to the battery.

LOW-MAINTENANCE BATTERIES (*2*)

A battery will evolve gas when it is being charged. Hydrogen is given off at the negative plate and oxygen at the positive. These gases result from the decomposition of

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[3] Italicized numbers in parentheses refer to items in the list of references preceding the appendixes.

water, and thus, the battery must be occasionally replenished with water.

A low-maintenance battery, as the name implies, is designed to relieve routine maintenance requirements of replacing water during the service life of the battery in recommended applications. Most types of low-maintenance batteries produce very little gas at normal charging voltages, and therefore, the rate of water loss is very low. Some have venting systems that are completely sealed, except for small vent holes, and water cannot be added.

Reduced water loss has been achieved primarily through improvements in battery plate grid alloys. In conventional battery grids, antimony is used as an alloying element to enhance castability and hardness. However, the presence of significant quantities of antimony can greatly increase the rates of water loss and self-discharge. The grids of low-maintenance batteries contain little or no antimony. Other metals such as calcium, cadmium, and strontium are often substituted to provide the necessary mechanical strength, while reducing gassing and self-discharge.

The internal construction of low-maintenance batteries may appear to be quite similar to that of conventional batteries. However, significant variations may include the use of envelope separators (sealed on three sides, open at the top), expanded grids, greater electrolyte reserve volume above the plates, and sophisticated venting systems designed to minimize water loss.

BATTERY RATINGS (*3*)

To provide meaningful measurements of battery performance, three basic methods of determining and expressing battery capacities are as follows:

Cold Cranking Performance. — The chemical reaction that produces electricity in a battery is retarded in cold weather. Cold cranking performance is a measure of the battery's ability to crank the engine under cold weather conditions. It indicates the number of cranking amperes the battery can deliver at 0° F[4] for a period of 30 s and maintain a minimum of 1.2 V per cell.

Reserve Capacity. — The reserve capacity rating is defined as the number of minutes a fully charged battery at 80° F can be discharged at 25 A and maintain a minimum voltage of 1.75 V per cell. This rating is expressed in minutes and measures a battery's ability to provide emergency power for ignition, lights, etc. in the event of failure in the vehicle's recharging system. This rating involves a constant discharge at normal temperature.

Ampere Hour (A·h). — The ampere hour is a unit of measure for battery capacity, obtained by multiplying the current flow in amperes by the time in hours during which the current flows. This is usually expressed as a "20-h rating." (For example, a battery that delivers 5 A for 20 h can be said to have delivered 5 A times 20 h, a 100-A·h capacity. This rating is declining in usage in favor of the cold cranking and reserve capacity ratings.

BATTERY STOCK PROCEDURES

CAUTION:

When working with acid, such as when filling batteries, wear a face shield. When batteries are handled, protective clothing such as rubber gloves, safety shoes, and acidproof clothing is advisable.

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[4] To convert to degrees Celsius (°C), use the formula $°C = \frac{5}{9}(°F - 32)$.

A maintenance person responsible for the battery room and inventory control should be trained in battery safety. Proper tools and equipment should be provided, and the person should be familiar with their usage. The equipment should consist of battery chargers, battery connecters, hydrometers, and thermometers. Various service items should be available such as terminal cleaners, water fillers, and a supply of baking soda for neutralizing acid. The battery room or area should be well ventilated because batteries vent explosive gases during charging.

STORING AND ROTATING BATTERIES (*4*)

Battery stock must be checked regularly and rotated on a first-in, first-out basis. This rule is important whether the battery is a conventional, dry-charge, or low-maintenance type. The factory shipping date code on the carton or battery should be used to accomplish this necessary rotation.

Batteries should never be piled on top of one another. Roller racks provide the best method for storing and rotating batteries (fig. 2). Racks should be marked on the front and back so the same type of battery will go in the same rack every time. If racks are loaded properly with each new shipment, the oldest battery of a particular type will always appear at the front. Be careful never to mix different types of batteries.

CONVENTIONAL BATTERY STORAGE

Check conventional batteries before placing them in stock to make certain they are fully charged and the electrolyte is up to the level indicator in all cells. The electrolyte level in very cold batteries will be lower than

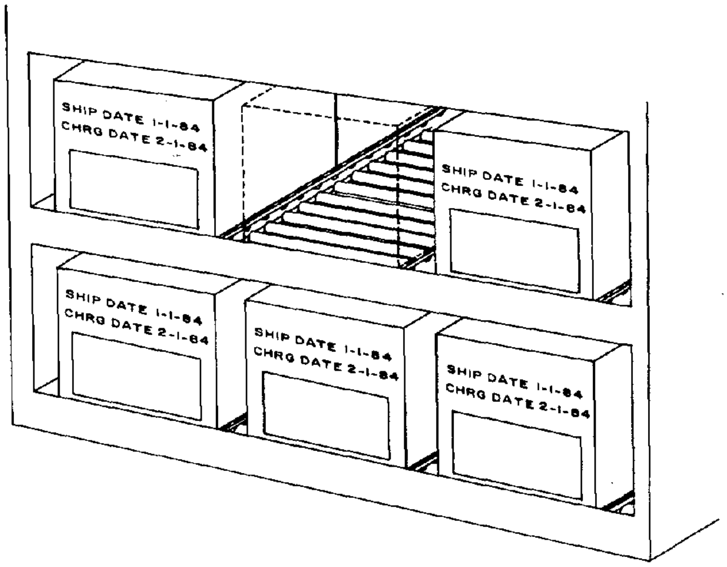


FIGURE 2.—Battery storage roller rack. (Adapted from data furnished by Gould Inc.)

normal, so let batteries warm to normal temperature before checking electrolyte levels.

A battery charged to 75 pct capacity is in no danger of freezing. Therefore, batteries should be kept at least 75 pct charged, especially in cold climates. The state of charge should be checked every 30 days. Refer to table 1 for typical open-circuit voltage and specific gravity values for states of charge.

LOW-MAINTENANCE BATTERY STORAGE

Low-maintenance batteries have excellent shelf life, approximately 1 yr, because of their low self-discharge rates. One major advantage is that they normally can be

TABLE 1.—Typical open-circuit voltage and specific gravity values

Charge level, pct	Specific gravity	Voltage (12)	Voltage (6)
100	1.265	12.7	6.3
75	1.225	12.4	6.2
50	1.190	12.2	6.1
25	1.155	12.0	6.0
Discharged	1.120	11.9	6.0

Source: Battery Council International.

installed without recharging if good stock rotation and inventory control are maintained.

Batteries in stock should be recharged when the stabilized voltage falls to 12.2 V or when specified by the manufacturer.

BATTERY INSTALLATION (*2*)

SELECTING THE SIZE

Batteries selected for replacement should equal or exceed the electrical capacity of the battery placed in the vehicle by the original equipment manufacturer. Replacing the original battery with one smaller in capacity may result in poor performance and a shorter life. If the replacement has considerably less capacity than the original battery, it will probably not crank the engine at low temperatures. A premium battery with more electrical capacity than the original battery provides a higher safety factor and gives longer service.

Make certain the replacement battery is dimensionally satisfactory: that it fits the tray and is compatible with the holddown device. If it is higher than the old battery, make certain that terminals on the top of the battery clear the battery compartment by at least ¾ in (19 mm).

PREINSTALLATION PREPARATIONS

There are two types of batteries: "dry charge" and "wet charge." The difference depends on the method of manufacture.

Wet-Charged Batteries

Wet-charged batteries contain fully charged plates and are filled with electrolyte before being shipped from the factory. If a wet-charged replacement battery is being installed, make certain the electrolyte specific gravity is at least 1.250. If the electrolyte specific gravity is below 1.250, fully charge the battery on a slow charge.

Dry-Charged Batteries

CAUTION:

Dry-charged batteries must be "activated" before they can be used.

Dry-charged batteries contain plates that have been thoroughly charged, washed, and dried. They contain no electrolyte when they leave the factory, so they are called "dry-charge" batteries. These batteries must therefore be activated before use. Procedures for safe activation are as follows:

1. Fill each cell of the battery to the top of the separators with the correct battery-grade electrolyte as specified by the manufacturer's instructions. Using higher or lower specific gravity electrolyte than recommended can impair the battery performance. Originally

filling each cell to the top of the separators permits expansion of the electrolyte as the battery is boost-charged.

2. When a manufacturer recommends the use of an electrolyte with a specific gravity of 1.260 or higher at 80° F, boost charge 12-V batteries at 15 A (6-V and 12-V heavy-duty batteries at 30 A), until the specific gravity of the electrolyte is 1.250 or higher and the electrolyte temperature is at least 60° F. Both conditions must be met. If electrolyte bubbles violently while charging, reduce the charging rate until excessive bubbling action subsides, then continue charging until 1.250 specific gravity and 60° F are reached.

3. Check volume of electrolyte in all cells and adjust to prescribed level with additional electrolyte as required.

Dry-charged batteries may be placed in service immediately after activation. After the dry-charged battery has been activated, it must be serviced, handled, and kept charged like any wet-charged battery.

BATTERY REMOVAL

Before removing a battery, carefully note the location of the positive battery terminal and mark the polarity on the positive cable. In this way you can avoid installing the new battery in a reversed position. Remove the "ground" terminal first. The ground lead is connected to the engine block, vehicle frame, or some other good metallic ground. This precaution is to avoid damage to wiring and the battery by accidental grounds with tools.

In removing or tightening the hex nut on the bolt of clamp terminals, use the proper size end wrench. Use an end wrench to remove cables from side terminals, stud terminals, or "L" terminals.

Inspect the cradle for possible damage caused by loss of acid from the old battery. Be sure the cradle and its holddowns are mechanically strong and free from corrosion. Clean and tighten the ground connection.

CABLES

Examine the cables to be sure they are the correct size. Battery cables must carry large currents with a minimum loss of voltage.

For determining cable gauge as based on the Society of Automotive Engineers (SAE) J541a recommended practice, see table 2. When replacing cables on vehicle batteries, follow the vehicle manufacturer's recommendations.

INSTALLATION

> ***CAUTION:***
>
> *All batteries should be fully charged before installation.*

The battery should rest level in the tray. Make certain there is no foreign object such as a loose nut or stone lying in the bottom of the tray.

The holddown should be tightened until it is snug. It should not be drawn tight enough to distort or crack the case. Use torque values specified in the vehicle manual. If they are not available, use the following torque values:

Top bar on top frame holddown	30 to 50 lbf·in
Bottom recess-type holddown	60 to 80 lbf·in
Bottom ledge-type holddown	70 to 90 lbf·in

The grounded cable should be connected to the battery last. Check for proper battery polarity with

TABLE 2.—Determining cable gauge (based on SAE J541a recommended practice)

System voltage and type	TOTAL CRANKING CIRCUIT, length in inches[1]											
	0	100	200	300	400	500						
24 V light duty	6 ga	4 ga	2 ga	1 ga	1/0	2/0						
12 V light duty, 24 and 32 V heavy duty automotive	6 ga	4 ga	2 ga	1 ga	1/0	2/0	3/0	4/0 or 2-1/0	2-2/0			
12 V heavy duty, vans and pickups	6 ga	4 ga	2 ga	1 ga	1/0	2/0	3/0	4/0	2-2/0	2-3/0	2-4/0	NR
12 V high output, single path to starter	[2]2/0	3/0	4/0 or 2-1/0	2-2/0	2-3/0	2-4/0	NR					
12 V high output, dual path to starter	[2]2-2/0	2-3/0	2-4/0	2-2/0	2-3/0	2-4/0	NR					

NR Not recommended.

[1] Total cranking circuit length includes cable from battery (ies) to starter and return to battery (ies), battery-to-battery series connections, and length of frame member used in return.

[2] Minimum gauge size recommended for high-output system. Dual-path system preferred.

NOTE. — This chart is designed as a guide to the minimum wire gauge allowable for an average system. A larger gauge cable will give you more starting power.

Source: Quick-Cable Corp.

respect to the vehicle specifications. Ground polarity is usually indicated. Reversed polarity can be avoided if the cables were marked as to their polarity when the old battery was removed. Reversed polarity may cause serious damage to the electrical system and can be a hazard. Mark the polarity of cables and be cautious to match cable and terminal polarity. Note that the positive tapered post is larger than the negative post. The following torque values should be used when attaching battery cables to the battery terminal posts:

Tapered terminal posts (SAE)	50 to 70 lbf·in
Side terminals	70 lbf·in
Stud terminals	120 to 180 lbf·in

The cable terminals should be cleaned before connecting them to the battery. After the connections have been made, apply a thin coating of petroleum jelly on the post and cable terminals to retard corrosion.

SERVICE PROCEDURES

Maintenance personnel should have the proper service tools available so that effective and safe battery servicing can be performed. This will prevent damage to the battery, battery cables, and holddowns and ensure the safety of service personnel.

A battery is a perishable item and requires frequent attention. With a reasonable amount of care, the life of the battery can be appreciably extended and battery-related injuries avoided. Neglect and abuse will invariably cause shorter life and introduce undue hazards.

WATER (*2*)

The most satisfactory water to use when preparing electrolyte is distilled water. This is also true for routine water additions to the battery. Generally speaking, any water that is safe to drink (excluding mineral waters) is safe to use in a battery. Do not use water of a known high mineral content. Avoid the use of metallic containers (except lead or lead-lined containers).

Metal impurities in the water will lower the performance of the battery. Many liquids such as salt water, vinegar, and alcohol, or harmful acids such as nitric, hydrochloric, or acetic, will ruin a battery.

BATTERIES

Inspection

A routine inspection should ensure that containers are not damaged and are clean and dry. Conventional batteries should be inspected for the electrolyte level.

Maintenance (*2*)

Conventional antimony batteries should be checked to maintain the correct electrolyte level at least every 30 days. Add distilled or drinking water to bring the liquid level to the level indicator. If the battery does not have a level indicator, bring the level to ½ in (13 mm) above the tops of the separators. Two devices are available for this purpose, a self-leveling filler that fills the battery to a predetermined level automatically and the syringe type. Battery cells should never be filled above the level indicator. When a cell is overfilled, the excess electrolyte may be forced from the cell by the gas formed in the battery. This will cause excessive corrosion of adjacent metal parts. If using the syringe to fill the cells, do not squeeze so hard that the water splashes acid from the cell opening.

Low-maintenance batteries do not require additional water and suffer minimal corrosion under normal operating conditions. An occasional check, however, is a good practice.

Batteries are best cleaned with a cloth wetted with ammonia or baking soda and water solution. Use a wire brush to scrub away corrosion.

Use a hydrometer or voltmeter to determine the state of charge of a battery (see table 1).

CABLES

Inspection

Make a visual inspection for defective cables to make certain the insulation is intact and the terminal or its bolt are not corroded so badly that part of the metal is eaten away.

Maintenance (*2*)

Consider replacing cables that have had temporary terminal ends bolted onto them. As acid eats away terminals and cables, the resistance increases and the voltage loss over the length of the cable increases. The increase in resistance due to corrosion also restricts the flow of charging current to the battery. This will cause the battery to gradually become undercharged and sulfated.

To remove a cable clamp from the battery terminal, loosen the clamp nut, using the proper end wrench, and then use a terminal puller (fig. 3). With the jaws of the terminal puller gripping the underside of the cable clamp, pull the clamp up by pressure exerted against the top of the battery terminal. This avoids damage from lateral or twisting forces.

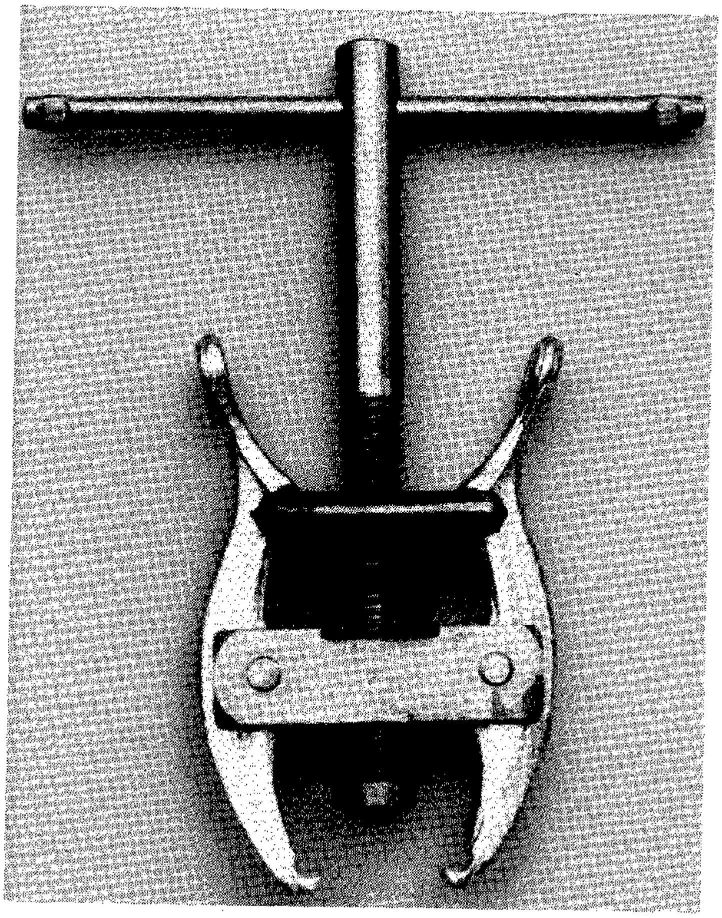


FIGURE 3.—Terminal puller.

After the cable clamps have been removed from the terminals and the clamp bolts have been loosened, use a spreader (fig. 4) to expand the cable clamps. They can

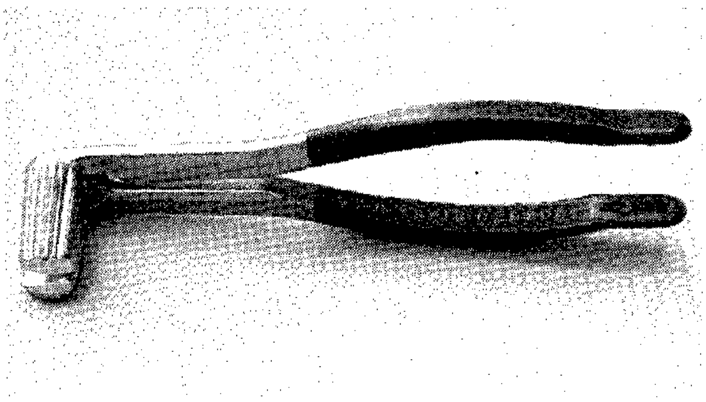


FIGURE 4.—Cable clamp spreader.

then be placed on the terminals in their correct positions without forcing them into position.

TERMINAL POST

Inspection

Inspect terminal posts for corrosion, looseness, or deformities.

Maintenance (*2*)

When there is corrosion on the terminal posts, remove the cable terminals from the battery (ground cable first) using the proper end wrench and terminal puller. Be sure to avoid subjecting battery terminals to excessive lateral or twisting forces. These forces damage internal components of the battery and create leakage at the terminals. A terminal cleaning brush can be used to clean tapered costs.

Never hammer cable terminals onto the battery posts. The covers, undercover post connections, or post-to-cover connections could be severely damaged. Do not paint battery terminals.

HOLDDOWN TRAY

Inspection

Inspect the holddown tray for tightness and corrosion.

Maintenance (*2*)

Corrosion or rust should be removed from the battery tray or the holddown. A wire brush and scraper can be used to remove dirt, corrosion, or rust from these parts. After rust is removed from a part with a wire brush, rinse with clear water, dry, and paint with an acid-resistant paint.

SPECIFIC GRAVITY AND HYDROMETER USAGE

CAUTION:

Wear gloves when using the hydrometer, as glass breakage is always a possibility.

Specific gravity is measured with a battery hydrometer, a device consisting of a bulb-type syringe that will extract electrolyte from the cell (*2*). A glass float in the hydrometer barrel is calibrated to read in terms of specific gravity. A common range of specific gravity used on these floats is 1.160 to 1.325. Figure 5 illustrates the correct method of reading a hydrometer. The barrel must be held vertically so the float is not rubbing against the side of it. Draw an amount of acid into the barrel so that, with the bulb fully expanded, the float will be lifted free, touching neither the side, top nor bottom stopper of the barrel. Keep the float clean. Make certain it is not cracked.

Hydrometer readings are affected by the temperature of the electrolyte. Temperature correction is necessary if the temperature of the electrolyte is more than 5° F above or below the 80° F hydrometer standard operating temperature (fig. 6).

Specific gravity is actually a ratio of the weight of the acid mixture to pure water. For batteries it is usually expressed as points. A reading of 1,265 points, for instance, is actually 1.265 specific gravity. The mixture is 1.265 times as heavy as water. The reading on the hydrometer stem is in points, and a temperature correction is given in points (*1*).

Table 1 illustrates typical specific gravity values for a cell in various stages of charge. A specific gravity of 1.265 corrected to 80° F is assumed to represent a fully charged battery.

Never take a hydrometer reading immediately after water is added to the cell. The water must be thoroughly mixed with the underlying electrolyte, by charging, before hydrometer readings are reliable. If a reading is being taken immediately after the battery has been subjected to prolonged discharging, it will be higher than the true value. The water formed in the plates during the rapid discharge has not had time to mix with the higher specific gravity acid above the plates.

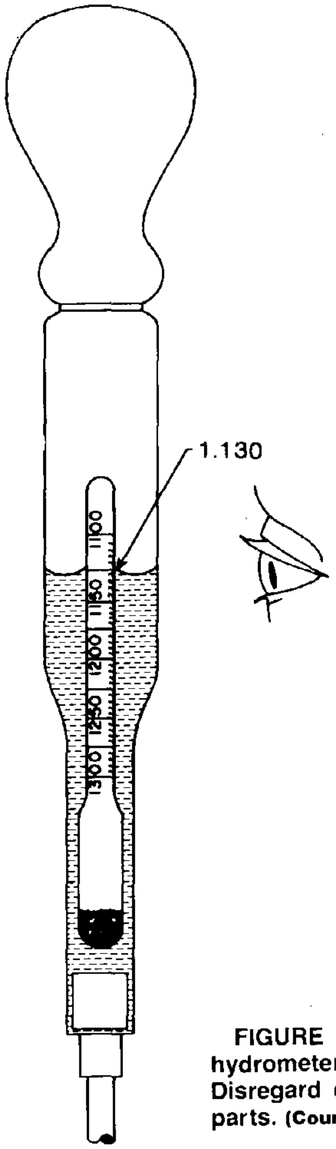


FIGURE 5.—Correct method of reading hydrometer. Eye on level with liquid surface. Disregard curvature of liquid against glass parts. (Courtesy Gould Inc.)

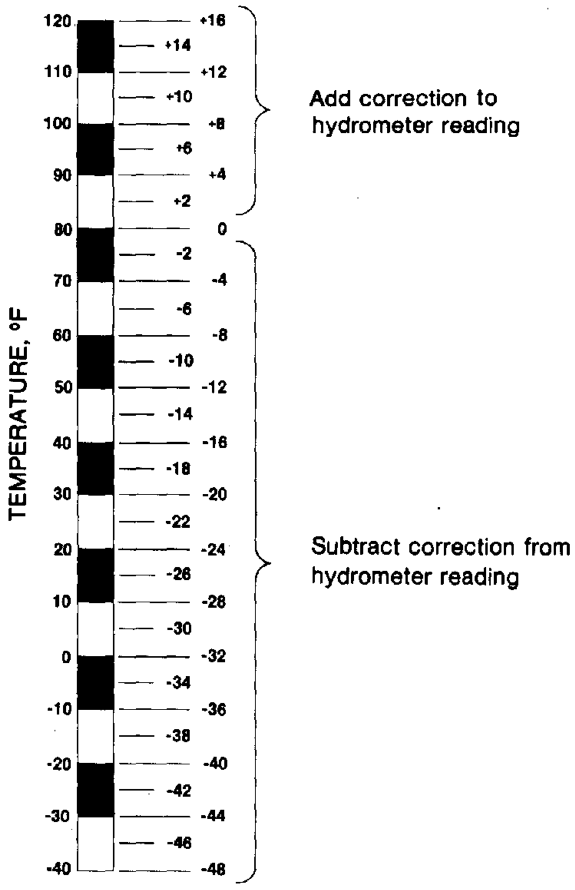


FIGURE 6.—Temperature correction scale for hydrometers. Add or subtract the amount of points shown on the right-hand scale according to the temperature. (Courtesy Tab Books)

BATTERY TESTING (*2*)

Battery testing should be considered an integral part of periodic battery maintenance.

TESTING CONVENTIONAL BATTERIES WITH ADJUSTABLE LOAD TESTER AND HYDROMETER

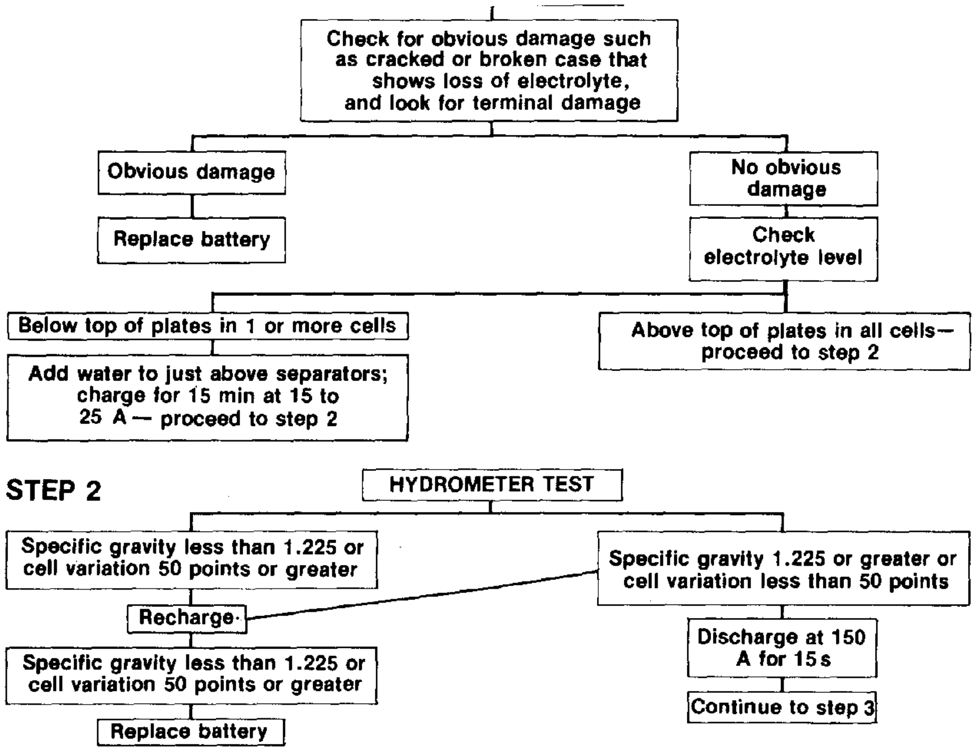
For testing batteries with an adjustable load tester and hydrometer, refer to the conventional battery testing chart (fig. 7).

Step 1—Visual Inspection.

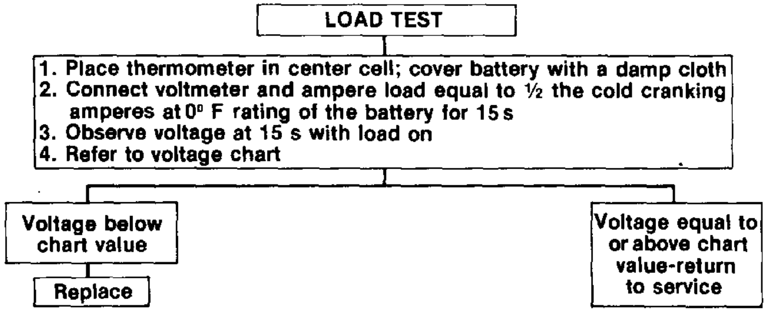
Step 2—Hydrometer Test.

Step 3—Adjustable Load Test.—The following instructions are intended as guidelines. The instrument manufacturer's instructions should be followed when available.

1. Disconnect battery cables, starting with ground cable.
2. Measure temperature of a center cell. If instrument has an integral temperature compensator, use attached probe.
3. Connect voltmeter and load test leads to appropriate battery terminals, making certain terminals are free of corrosion.
4. Connect current transducer (if necessary) to appropriate lead.
5. Apply test load equivalent to 50 pct of cranking performance rating of battery for 15 s. If cranking performance is unavailable, use 3 times the ampere hour capacity.
6. Read voltage after 15 s, then remove the load.
7. Determine minimum voltage required at electrolyte test temperature from chart in figure 7. If test voltage is above minimum, return battery to service. If test voltage is below minimum, replace battery.


Check for obvious damage such as cracked or broken case that shows loss of electrolyte, and look for terminal damage
Obvious damage
Replace battery
No obvious damage
Check electrolyte level
Below top of plates in 1 or more cells
Add water to just above separators; charge for 15 min at 15 to 25 A — proceed to step 2
Above top of plates in all cells— proceed to step 2
STEP 2
HYDROMETER TEST
Specific gravity less than 1.225 or cell variation 50 points or greater
Recharge
Specific gravity less than 1.225 or cell variation 50 points or greater
Replace battery
Specific gravity 1.225 or greater or cell variation less than 50 points
Discharge at 150 A for 15 s
Continue to step 3

STEP 3



LOAD TEST

1. Place thermometer in center cell; cover battery with a damp cloth
2. Connect voltmeter and ampere load equal to ½ the cold cranking amperes at 0° F rating of the battery for 15 s
3. Observe voltage at 15 s with load on
4. Refer to voltage chart

VOLTAGE CHART		
Estimated electrolyte temperature		Minimum required voltage under 15-s load (use ½ these values for 6-V batteries)
70° F and above	21° C and above	9.6
60° F	16° C	9.5
50° F	10° C	9.4
40° F	4° C	9.3
30° F	-1° C	9.1
20° F	-7° C	8.9
10° F	-12° C	8.7
0° F	-18° C	8.5

FIGURE 7.—Conventional battery testing chart. (Courtesy Battery Council International)

TESTING LOW-MAINTENANCE BATTERIES

Low-maintenance batteries of the latest design may incorporate flame-arrestor vents to reduce the possibility of explosions caused by external sparks. Therefore, during charging and testing, the flame-arrestor vents should remain in place. A wet cloth may be placed over the vent openings as an additional precaution. Refer to the low-maintenance battery testing chart (fig. 8).

Step 1—Visual Inspection.

Step 2—Electrolyte Levels and State of Charge. Although these batteries are designed to preclude the need to add water, the volume of reserve electrolyte above the plates may eventually be depleted. In most cases, this will signal the end of the battery's useful life. Since many have sealed covers in place of filler caps, it may not be possible to check the electrolyte levels by looking directly into the cells. However, many of the batteries are contained in translucent plastic cases, which may allow electrolyte levels to be observed. Other models utilize built-in hydrometers that also serve as electrolyte level indicators. If electrolyte levels can be observed and are found to be low, check for charging system malfunction, loose battery trays, and loose holddown clamps.

If vents are removable and the electrolyte level is at the tops of the plates in any cell, add water before proceeding further; if water cannot be added, replace the battery.

The state of charge of low-water-loss batteries can be determined with an accurate voltmeter. A voltmeter should be checked frequently against one of known accuracy.

If the stabilized open-circuit voltage is below 12.4 V (6.2 for 6-V batteries), charge the battery as described in the section "Charging Low-Maintenance Batteries." A stabilized voltage reading is assured after the battery has remained on open circuit overnight or for several hours.

When a hydrometer reading can be taken, a value of 1.225 at 80° F can be used instead of the voltage reading. If the battery has a built-in hydrometer, follow the instructions of the manufacturer. After the battery is charged, proceed to step 3.

If the state of charge of a battery cannot be determined, it must be charged. After the battery is charged, proceed to step 3.

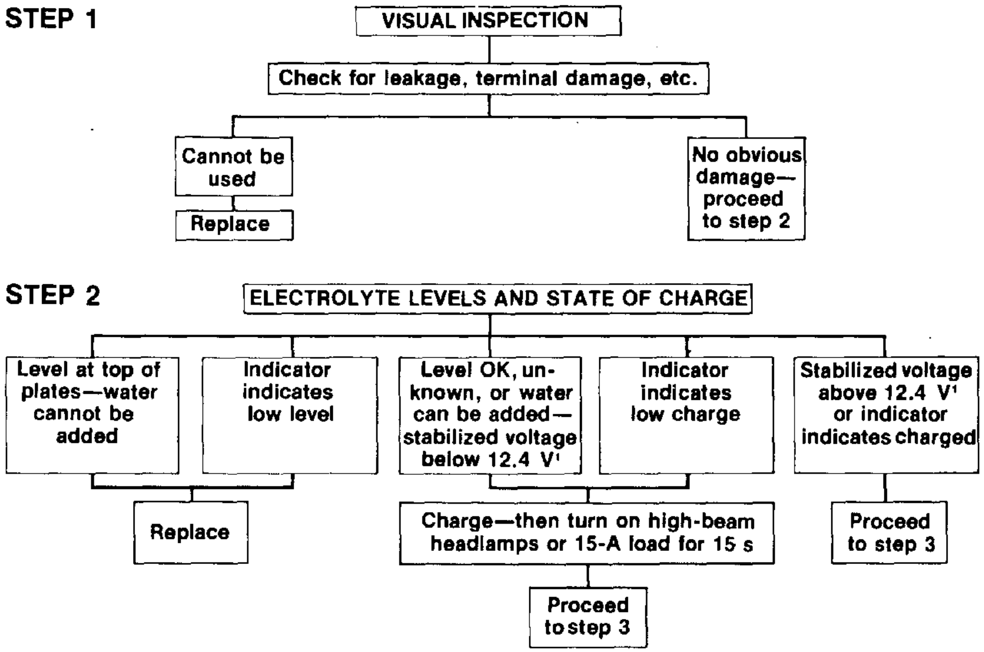
If the stablilzed voltage of the battery is 12.4 or above when it is first examined, or the built-in hydrometer indicates the battery is charged, proceed to step 3.

Step 3—Load Procedure.—The load test procedure is conducted to determine if the battery has adequate electrical performance or must be replaced.

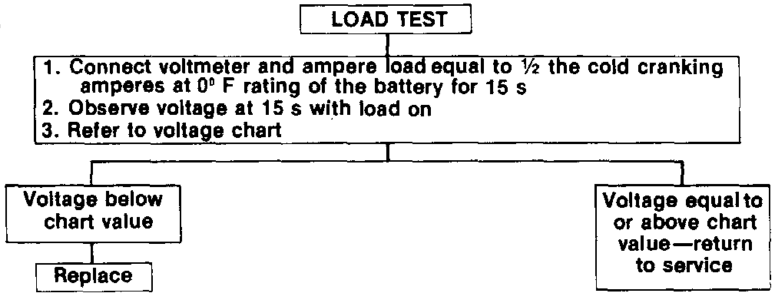
IMPORTANT:

This procedure is valid only if the battery is at or above the state of charge specified in step 2.

1. If the battery must be charged prior to load test, charge according to the charging guide in the section "Charging Low-Maintenance Batteries."
2. If battery is at an adequate state of charge for load test, connect voltmeter and load test leads to battery terminals, making sure load switch is in "OFF" position.
3. Apply test load equal to one-half of the cold cranking amperes at 0° F rating of the battery.
4. Read voltage after 15 s with load connected. Remove load.
5. Estimate or measure battery temperature and compare voltage reading with voltage chart (fig. 8). If voltage is less than minimum specified, replace battery. If voltage meets or exceeds specified minimum, return battery to service.


STEP 1
VISUAL INSPECTION
Check for leakage, terminal damage, etc.
Cannot be used
Replace
No obvious damage—proceed to step 2
STEP 2
ELECTROLYTE LEVELS AND STATE OF CHARGE
Level at top of plates—water cannot be added
Indicator indicates low level
Level OK, unknown, or water can be added—stabilized voltage below 12.4 V¹
Indicator indicates low charge
Stabilized voltage above 12.4 V¹ or indicator indicates charged
Replace
Charge—then turn on high-beam headlamps or 15-A load for 15 s
Proceed to step 3
Proceed to step 3

STEP 3



1. Connect voltmeter and ampere load equal to ½ the cold cranking amperes at 0° F rating of the battery for 15 s
2. Observe voltage at 15 s with load on
3. Refer to voltage chart

VOLTAGE CHART

Estimated electrolyte temperature		Minimum required voltage under 15-s load (use ½ these values for 6-V batteries)
70° F and above	21° C and above	9.6
60° F	16° C	9.5
50° F	10° C	9.4
40° F	4° C	9.3
30° F	-1° C	9.1
20° F	-7° C	8.9
10° F	-12° C	8.7
0° F	-18° C	8.5

[1] If water can be added to battery, a hydrometer reading of 1.225 at 80° F can be used instead of the 12.4-V reading. (Use 6.2 V for 6-V batteries.)

FIGURE 8.—Low-maintenance battery testing chart. (Courtesy Battery Council International)

CHARGING BATTERIES (*2*)

CHARGING CONVENTIONAL BATTERIES

CAUTION:

Do not attempt to charge a frozen battery. The rapid heating produced during charging can cause an explosion. Allow the battery to warm to 60° F before placing on charge.

Before placing a battery on charge, clean the battery terminals, if necessary. Carefully attach the clamps to the battery in proper polarity. Keep open flames and sparks away from the battery; the gases coming from it are highly explosive. Ventilate the battery well during charging. Follow the battery charger manufacturer's instructions. When possible, use chargers with alternator or polarity protection, which prevents charging a battery in reverse. The charge a battery receives is equal to the charge rate in amperes multiplied by the time in hours. Thus a 5-A rate applied to a battery for 10 h would be a 50-A·h charge to the battery. To fully recharge a battery, you must replace the ampere hours or ampere minutes removed from it plus an extra 20 pct charge. This is due to the fact the batteries are not 100 pct efficient on recharging.

Follow the manufacturers' battery charger guides, if available. If they are not, the conventional battery charging guide (table 3) may be used.

The lower charging rates in amperes are recommended. They must be used when a battery is suspected to have a problem, in effect, to be sulfated or have a temperature below –15° F.

TABLE 3.—Conventional battery charging guide (6- and 12-V batteries): recommended rate and time for fully discharged condition

Rated battery capacity, reserve min	Slow charge		Fast charge	
	Time, h	Rate, A	Time, h	Rate, A
80 or less	10	5	2.5	20
	5	10	1.5	30
Above 80 to 125	15	5	3.75	20
	7.5	10	1.5	50
Above 125 to 170	20	5	5	20
	10	10	2	50
Above 170 to 250	30	5	7.5	20
	15	10	3	50
Above 250	24	10	6	40
			4	60

Source: Battery Council International.

The best method of making certain a battery is fully charged, but not overcharged, is to measure the specific gravity of a cell once per hour. The battery is fully charged when the cells are gassing freely at a low charging rate and no change in specific gravity occurs over a 3-h period.

When any battery is being charged, periodically measure the temperature of the electrolyte. If the temperature exceeds 125° F or if violent gassing or spewing of electrolyte occurs, the charging rate must be reduced or temporarily halted. This must be done to avoid damage to the battery. Add water sufficient to cover the plates. Fill to the proper level near the end of charge. If the battery is extremely cold, allow it to warm before adding water because the level will rise as it warms. In fact, an extremely cold battery will not accept a normal charge until it becomes warm.

CHARGING LOW-MAINTENANCE BATTERIES

Battery chargers for low-maintenance batteries should include a charge duration control of some type. The simplest control is a timer that the operator sets.

TABLE 4.—12-V low-maintenance battery charging guide

Rated battery capacity, reserve min	Slow charge		Fast charge	
	Time, h	Rate, A	Time, h	Rate, A
80 or less	10	5	2.5	20
	5	10	1.5	30
Above 80 to 125	15	5	3.75	20
	7.5	10	1.5	50
Above 125 to 170	20	5	5	20
	10	10	2	50
Above 170 to 250	30	5	7.5	20
	15	10	3	50

Source: Battery Council International.

If, when the battery is being charged, violent gassing or spewing of electrolyte occurs, or the battery case feels hot (125° F), reduce or temporarily halt charging to avoid damaging the battery.

For best results, batteries should be charged while the electrolyte is at room temperature (55° to 85° F). A battery that is extremely cold or has remained in a completely discharged condition may not accept current for several hours after the charger is started. Follow the manufacturers' battery charger guides, if available. If they are not, the 12-V low-maintenance battery charging guide (table 4) may be used.

BATTERY HOOKUPS

Batteries may be connected to the charging source in series, in parallel, or individually, depending on the type of charger used. More than one battery (all 12 V or all 6 V) can be charged on high-rate fast chargers. When this is done, connect the batteries in parallel, that is, connect the positive (+) terminal of one battery to the positive terminal of the next battery and the negative (–) terminal of one battery to the negative terminal of the next battery. The number of batteries that may be connected in parallel depends on the current capacity of the charger.

The output of the charger would divide equally among the number of batteries in parallel, if they were identical (same rating, same state of charge, etc.) and there were no high-resistance connections. For example, if five batteries are being charged in parallel, and the charger output is 20 A, each battery is receiving one-fifth of the total output or 4 A (fig. 9).

A series connection is one in which the positive (+) terminal of one battery is connected to the negative (–)

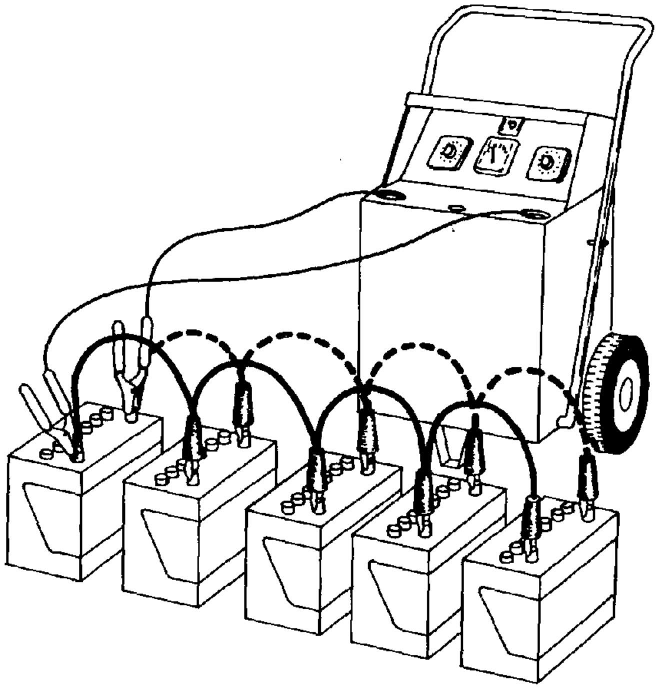


FIGURE 9.—Parallel connection. (Courtesy Battery Council International)

terminal of the next battery (fig. 10). Each battery in the series connection receives the full current output of the charger. The number of batteries that may be connected in series is dependent on the voltage rating of the charging source. Batteries with different capacities can be charged in series, but the proper charge rate and charging time for the lowest capacity battery must be used.

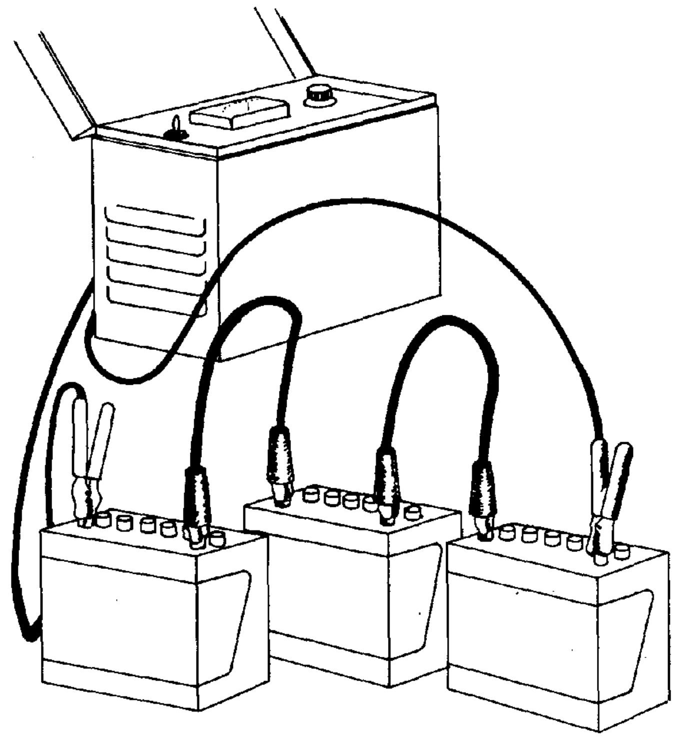


FIGURE 10.—Series connection. (Courtesy Battery Council nternational)

AUTOMATIC CHARGERS

Automatic chargers include circuits that sense the battery voltage and turn the charger off or almost off when the battery reaches or approaches the fully charged state. Since charge voltage depends on battery temperature, the control must include a means of temperature sensing and correcting. Ideally, the control should also sense polarity and prevent charging and sparks if the charger clamps are connected in reverse by mistake. Automatic chargers are generally recommended because they can furnish a safe, full charge without operator skill or knowledge.

HIGH-RATE FAST CHARGING

The fast charge method provides a high charging rate for a short period of time. The charging rate should be limited to 60 A for 12-V batteries. Maximum charging rate for popular 6-V batteries (above 180 reserve capacity minutes) can be approximately double this value.

The battery temperatures must be watched carefully on any type of charger without proper time and rate control. If the battery is badly sulfated, the temperature may rise rapidly soon after it is placed on charge. As the sulfate starts to break up, the charge rate in amperes will increase noticeably. These batteries should be placed on a slow charge. The temperature of a normal battery may rise above the desired maximum of 125° F if it reaches the fully charged state and is left on charge.

Ideally, fast charges should be limited to the charging times shown under "Fast charge" in the conventional battery charging guide (table 3). The battery generally cannot be fully charged within these time periods, but it will receive sufficient charge (70 to 90 pct) for practical service. To completely recharge a battery, follow the fast charge with a slow charge until no change in specific gravity occurs over a 3-h period.

A battery with electrolyte specific gravity of 1.225 or above should never be charged at a high rate. If the charger has not tapered to a low rate, adjust to a slow charge, preferably at a rate of 1 A per positive plate per cell.

BOOST CHARGE

The intent of a boost charge is to give the battery enough recharge to enable it to perform its functions until the vehicle charging system can bring it to a state of full charge. A 12-V battery should be charged at 40 to 60 A for 30 min.

TAPER CHARGING

Taper chargers start the charge at a high rate, and as the battery voltage builds up, the charge rate tapers to a lower value depending on the design of the charger and on the condition, age, and temperature of the battery. The fact that the charge rate tapers to a lower value reduces the amount of overcharge the battery can receive.

CONSTANT-CURRENT SLOW CHARGING

Batteries recharged by the constant-current method use a low charging rate for a relatively long period of time. Charging rates of 3 to 5 A are common. Another widely used rate for slow charging is 1 A per positive plate per cell. If the battery has nine plates per cell, four of the nine will normally be positive plates. Therefore, the slow charge rate would be 4 A. Charging periods as long as 24 h may be needed to bring a battery to full charge. The battery is fully charged when the cells are gassing freely at a low charging rate and no change in specific gravity occurs over a 3-h period.

Batteries that have stood in a discharged condition for long periods of time without a recharge have become sulfated and must be recharged at a low rate to avoid overheating and excessive gassing. It may require 2 or 3 days of slow charging to bring a sulfated battery to a fully charged condition. Do not give sealed low-maintenance batteries this type of treatment.

Some batteries are so badly sulfated they cannot be restored to a normal operating condition, regardless of the rate of charge or the length of time the charge is applied. Some special procedures used to remove the hard sulfate from the plates softens the active material. The battery then fails prematurely because of shedding of the active materials from the plates. Therefore, if a battery cannot be restored to a fully charged condition by slow charging, it should be rejected.

COMMON CAUSES OF BATTERY FAILURE AND REMEDIES

The four most common causes of premature battery failure are overcharge, undercharge, vibration, and neglect (*5*).

OVERCHARGE

This number one cause of battery failure often occurs because of a faulty voltage regulator and/or alternator setting. A consistently high panel ammeter reading is a clear indication of an overcharge condition. With the wrong setting, the alternator continues to charge the battery even though it is already fully charged. The result is warped or broken plates, damaged separators, severe shedding of the active materials pasted to the plates, and excessive loss of water, which causes the plates to dry out.

Overcharging can be avoided through periodic testing of voltage regulator outputs.

UNDERCHARGE

Usually this problem is the result of a faulty regulator and/or alternator setting. Other causes include a slipping regulator and/or alternator drivebelt and equipment operating cycles that require the battery to operate in a partially discharged condition. The result is sulfation, a hard, varnish-like coating that forms on the negative plates. The longer a battery is undercharged, the harder the sulfation becomes — until finally it becomes so bad that the battery will not accept a charge and its capacity is drastically reduced.

Slow charging at 6 to 8 A for up to 24 h will sometimes remove the sulfation. The battery can be saved, although possibly not to full capacity. In severe cases, the battery is ruined.

VIBRATION

A loose holddown can permit a battery to vibrate excessively. Active material is shaken from the plates and accumulates in the sediment wells, eventually causing a short circuit. A short circuit can also be caused if the battery plate separators shift, allowing the plates to touch.

The only remedy for vibration damage is to be certain that it does not occur in the first place — which is best accomplished by making certain the holddown is properly secured.

NEGLECT

When the electrolyte level in conventional antimony batteries is never checked, a low electrolyte level can result. The level falls below the top of the plates and allows the plates to dry out. Once the plates have dried, they cannot be reactivated, and the capacity of the battery is reduced in direct proportion to the area of plate surface that has become dry.

In conventional antimony batteries, maintain the electrolyte level above the plates and below the vent cap openings. Never allow the electrolyte to drop below the top of the plates; a low electrolyte level can cause a battery to be constantly undercharged and can also put undue strain on the alternator.

CAUTION:

When vehicles are unused and are left unattended for longer than 10 days, disconnect the ground terminals so batteries will not discharge because of parasitic electrical loads.

JUMP STARTING AN ENGINE — BOOSTER CABLE INSTRUCTIONS (2)

CAUTION:

WARNING — BATTERIES PRODUCE EXPLOSIVE GASES!

These instructions are designed to minimize the explosion hazard. Keep sparks, flames, and cigarettes away from batteries at all times — protect eyes at all times — do not lean over batteries during this operation.

Position the vehicle with the booster battery adjacent to the vehicle with the discharged battery so that booster cables can be connected easily to the batteries in both vehicles. Both batteries should be of the same voltage (6, 12, etc.). Make certain vehicles do not touch each other.

1. On both vehicles turn off all electrical loads. Set the parking brake. Place automatic transmissions in "PARK" (manual transmissions in "NEUTRAL").

2. Determine whether the discharged battery has the negative (–) or positive (+) terminal connected to ground. The ground lead is connected to the engine block, vehicle frame, or some other good metallic ground. The battery terminal connected to the starter relay is the one that is not grounded. All vehicles manufactured in the United States since 1964 have the negative battery terminal grounded. All European vehicles have been negative grounded since 1971.

3. Be sure that the vent caps are tight and level on

both batteries. Place a damp cloth over the vent caps of each battery, making certain it is clear of fan blades, belts, and other moving parts. A damp cloth can reduce the possibility that a flame will get inside the battery to produce an explosion, and can prevent acid from being splashed if an explosion should occur.

The following steps must be performed in sequence:

4. On the negative-grounded system, first connect one end of the positive cable to the positive (+) terminal of the discharged battery, and then connect the other end of the same cable to the positive post of the booster battery (fig. 11).

5. Connect one end of the other cable to the negative (–) terminal of the booster battery.

6. Connect other end of cable, away from battery, to engine block, vehicle frame, or some other good metallic ground, except carburetor, fuel lines, or brake lines, on vehicle with discharged battery.

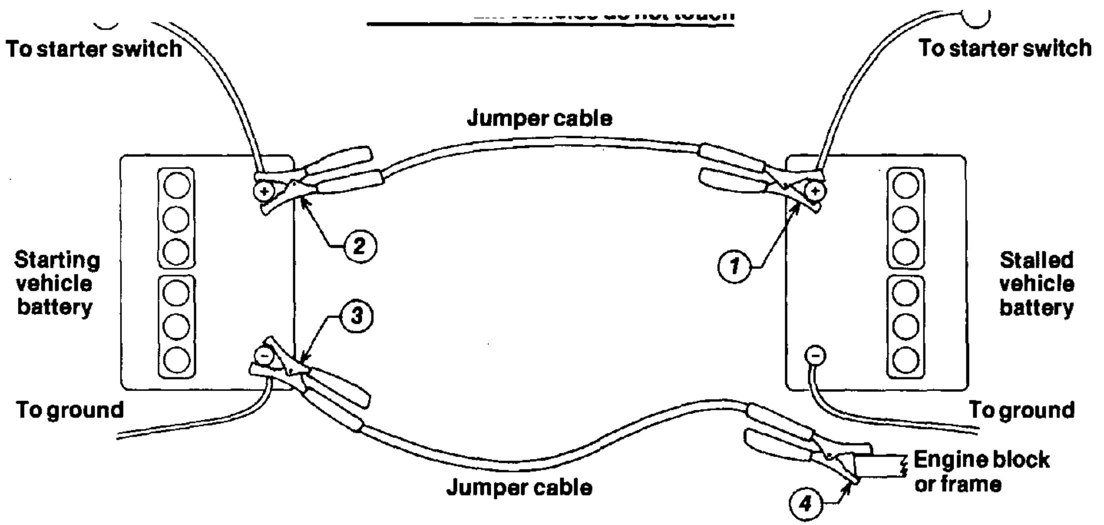
7. Make certain that all cables are clear of fan blades, belts, and other moving parts of both engines, and be sure everyone is standing away from vehicles. Then start the engine of the vehicle with the booster battery. Wait a few minutes, then attempt to start the engine of the vehicle with the discharged battery.

8. If the vehicle does not start after cranking for 30 s, STOP PROCEDURE. Cranking for more than 30 s seldom starts the engine unless some mechanical adjustment is made.

9. After starting, allow the engine to return to idle speed, remove the cable connection at the engine block, vehicle frame, or good metallic ground. Then remove the other end of the same cable from the booster battery.

10. Remove the other cable by disconnecting at the booster battery first and then disconnect the opposite end from the discharged battery.

11. Discard the damp cloths that were placed over the battery vent caps.



MINIMUM INSTRUCTIONS FOR USE ON OR NEAR BATTERIES—BOOSTER CABLE INSTRUCTIONS

1 Connect positive (+) cable to positive post of discharged battery (stalled vehicle).
2 Connect other end of same cable to same marked post (positive) of booster battery (starting vehicle).
3 Connect second cable (negative) to other post of booster battery.
4 MAKE FINAL CONNECTION ON ENGINE BLOCK OF STALLED VEHICLE AWAY FROM BATTERY. STAND BACK.

Start engine and remove cables in reverse order of connection.

FIGURE 11.—Hookup for negative-ground vehicles. (Courtesy Battery Council International)

An improved jumping system design is available to protect the operator and equipment utilized during a jump start. This jumper cable system prevents closure of its circuit if the cables are not attached in the proper polarity and automatically opens the circuit when any one of the jumper cable terminals is disconnected.

SAMPLE SAFE JOB PROCEDURES

Safe job procedures (SJP) have become a common means of instructing employees in the proper and safe way to accomplish repetitive tasks.

Three basic methods are used to develop SJP's:

1. A job safety analysis (JSA) conference is held between the supervisor and employees experienced at performing the job. This is the preferred method because it involves everyone who has an interest in the job and promotes employee commitment to the finished SJP.
2. The supervisor observes employees performing the job and writes the SJP based on these observations.
3. The supervisor writes the SJP based on personal knowledge and past experience.

The three methods are sometimes combined to produce SJP's.

Many supervisors use SJP's as a principal resource for training employees assigned new tasks. Supervisors usually review SJP's from time to time and conduct employee safety meetings using the SJP's as discussion topics.

Accident and training research has shown that the principal reasons for the number of battery-related accidents in surface mines are that employees are not fully aware of the hazards associated with lead-acid batteries or become complacent. Proper training and strict adherence to appropriate SJP's should reduce the frequency and severity of such accidents and injuries.

The sample SJP's that follow (tables 5-7) have proven effective at one mine. Modifications to suit local conditions may be necessary.

TABLE 5.—Sample safe job procedure—remove 12-V storage battery from production truck

(Department: Electrician—field)

Operations (steps)	*Procedures*
Select tools..........	1. Select and inspect proper tools.
	2. Inspect and clear immediate work area. Check truck for overhanging chunks and dirt.
	3. Climb into cab using steps and handholds. Be alert to grease, ice, and mud, in season, on steps and handholds.
Prepare for removal ..	4. Prepare for removal:
	a. Open disconnect switch, being alert to pinch points.
	b. To remove battery box cover, remove harness snap and open hasp or unhook latches. Raise cover and slide forward. Lift cover from box and place in the clear. Beware of pinch points and striking against hazards.
	c. Remove battery holddown by loosening and removing nuts with the proper wrenches. Lift holddown clear of battery and bolts and place in the clear, being alert to pinch points and striking against hazards.
	d. Loosen and remove battery cable clamps, and swing cables clear of the battery. Beware of striking against the battery and box. Always remove grounded battery cable clamp first.
Remove battery......	5. Remove battery:
	a. Position battery lift in doorway of cab. Stand in the clear to avoid being struck by or caught between the battery lift and the door.

TABLE 5.—Sample safe job procedure—remove 12-V storage battery from production truck—Continued

(Department: Electrician—field)

Operations (steps)	*Procedures*
Remove battery—Continued.	b. Make sure battery handles are in good condition. Assume good lifting position, grasp battery handles and lift battery straight up and place across the corner of the battery box. c. Reposition self, if necessary, and move battery lift, keeping hands clear of pinch points. d. Move battery lift clear of truck and lower to transporting height.

Hazards (safety contacts)

Beware of acid and electrical burns. Wash acid off with water.
Assume good lifting position to avoid strain.
Alert other personnel to job being done.
Plan job and have good communication and cooperation between partners.
Do not wear rings when working around electrical equipment.

Protective apparel

Hard hat.
Safety glasses with side shields.
Recommend safety shoes with metatarsal guards.
Personal safety lock.
Hand protection.

Source: United States Steel Corp.

TABLE 6.—Sample safe job procedure—replace 12-V battery in production truck

(Department: Electrician—field)

Operations (steps)	*Procedures*
Select and pick up battery.	1. Select battery; check handles to make sure that they are secure. Raise battery lift to bench height. Two employees grasp battery by the handles and slide battery onto battery lift. Be sure to have good lifting stance and beware of pinch points.
	2. One employee climbs into cab using steps and handholds. Be alert to grease, ice, and mud, in season, on steps and handholds. When in the cab, stand in the clear to avoid being struck by or caught between battery lift and truck cab or door.
	3. Partner moves battery lift to truck and raises to proper height, then walks around truck and climbs into truck cab on driver's side. Use the steps and handholds as in procedure 2.
Install battery in battery box.	4. Both employees assume good lifting position and grasp handles of battery and lower into battery box. Always be aware of acid around battery and box. If battery box has a side opening, remove side plate and slide battery from battery lift into battery box. Always be aware of pinch points in lowering or sliding battery into battery box.
	5. Replace battery holddown bracket. Be aware of getting fingers pinched between battery and holddown bracket, or holddown bracket and box.

TABLE 6.—Sample safe job procedure—replace 12-V battery in production truck—Continued

(Department: Electrician—field)

Operations (steps)	*Procedures*
Install battery in battery box—Continued.	6. Clean battery posts and battery terminals. Connect battery cables, making sure ground cable is connected last. Close disconnect switch and replace battery box cover. Use care in closing the disconnect switch and replacing the battery box cover to avoid getting fingers pinched or striking against hazards.

Hazards (safety contacts)

Beware of acid and electrical burns. Wash acid off with water.
Assume good lifting position to avoid strain.
Alert other personnel to job being done.
Plan job and have good communication and cooperation between partners.
Do not wear rings when working around electrical equipment.
Use extra care in working in crowded and cramped conditions.

Protective apparel

Hard hat.
Safety glasses with side shields.
Recommend safety shoes with metatarsal guards.
Personal safety lock.
Hand protection.

Source: United States Steel Corp.

TABLE 7.—Sample safe job procedure—service batteries on production truck

(Department: Electrical shop and field)

Operations (steps)	*Procedures*
Lock out	1. Lock out main air valve with personal safety lock.
Remove battery box cover.	2. Remove battery box cover and place in safe place.
Wash battery	3. Wash batteries off with water and baking soda.
Remove cell caps	4. Remove cell caps.
Test cells	5. Test cells: a. Test cells with hydrometer. b. If necessary to use cell tester, blow out gas with hydrometer. c. When using cell tester, hold by handle only to prevent burns from resistor. d. Press tester firmly on cell to prevent arcing.
Add water	6. Add water, if necessary, to proper level.
Replace caps	7. Replace cell caps.
Check cables	8. Check all cables and terminals.
Replace cover	9. Replace battery box cover.

Hazards (safety contacts)

Acid burns.

Always remove cell caps and blow out gas when using cell tester to prevent explosion.

Protective apparel

Hard hat.
Safety glasses with side shields.
Recommend safety shoes with metatarsal guards.
Personal safety lock.
Hand protection.

Source: United States Steel Corp.

GLOSSARY OF TERMS

Ampere (A) — The unit for current flow, measured by an ammeter.

Ampere Hour (A·h) — A unit of measure for battery capacity, obtained by multiplying the current flow in amperes by the time in hours during which the current flows. (Example: A battery that delivers 10 A for 20 h has delivered 10 A times 20 h, or 200 A·h).

Capacity — A term used to denote the ability of a fully charged battery to discharge a specified quantity of electricity over a definite period of time. Capacity is basically determined by the number and size of plates, as well as the amount of sulfuric acid present in the electrolyte.

Charging and Discharging — When a battery is receiving electrical power from an outside source, it is said to be charging or on charge. When a battery is delivering electrical power, it is said to be discharging.

Circuit — The complete path provided for current flow. The complete path is a closed circuit. When its continuity is broken, an open circuit exists.

Circuit (Parallel) — A circuit that provides more than one path for current to flow. A parallel arrangement of batteries has all positive terminals connected to a conductor and all negative terminals connected to another conductor.

Circuit (Series) — A circuit that has only one path for the current to flow. Batteries arranged in series are connected with the negative of the first to positive of the second, negative of the second to positive of the third, etc. If two 12-V batteries are connected in series, the circuit voltage is equal to the sum of the two battery voltages, or 24 V.

Cold Cranking Rating — The number of amperes a battery at 0° F can deliver for 30 s and maintain a voltage of 1.2 V per cell or higher.

Current (Direct) — An electrical current flowing in one direction only. A battery delivers direct current (DC) and must be recharged with direct current.

Cycle — In a battery, a discharge and a recharge is a cycle.

Drop (Voltage) — The net difference in electrical pressure (voltage) when measured across a resistance or impedance.

Electrolyte — In a battery, a mixture of sulfuric acid and water. Dilute sulfuric acid.

Forming — In battery manufacturing, charging the battery electrochemically changes the lead oxide paste on the plate grids to lead peroxide for the positive plates and to metallic lead for the negative plates.

Ground — The connection made in grounding a circuit. In mobile use, the result of attaching one battery cable to the body or frame, which is used as a path for completing a circuit in lieu of a direct wire from a component.

Hydrometer — A float-type instrument used to determine the state of charge of a battery by measuring the specific gravity of the electrolyte (that is, the amount of sulfuric acid in the electrolyte).

Load Tester — An instrument that puts a simulated electrical load on the battery to determine its overall condition and its ability to perform under actual engine starting conditions.

Ohm — The unit of electrical resistance opposing current flow and causing heat when current flows.

Shedding — Active material that has worn out or fallen out of the plate grid to which it was originally attached, resulting in a loss of capacity originally built into the battery.

Sulfation — When a cell is discharged by completing an external circuit, as in switching on lights, the sulfuric acid acts on both positive and negative plate active materials to form a chemical compound called lead sulfate. This is supplied by the electrolyte, which becomes weaker in concentration as the discharge proceeds. The amount of acid consumed (by the plate) is in direct proportion to the amount of electricity removed from the cell.

Volt (V) — The unit of measure for the electrical pressure for each cell measured by a voltmeter. The open-circuit voltage for a fully charged cell is 2.10 V.

Watt (W) — The unit for measuring electrical power. One watt is the product of 1 A times 1 V (formula: amperes times volts is equal to watts).

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2. Garwood, R. P. (ed.). Battery Service Manual. Battery Council Int., Chicago, IL, 9th ed., 1982, 64 pp.

3. ESB Inc., Automotive Division (Cleveland, OH). Battery Training Guide. Undated, 21 pp.

4. Gould Inc. (St. Paul, MN). Stocking Procedures—Storing and Rotating Maintenance Free Batteries. Undated, 1 p.

5. ———. Battery Service Manual. 2d ed., 1977, 17 pp.

APPENDIX A.—BATTERY MANUFACTURERS

There are a number of sources for battery-related equipment for mobile mine equipment systems. The following partial list of manufacturers is intended as a guide only and does not imply endorsement by the Bureau of Mines.

Delco Remy
Division of General Motors Corp.
2410 Columbus Avenue
P.O. Box 2439
Anderson, IN 46018-9986

Douglas Battery Manufacturing Co.
500 Battery Drive
Winston-Salem, NC 27107

Exide Commercial Batteries
101 Gibraltar Road
Horsham, PA 19044

Gould, Inc.
Truck Battery Department
P.O. Box 43140
St. Paul, MN 55164

APPENDIX B.—BATTERY CHARGER AND EQUIPMENT MANUFACTURERS

There are a number of sources for battery-related equipment for mobile mine equipment systems. The following partial list of manufacturers is intended as a guide only and does not imply endorsement by the Bureau of Mines.

Applied Power Inc.
Battery Chargers, Testers, and Accessories
Automotive Division
11333 W. National Avenue
Milwaukee, WI 53227

Auto Meter Products, Inc.
Battery Testers
413 W. Elm Street
Sycamore, IL 60178

Bergman Tool Manufacturing Co., Inc.
Battery Service Tools
1573-75 Niagara Street
Buffalo, NY 14213

Bitrode Corp.
Battery Chargers and Testers
719 Rudder Road
Fenton, MO 63026

Exide Corp.
Battery Charging and Testing Equipment
101 Gibraltar Road
Horsham, PA 19044

Francis L. Freas Glass Works Inc.
Hydrometers — Thermometers
148 E. 9th Avenue
P.O. Box 26
Conshohocken, PA 19428

Gould, Inc.
Industrial Battery Division
2050 Cabot Blvd. West
Langhorne, PA 19047

Hydrocap
Catalyst Battery Caps
Box 380698
Miami, FL 33138

Julian Electric Inc.
Battery Cable Division
701 Blackhawk Drive
Westmont, IL 60559

Quick-Cable Corp.
Heavy Duty Battery Cables and Terminals
2501 Eaton Lane
Racine, WI 53404

Ratelco Inc.
Battery Chargers
1260 Mercer Street
Seattle, WA 98109

Spark Guard
Battery Jumping Systems
Ristance Products, Inc.
P.O. Box 93
Argos, IN 46501

Terado Corp.
1068 Raymond Avenue
St. Paul, MN 55108

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